A New European Initiative to Improve Efficiency of Motor System: The Motor Systems Energy Efficiency Challenge Programme

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ABSTRACT

Electric motor-driven systems account for the largest portion of industrial electricity consumption in Europe. Numerous studies on individual components (motors, pumps, compressors) and on their consumption characteristics have shown considerable potential for improvement of energy efficiency of these systems, and have recommended suitable policy actions.

A number of policies have succeeded in making improvements on the supply side for individual components of systems, such as the electric motor itself. For electric motors an European wide classification scheme and labelling exist together with a voluntary agreement by motor manufacturers to substantially improve the efficiency of motors placed on the market.

Following the recommendation of experts, the European Commission decided that a concerted effort on the demand side could very usefully complement the efforts being spent on components and technologies. The European Commission has decided to launch the "The Motor Systems Energy Efficiency Challenge Programme" (The "Challenge Programme"). This is a voluntary programme for motor systems users to agree to look at their system and to carry out within a specific time frame all the savings measure that are economically justified.

The paper describes the Challenge Programme design. The programme is based on the analysis of the main reasons why profitable energy-savings measures are not put into practice in private companies and on successful examples where high level management made the necessary decisions to carry out motor systems energy efficiency programmes.

Current Motor System Electricity Consumption and Energy Efficiency Potential

In 1998 - the base year for the characterisation of motor electricity use- motor driven systems electricity consumption in the industrial and in the commercial sectors in the EU in 1998 was responsible for 69% (590TWh) and 38% (190TWh) of the total electricity consumption (University Of Coimbra 1999).

Based on the Pumps (ETSU 2000), Air Compressor (ADEME 2000) and the market characterisation (University of Coimbra 1999) studies the economic electricity saving potential are estimated to be of 108.8 TWh per year by year 2015. The electricity savings potential are estimated for the year 2015. The annual average growth rates of the electricity consumption up to 2015 in the industrial and commercial sectors are assumed to be 1.2% and 1%, respectively.

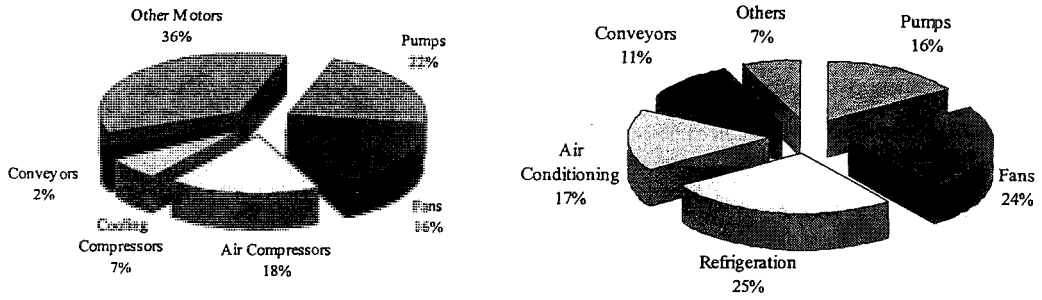

Figure 1: Share of Motor Electricity Consumption by End-Use in the Industrial and Tertiary Sectors in the EU(University of Coimbra 1999)

For the estimation of the motor electricity and carbon savings potential the efficiency improvements considered are the application of Energy-Efficient Motors (EEMs), Variable Speed Drives (VSDs), and energy efficient end-use devices and systems (pumps, fans and air compressor systems). The total technical and economic electricity and CO_2 savings potential in industry and in the commercial sector in 2015 are presented in Table 1:

Table 1. Total Final Technical and Economic Electricity and CO_2 Savings Potential in Industry and in Commercial Sector by 2015 (University of Coimbra 1999)

		TWh Savings by 2015	*CO_2 Mtons Savings*
Technical	Industry	107.1	42.9
	Tertiary	36.7	14.7
Economic	Industry	84.3	33.7
	Tertiary	24.5	9.8

Figure 2 gives the economic savings potential in industry by major end-use by 2015. The above estimated savings potential would be higher if other efficiency improvements were included, such as improving maintenance practices, reducing waste, switching off the equipment when it is not being used (for example for the case of belt conveyors). These "housekeeping measures", deserve to be strongly publicised among motor users. Drive-train and connection systems are another possibility for efficiency improvements (gears, belts, chains and bearings). Losses in the power transmission system are often surprisingly large, but careful selection and maintenance of drive-trains and their components are crucial for improving energy efficiency.

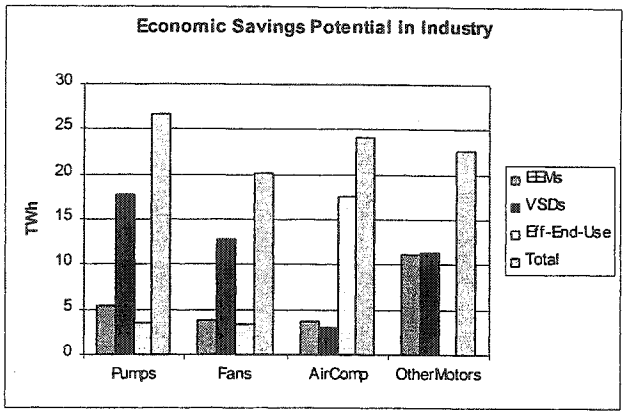

Figure 2. Economic Savings Potential in Industry by Major End-Use by 2015 (University of Coimbra 1999)

A number of programmes have succeeded in making improvements on the supply side for individual components of systems, such as the electric motor itself. For electric motors a European classification scheme, shown in Figure 3, and labelling exist together with a voluntary agreement by motor manufacturers to substantially improve the efficiency of motors placed on the market. A similar action is now under discussion for pumps for clean water.

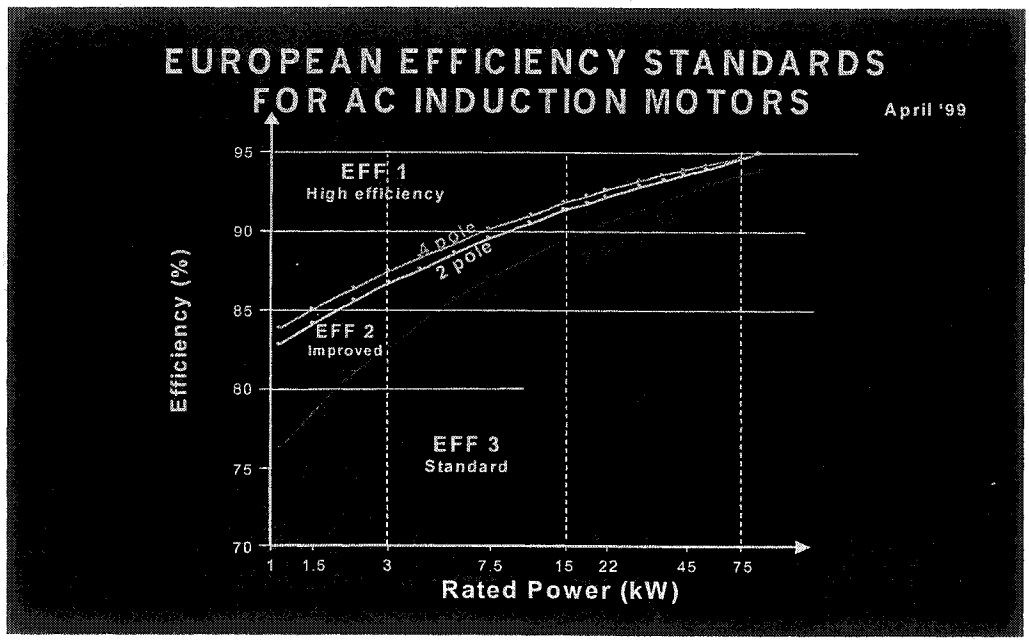

Figure 3. EU/CEMEP Motor Efficiency – Classification Scheme (Bertoldi 2000)

Following the recommendations of experts, the European Commission ("EC")has decided that a concerted effort on the demand-side could very usefully complement the efforts being spent on components and technologies. The EC has decided to launch the

"Motor Systems Energy Efficiency Challenge Programme" ("Challenge Programme"). The essential thrust of this Challenge Programme is:

- raise awareness among industrial users of motor systems about the potential for energy saving (and money saving) measures;
- make available a wide range of information tools, to aid users in optimally designing, purchasing, installing and operating motor driven systems;
- create a European wide framework to encourage top level decision makers to make the implementation of these energy savings measures a management priority. This framework could adopt some of the successful elements of similar programmes, such as the European Union GreenLight programme, or the US DoE Compressed Air or Motor Challenges.
- Get a clear commitment by the company top management to carry out energy efficiency measures.

The Challenge Programme is designed to address a number of barriers to investments in energy-efficient motor systems.

There are multiple reasons that explain why profitable (sometimes very profitable) energy savings measures are not put into practice in the private sector:

- Motor systems electricity consumption is "invisible" to top management, since it is most often a relatively small cost item for any one company.
- Electricity consumption in general, and motor systems consumption in particular, is usually treated as a general overhead item in company analytical accounting schemes. Thus reducing this cost item is not the responsibility of any particular manager.
- Measures to optimise the cost of equipment purchases, such as competitive bidding procedures, rarely take into account long term operating costs due to electricity consumption. Thus these cost cutting practices can be counterproductive in terms of reducing life cycle costs for electricity. This is particularly true since the optimal systems according to the electricity consumption criterion often require higher initial investment. Thus they are not even proposed by suppliers in competitive bidding procedures.
- Responsibility for potential optimisation measures is largely diffused among several management functions: Production, Maintenance, Purchasing, and Finance. It is difficult to get high-level management agreement, cutting across departmental responsibilities, on a low priority item such as electricity consumption.

Despite all these difficulties, in those cases where high level management makes the necessary decisions to carry out motor systems energy efficiency programmes, the results are often outstanding, and management retrospectively is happy with the decision (ADEME 2000). Many European Union and Member State programmes have focused on the problem, and have had some success in stimulating the necessary high level consideration of the problem.

The "Electric Motor Driven Systems" considered in the Challenge Programme are the typical fluid handling application such as compressed air, pumping or ventilation. These applications have in common:

- an electric drive (consisting of a motor and perhaps an electronic motor controller) which converts electrical energy into mechanical energy in the form of a rotating shaft:

- a second conversion device (compressors, pumps or ventilators) which use the mechanical energy delivered by the drive to displace and/or compress a working fluid;
- a network through which the fluid circulates. (In compressed air systems, this network may terminate with an end use device which again transforms the mechanical energy in the air into some other type of service);
- some kind of control mechanism to adjust the output of the system to the needs of the application.

For the purposes of energy efficiency, it is essential to note that the overall efficiency of these fluid circulation applications depends of course on the efficiency of the drive and of the conversion device. It depends even more on the design and operation of the networks of which they are a part, and the inter-relationships between the components. For these reasons, the Challenge Programme will mainly address the systems, and not just the individual components.]

The publicity aspect of the programme would be used to convince top management of the usefulness of subscribing to the "Challenge Programme Guidelines", in some ways similar to the existing EU "GreenLight" Programme commitment. Because of the very wide variety of situations, this commitment would have to be open ended and flexible, a sort of "variable geometry" system, where each company, with aid from the Commission, would target those areas and measures most likely to be effective in its operations. The company will commit to carrying out these measures, and reporting on the results, within an agreed upon time period.

The Framework of the Challenge Programme

The first activity has been to establish the basic elements of the Challenge Programme including the Guidelines. As the GreenLight programme has demonstrated, it is expected that this will be an iterative process, and that experience from the pilot tests phase will be used to correct and improve the proposed Guidelines.

The purpose of the Guidelines is to define the nature of the commitment of companies, which choose to participate in the Challenge Programme, and the requirements, which have to be fulfilled by participants. While the Challenge Programme must be sufficiently flexible to accommodate diverse situations, the general requirements of the approach must be sufficiently rigorous so that the commitment to the Guidelines has meaning. Thus, the commitment must contain clearly defined and verifiable actions, which the companies will carry out. These actions must be of such a nature, that they will lead to realising the bulk of profitable energy savings measures in plants of participating companies. The actions will include:

- a public Commitment, including internal communication of this Commitment;
- integration into management procedures of those reporting and evaluation mechanisms necessary to verify dissemination of the Challenge Programme action within the company;
- inspection and audit procedures, to allow top level management to control energy consumption;
- integration of energy consumption criteria into design and purchasing procedures (including, for instance, "Life Cycle Costing").

The Challenge Programme is based on a number of "building blocks" covering three of the main types of motor driven systems (Compressed Air, Pumping and Ventilation Systems, plus an horizontal block on VSDs), for which major energy savings potentials exist. These three applications account for about half of industrial energy consumption, and an even larger percentage of the savings potential. It has been decided not to include in the initial stage the refrigeration systems because large refrigeration systems are common to both service and industry. Thus it would appear logical to treat them at a future stage when the Motor Systems Challenge is extended to service sector activities.

A specific building block will address the horizontal elements such as motors, transmission element and adjustable speed drives. The use of high performance motors and of electronic motor controllers are common elements to all motor driven systems and can in any case lead to substantial energy savings. The wide experience already gained through the use of EuroDEEM database together with the motor classification scheme would play a major role in the construction of this block.

The basic element of each building block will be to define the technical nature of an appropriate commitment for the specific type of motor-driven system. Because of the very heterogeneous nature of these systems, and the diversity of specific company installations, the "building block" must specify a general approach, consisting of verifiable actions, which when carried out lead to optimal system functioning.

Previous European Commission studies of compressed air systems (ADEME, 2000), pumps (ETSU 2000), ventilators (FhI, 2001), motors (Univeristy of Coimbra, 1999), electronic motor controllers (Univeristy of Coimbra, 2001), have already identified the savings potentials of technical and organisational measures.

The building block must define the notion of a "profitable energy savings measure". It is clear that this cannot be limited to lowering cost, but must include reliability and quality of service criteria. One important consideration is that the targeted types of systems (compressed air, pumping, and ventilation) are usually considered as "technical services" within a production facility. Their failure, or a drop in quality of service, can have catastrophic results on production. Thus, from an industry management point of view, reliability and quality of service are overriding criteria for judging the cost effectiveness of the service, rather than the actual cost of producing the service. For this reason, the Challenge Programme Guidelines will clearly state that profitable energy savings must maintain or improve reliability and quality.

The Challenge Programme Guidelines

The Challenge Guidelines will contain an overall framework for the four "building blocks" already described. The framework will be modular, so as to permit the incorporation, in the future, of new building blocks (for instance on refrigeration systems).

The framework must be of an "à la carte" nature, so that companies are able to choose the elements or types of systems relevant to their operations. In general this means that a company will commit to examine those types of motor driven systems (compressed air, pumping and ventilation systems) that are large energy users in its plants. Some companies might also choose a transversal approach focused on the drives: high performance motors or adjustable speed drives. Furthermore, the framework must be compatible with the range of approaches of the Member State Energy Efficiency programmes for electric motors systems.

In any case it is not possible to specify quantitative requirements for energy savings (as is the case for the "Green Lights" programme), since the level of savings possible depends on the precise nature of each installation and given the wide range of applications. Rather, the target for energy savings must be determined as a part of the audit process to which the company commits itself when signing on to the Challenge Programme.

The Guidelines will define the process and modalities in which companies joining the Challenge Programme, define their specific company plan, carry out their plan and evaluate the results.

Since the process is similar to other environmental and quality certification methods such as ISO 9000, ISO14000 and EMAS (the European Environmental Management and Audit Scheme), care has been taken to use elements from these methods so as to simplify and reduce the cost of committing to the programmes.

The guidelines will be accompanied by the following documents, initially available only in English, which at a later stage will be translated into national languages:

- awareness-raising material to help top company decision-makers understand the purpose of the Challenge Programme and the potential for energy savings. Special attention will be paid to the reliability and quality of service criteria;
- guidelines for the audit and implementation processes, including initial measurements and ex post evaluation procedures;
- lists of resources (co-operating equipment manufacturers, engineering consultants, software, documents and books, training material, list of possible financing mechanism, list of ESCOs operating in this field, etc.).

As it was experienced with the GreenLight Programme, initially there will be an ongoing improvement and revision of the Challenge Programme. Thus, it is to be expected that more than one working version of Guidelines will be issued during the course of the programme, leading to a consolidated version about one year after the launch of the programme. The first year will be used to test the overall Challenge concept, and should contribute to improving and validating the Challenge Guidelines.

The Programme Implementation

Negotiate Participation Of Industrial Enterprises

Perhaps the most difficult task of this phase will be to obtain the agreement of companies to participate in the programme. Since at this stage, the Challenge Programme will not be well known and publicised, programme participants will not have incentives to participate, including the benefit of the full-scale public information campaign. There will not yet be "name recognition" for the Challenge Programme, nor for the logo that will be associated with it. It is to be expected that many companies will adopt a "wait and see" attitude with respect to an approach that will be new and untested.

It will thus be necessary to use the full political weight of the European Commission and of the National Energy Agencies ("national promoters") to convince companies to serve as test beds for the programme.

Each national promoter will seek to obtain the agreement of at least one company during the first year. These companies will be chosen by each promoter as a function of national priorities and programme constraints. Although the Challenge Programme will ask

companies to involve all of their major production facilities, during this pilot test phase, the commitment will most likely be for only one plant, and perhaps for only one service (pumping, compressed air, ventilation). Since it is possible that some of the companies to be approached will be large multinationals, the project participant responsible for this task will co-ordinate the efforts of the project, so that companies do not receive multiple and contradictory offers.

According to the procedures set out in the Guidelines, the commitment will specify the types of motor systems that will be covered by project activities. The Guidelines should also specify that the results of the pilot operations may be made public in order to further the aims of the Challenge Programme. In some cases, this will necessitate negotiation on the nature of information to be made public, in order to protect confidential information.

Carry Out Audits

The National Energy Agencies, in accordance with the terms of their particular national programmes, will carry out the audits during the first year to stimulate company participation. All audits will include description and measurement of the initial state of the motor systems, so as to permit ex post evaluation of the success of actions carried out. The audit recommendations will of course respect the "Reliability" and "Quality of service" clauses of the Guidelines.

It is expected that public funds will be used to co-finance some parts of the audit process, in order to encourage companies to participate in the pilot phase. In some countries, this would be done within the framework of existing audit programmes.

Accompany Enterprises In Implementation

The complete implementation of the Guidelines and of the audit recommendations will probably take much longer than the initial phase of the programme. This is because many of the recommendations will bear on design and purchasing decisions for the creation, renewal or upgrading of major systems. Some of the major components (compressors, pumps, ventilators, piping and ducts, etc.) have typical life cycle of 10 to 20. Thus, it is thus likely that many of the recommendations will not have been carried out during the life of the Challenge programme, which is initially limited to five years.

However, at a minimum, the participating company would have put into place:

- those improvements for maintenance and operations procedures for which rapid implementation is technically feasible (for instance leak detection programmes for compressed air systems, and energy efficient drive belts in ventilators drives);
- some retrofit operations, when they are technically feasible and have very short payback times;
- the basic architecture of a management structure to carry out the plan in the long term. This would include:
  - tools for internal communication on the objectives of the companies commitment to the Programme;
  - guidelines for the integration of energy considerations into purchasing procedures (in particular appropriate elements of Life Cycle Costing).

The Information Campaign

Participating national energy agencies will develop prototype information campaigns. The agencies will:

- define the way in which the Challenge Programme message can be best adapted to national circumstances;
- develop the message to be delivered to the national companies. In particular, the European message will be adjusted to correspond to the specific national energy efficiency programmes;
- identify the best vectors to touch the target group of high level industry management;

The first step will include the testing of elements of the proposed campaign through interviews with a sample of industry managers. This is one of the major tasks of the initial phase. It must capitalise on the experience gained during the pilot test, in order to lay the groundwork for successful launching of the full scale Challenge Programme.

The Challenge Programme Web-Site

The technical basis for the Challenge Programme (identification of the technical measures necessary, auditing procedures, measurement tools, etc.) have been established in previous European programmes. A key contribution to gathering all this information will be made through the use of the existing EuroDEEM database and web-site.

The European Commission has developed a European database for motor system, called EuroDEEM. This activity started in 1995 with the design of a tool for the promotion and selection of Energy Efficient Electric Motors (EEM). The scope of the database containing electric motor data was to make available an important information tool that allows users to easily carry out an evaluation of the best installation or replacement options, therefore helping the promotion of electricity efficiency. The EuroDEEM software package will permit users to select the most suitable electric motor for their purposes, evaluating energy and financial savings.

The first version of EuroDEEM containing only the motor selector database was completed and realised in 1998 with about 3000 motor models available on the EU market. The motor data are loaded directly from motor manufacturers.

EuroDEEM has been created to be a complete tool for very wide promotion and dissemination of information about energy efficiency in motor systems to a large range of end-users.

EuroDEEM included in 1996 the Motor System Inventory DataBase for keeping track of all motor systems and electricity consumption in a Company. In 1998 it was decided to expand the database to other important motor system components such as Variable Speed Drives (VSDs), pumps, compressors, fans and other transmission and control devices. Development activities for the pump and VSD module have started in 1999. A first Demo version of the pump module is available. In year 2000 a motor system audit procedures has been developed and it has been integrated in EuroDEEM.

The central Challenge Programme web-site will be located at the EuroDEEM server. It will help in outreach for the Programme, and will provide specific technical information on

energy-efficiency measures for European companies. It will also help users to easily access the distributed elements of the information centre, located at National Energy Agency sites, trade association sites, equipment producer or distributor sites, etc. Existing tools to aid in optimal decision making in the design, purchase, installation and operation of motor driven systems will either be referenced, or where possible integrated into the information centre. It would include references to many different types of resources.

The web-site will also contain a list of resources that could aid companies in achieving the potential energy use savings, while maintaining or improving reliability and quality of service. The lists would include specialised software, written material (journals, articles, books), multimedia training supports, etc.

Expected Results

The Challenge Programme allocated budget is about 1 billion US$ for the first two years. A third of this amount approximately will be spent in energy audits. The budget will directly finance at least 12 energy audits and follow up on efficiency measures. Experience shows that industrial energy use audits catalyse decision making on technical measures with a value approximately 10 to 20 times the value of the audit. Thus, the project should stimulate at least 3 billion US$ of energy efficiency investments. The initial commitment by the European Commission is to support the Challenge Programme for an initial period of five years.

The long term effect of the programme would of course be much greater. The average payback time for the type of energy efficiency measures that the programme aims to encourage is under two years[1]. Thus the investments directly stimulated by the programme should permit over 2 000 000 US$ of annual energy savings, equivalent to well over 20 000 MWh in annual savings.

The Challenge Programme directly aims to create the conditions for an energy efficiency commitment by top level management in industry. Experience in the US "Motor challenge" and "Compressed Air Challenge" is that the original target of 15 to 20% energy savings will more than be met. It may reasonably be hoped that a broader scale European Programme would be equally successful.

The overall benefits of a successful Challenge Programme would be very substantial. A conservative estimate would be 10% of industrial electricity use, i.e. about 70 TWh per year to be achieved after the five years life of the Programme.

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[1] Note that 2 year payback time, while typical of current industrial practice, is nonetheless a pessimistic estimate. It is hoped that the decision criteria of industrial enterprises will evolve (in part because of the Challenge Programme), so that longer payback time measures will be implemented. The use of Third Party or ESCO financing could play a role.

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