Selection tools for Energy Efficient Electric Motor System Components

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1. Abstract

Motor driven systems consume a significant percentage of electricity produced. Potential for energy savings is high. The current work presents a tool which addresses one of the most important barriers in the penetration of efficient systems, namely the lack of comparative information to help the consumer. The decision support tool was developed to analyse motor driven systems, including motor drives, pumps, compressed air systems and heat pumps used in industrial and tertiary installations. Depending on the motor system and the information available, the approach taken was analytical or database driven. The paper presents the components of the tool, discusses the advantages and disadvantages of the approach taken for each system. It finally presents the acceptance of the tool by the end users and the manufacturers of electric motor driven systems.

2. Introduction

In 2000, total electricity consumption in the EU-15 was 2 574 TWh, of which 951 TWh was used in industry [1]. Of this, 614 TWh, or 65%, was consumed by motor driven systems. A number of SAVE studies [2-5] identified that, where modern high efficiency equipment was properly selected and installed, large energy savings were possible. The studies calculated the economical savings potential of those industrial motor driven systems to be 181 TWh, or 29%.

Electricity driven heat pumps used for air-conditioning, commercial and industrial refrigeration purposes, on the other hand, are foreseen to consume 270 TWh by the year 2010, with a potential for savings of 55 TWh [6].

A decision support tool has been developed, under the ProMot project [7], aiming to aid end-users to explore the possibility of energy savings, in motor systems of an industrial or tertiary installation. The tool addresses what has been recognized to be one of the most important barriers for the penetration of energy efficient systems, namely “the lack of good comparative information to help the consumer” [8]. It has been designed for users having basic (low level) technical expertise. Motor systems considered and analyzed by the tool include

- electric motors
- chillers (heat pumps),
- compressed air
- pumps as well as

while fans and other relevant topics are also addressed. General introductory information is provided on the topics treated. The tool helps in auditing an installation, and performing simple meaningful calculations of purchasing, replacing existing or retrofitting electric motor systems. These technical and economic calculations are based on equipment data retrieved from widely accepted and regularly updated European databases and methodologies.

The ProMot support tool is located on the web at the address www.eu-promot.org, hosted by CRES and has been available to interested users, since spring 2005. A continuous improvement procedure was realised throughout the project duration, though in-house demonstrations and tests from experts. Chiller databases are updated periodically.

Parts of the tool have been translated, to a variable degree depending on the country. Publications, workshops and on-site presentations in participating countries have been used to effectively disseminate and further improve the tool.

2.1 Structure of the tool

Programming had to follow the nature of EU co-financed projects. Project partners come from across Europe, have complementary fields of expertise, work independently and meet during regular intervals to exchange information and plan further work.

Structure and presentation of the tool is of great importance. Lengthy exchanges of ideas and discussions took place before the tool was formed. It was decided, that although useful, using a common programming language could not be forced to the programmers, since they came from different backgrounds and EuroDEEM International was a black box for the project (so its language could not be changed). In addition, programming is a very time consuming task. So each of the four modules should be written in the language the programmer felt most comfortable with.

In addition it was determined that the most effective way of presenting the tool was through a website, dedicated to it. The basic structure of the ProMot decision tool was then decided. Structure evolved during the project execution and the final form (to date) is shown in Fig. 1. Apart from the general project information and download capabilities, the ProMot decision tool consists of four basic modules (Motors, Chillers, CAS and Pumps). Each module includes:

- A front end (presented in "Overview" page)
- A technical calculation module (combined with Overview for CAS)
- Audit forms for each component
- Relevant Studies for each component, or the topic as a whole

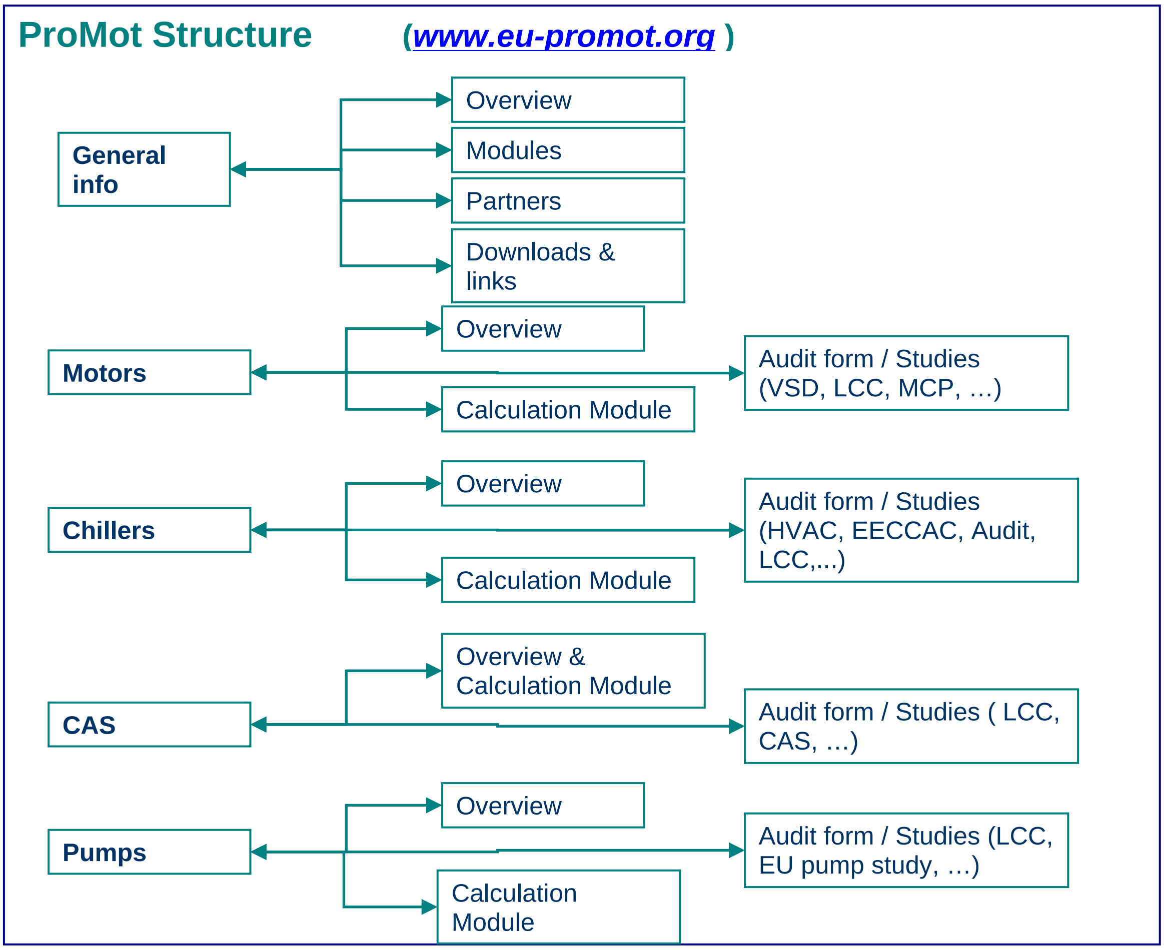

Fig. 1 Website (tool) structure

2.1.2 Motor and Drive Module

Motor and Drive Systems "overview" part of the module informs the user of the existing motor efficiency classifications and the benefits of using a high efficient motor and drive system. It also guides the user on proper sizing of a motor system and gives tips on how they can reduce transmission losses.

The calculation part of the module "EuroDEEM International" was created by the Washington State University Extension Energy Program [9] with the support of JRC, the International Copper Association and others. It is based on the EuroDEEM electric motor database and was provided to the project in executable form by JRC. This technical calculation module (see Fig. 2) is a standalone software which allows the user to specify parameters for a desired motor system, such as power, speed, manufacturer, etc. Based on the input and using data for over 18,000 products in the EuroDEEM database, available motors as well as economic analysis is presented to the user.

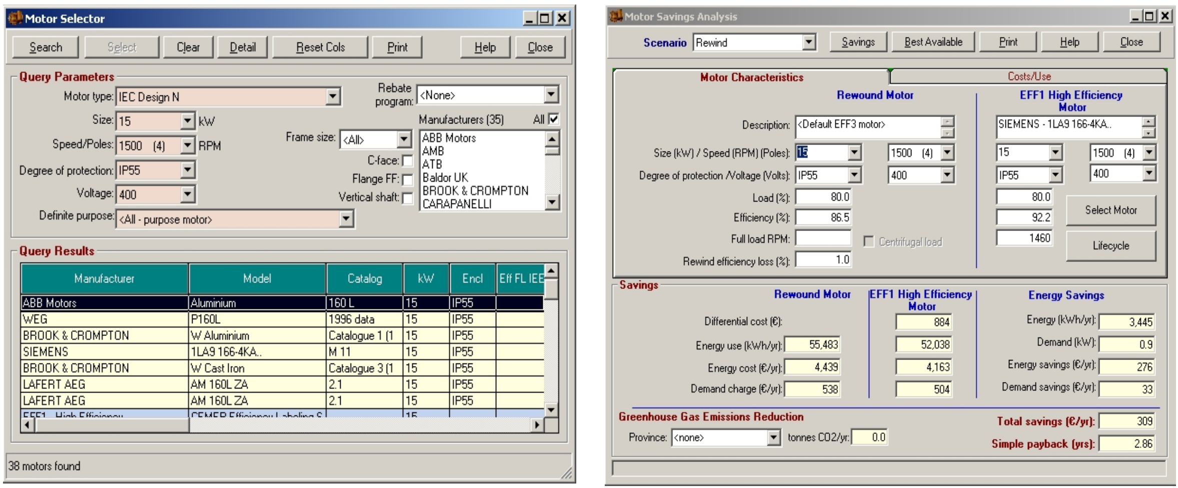

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Figure 2: Motor and Drive Calculation Module

2.1.2 Chiller (heat pump) Module

The Chiller (heat pump or HVAC) "overview" part of the module provides general information on the basic components of an HVAC system (chillers, pumps/fans, pipes/ducts, AHUs and FCUs, ventilation, etc). It provides direct links to the pumps module and the Eurovent - Cecomaf site for up-to date information on these products.

A methodology had to be created, to analyze the energy and economic aspects of the chiller operation, based on the data available in the chiller database of Eurovent. The methodology had also to account for the two types of chillers of the database, namely air and water cooled. The user can calculate the energy (and water) consumption and analyze the effect of choosing various chillers for a new or an under refurbishment installation.

For Chillers, the technical and economic analysis technical module was developed. The basic requirements for the module were set at the beginning of the project and they are

- to look like the motors and drives EuroDEEM International module. This way the user will work in similar looking environments.
- to be both web based (interactive) as well as standalone
- to utilise the Eurovent chiller database for analysis

Data for the analysis is drawn from the Eurovent-Cecomaf database. Differences in energy performance initially from 3,600 (to appr. 5600 currently) different tested machines from 44 manufacturers contained in the database are very significant and lie in the range shown at the following table. Chiller database is regularly downloaded and updated, and this will continue on a voluntary basis from the developers for 2 years after project completion

Energy performance at full load		
Chiller type	**EER** ***Min- Max***	**COP** ***Min- Max***
Air cooled	**1.61 - 3.97**	**2.16 - 4.18**
Water cooled	**2.62 - 6.38**	**2.33 - 4.94**

Chiller module, web-based version was based on the Microsoft .NET platform (ASP.NET technology). This software could be downloaded at the beginning of the project, but it is a standard part of Windows XP. The stand-alone version of the module runs, using the same platform, on a pseudo Internet Explorer environment automatically created on the computer of the user.

The main functions of the chiller module are:

- Allows users to retrieve information for all chillers stored in the database.
- Guides the user in the selection of a specific chiller satisfying user-defined technical criteria for a specific application.
- Identifies and ranks a number of chillers based on energy consumption for user defined heating/heating loads.
- Calculates the energy and cost savings under different scenaria.

The chiller module contains two independent functional sub-modules: the Chiller Selector and the Chiller Savings Analysis (Fig. 3).

The Chiller Selector sub-module provides parameters for selecting and sorting lists of chillers from the database. The available query parameters include a great number of chiller parameters existing in the Eurovent database, as well as the desirable range of cooling and heating capacities. The user can also select chillers from all manufacturers or from one or any combination of selected manufacturers.

The Chiller Savings Analysis sub-module is used to calculate the annual reduction in energy use and monetary savings given that the user selects a specific Efficient Chiller instead of a standard one for a particular application. It enables the user to identify the most cost-effective alternative under three different scenarios:

- New (Compare New Chillers) compares the costs of acquiring and operating a new standard chiller with those of an efficient model. A standard chiller is assumed to be the “base case”. The module determines the energy and cost savings achievable due to purchase of the higher over a lower efficiency chiller model. Then, assuming that the efficient chiller is also more expensive to purchase, it determines the simple payback on the investment in the efficient chiller.
- Refurbishment (Repair versus New Motor Purchase) compares the cost-effectiveness of rewinding a standard chiller against the cost of purchasing a new efficient model. This comparison takes into account a reduced efficiency for the rewound chiller attributable to age and rewind losses.

- Replace Existing (Replace Operable Chiller) analyzes the cost-effectiveness of replacing an operable standard chiller with a new efficient model. This scenario is used to decide if it is cost-effective to immediately replace older, low-efficiency, rewound, and oversized and under-loaded chillers. The analysis considers the entire new chiller purchase price plus installation costs as the chiller price premium when determining the simple payback.

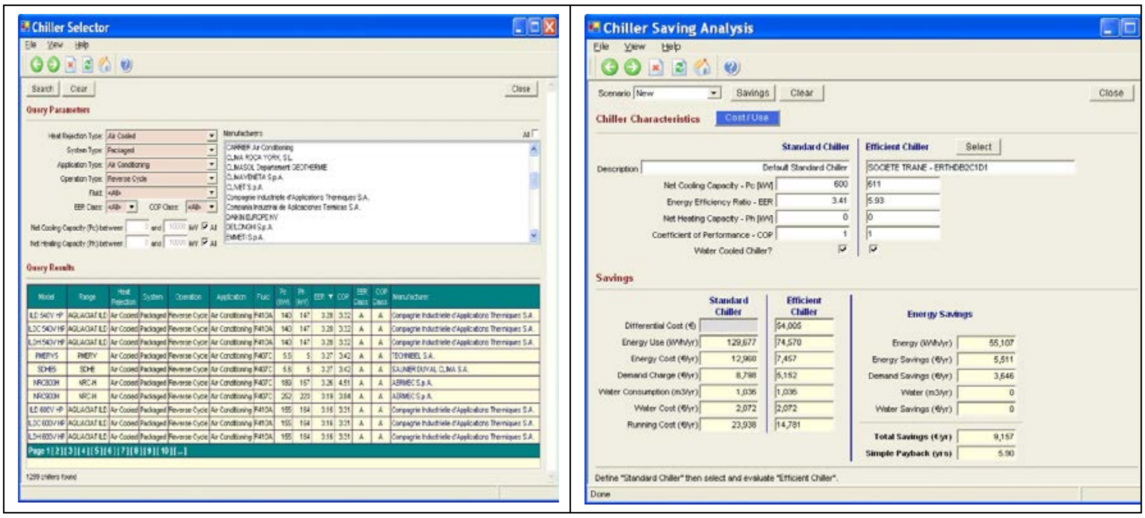


Figure 3: Chiller Calculation Module

By the end of the project the Chiller calculation module masks was translated in 5 different languages – English, French, Greek, Germany and Portuguese.

2.1.3 Compressed Air System (CAS) Module

Compressed Air Systems is the least technical module in the tool. As described at the outset of the project, it does not contain significant calculation capabilities or a database. Following the description in the proposal the module takes the user through a "Guided Tour" of the existing system, to identify the priority actions for energy savings. It provides information, cost and saving analyses for three cases:

- Low cost measures to improve operation and maintenance
- Major repair or extension and
- Design, purchase and installation of a new compressed air system.

CAS calculation part has the basic features presented below.

- *Characterisation of user needs***.** Interviews with users and experts of PNEUROP were combined with study of literature and the specification of end-user to determine the nature and level of complexity of information that would be most useful to the projected future users of the tool.
- *Specification of the precise data to be displayed.* On the basis of the characterisation of user needs, a further phase of work defined the precise data set that would be displayed. This was based, notably, on the SAVE CAS study, and on ADEME tools.
- *Design of the mode of presentation.* Discussion internal to the ADEME, coupled with examination of existing energy efficiency tools led to the definition of a three pronged approach to displaying data.
    - o display by potential cost and savings by system component and by type of action

- o display through a ten step walk through, or "guided tour" of a CAS system
- o display organised by the major phases of the life cycle of a system: design and building of a new system; overhaul and major repair; regular operation and maintenance.

➢ *Specification of the type of interactivity of the system.* A data set was defined, with the double objective of permitting the generation of useful and relatively precise information tailored to the user's system, while not imposing an unreasonable load on the user for data collection.

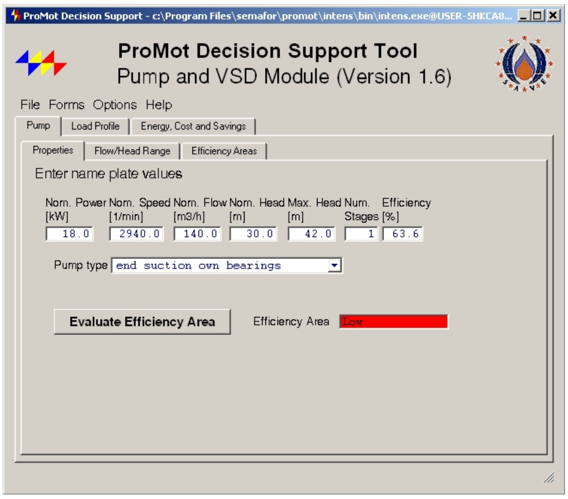
2.1.4 Pump Module

Developing the pump module [10] was one of the most difficult parts of the project. The initial version was based on the Swiss model OPAL. The next step was to create a database. Since no manufacturer offered data, the module developer obtained actual pump data existing on the web, from three major pump manufacturers. A technical module was developed to handle the database. The resulting technical module offered the capability to compare different pumps, based on real data, for a certain application and chose the most energy efficient one for an application at hand.

Upon completion of the module the European Pump Association - Europump, informed the project group that the pump industry strongly resists comparison of different products between manufacturers. This attitude might change with time, but not within the project duration.

The project group had to retreat to the theoretical, non-database, type of analysis – technical module. Range of application was further narrowed to clean water pumps, which are of high importance to the average user, especially for the end-users targeted in this project.

The Pumping Systems module examines the possibilities for energy savings from (clean water) pumping equipment and associated controls. Like other systems, the initial purchase cost of a pump is a small fraction of its operating energy cost. The introductory part “Overview” of the module (Front-End) provides general guidance on choice of pumps and associated systems.



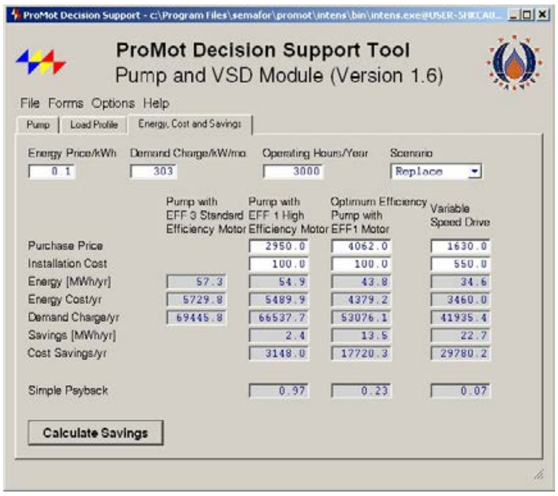


Figure 4: Pump Calculation Module

The calculation part (see Fig. 4), finally developed, lets the user define the nameplate values of pumps and the load profile and calculates the energy consumption based on operating costs. It is, like Motor and Drive Calculation module, a stand alone program, after examining the existing programs on pumps (OPAL, DEFU). The user can determine the efficiency category of a given pump and find the most cost and energy effective action for a pumping system. The benefit of control by Variable Speed Drives (VSD) systems for the given load profile is also treated in this module.

An important development for future work took place towards project conclusion. The Danish partners (DEA) have developed a simple web-based module for pump selection, with data from 4 manufacturers operating in Denmark. These manufacturers were contacted and gave the project permission to use the existing tool. A link was thus made from ProMot to the Danish web-based database module.

2.2 Defining and targeting the ‘end-user’

The end-users were defined as the decision makers who specify, market and/or operate energy-consuming equipment. They can be technical people (engineers and technicians, design department, maintenance and operating department), commercial people (buying department), management people, agriculture /stock production people (especially for ventilation, pumping with irrigation systems and refrigeration). To sum up, they can be purchasing, operating, maintenance people, engineering staff, decision makers. This means that they can have technical, economic or commercial skills. The users may also be the manufacturers, who are analyzing the market, to identify in which directions their products should be developed (the equipment proposed in Promot can play the role of a golden carrot). Financing people are not the main direct targets of the Promot tools but technical people can use the results (for instance internal rate of return, net present value) of the Promot tools to convince them with the financial analysis performed with the tools.

‘End-users’ are both numerous and very heterogeneous. Even if the ProMot tool needs to target the technical people, the other potential users (commercial and management people) should be able to find some guidelines to choose a motor and optimise its environment. The end users are people with very basic technical and economic understanding. They should be provided with the incentives (presentations-literature), the tool (database) and the calculation method (basic engineering & economic) to make a choice and be able to support it. For each sector, the technical knowledge of a "decision maker" in terms of equipment can be minute or very detailed, so some differences in approach should be considered: one approach for those that have some technical knowledge and a second approach for those that know little about energy/electricity/choice of equipment, etc.

2.3 Adaptation of the tool to national context

Software dissemination is best achieved when people easily understand its contents. The tool developed is targeted across the EU, so it had to be adapted to national languages. Degree of translation is country-dependent. In some participating countries English is less of a problem than for others. It was mandatory that ***only*** the introductory page was to be translated. Some countries (France, Austria, Italy) felt it is necessary to do more that.

As a result various parts of the website have been translated to different degrees. The chiller module is the most translated part, due to an automatic translation procedure set up by the developers of the module.

2.4 Dissemination

Dissemination was an integral part of the project. It was used to demonstrate the tool as well as to determine shortcomings of the formation and help improve them.

Testing and improvement was a continuous process in this project. ProMot partners started testing, updating and suggesting improvements for the ProMot decision tool since its first version was placed on the web.

The first tests to be made outside the project group were within the (energy related) organisations of the partners. Some partners used consultants for this purpose. Several constructive comments were received from the tests.

A series of on-site demonstrations of the tool was organised in each country. The tool was shown to professionals working in the field of energy efficiency in industry or large buildings. Several constructive comments were received.

Universities participating in this project have demonstrated the decision tool to postgraduate classes of students as a part of their homework on real buildings and ask them to solve problems and comment on its effectiveness. The tool has been adopted as a part of final year projects.

Europe wide dissemination was achieved through personal meetings with consultants, industry and building operators, through participations and demonstrations in conferences, meetings, international fairs etc. Each country used its own mechanisms to reach the maximum number of interested audiences.

An indication of the acceptance of the tool can be given by the number of access/downloads. The access statistics of ProMot website have shown that over 2500 internet users have had access to the tool world-wide, within the period of basic tool completion-final reporting to the Commission ie. 1 September 2005 – 31 May 2006. It is worth mentioning that

- many users are outside the participating countries
- usage of the website exhibits an increasing trend which continues after completion of the project in March 2006.

In addition to the aforementioned connections, several copies were handed out in the form of CDs. This occurred f.ex. in the case of University students, seminars in third countries, and other instances where audiences might not have fast connections to download parts of the tool, such as the EuroDEEM module.

3 Evaluation of modules

The four basic parts of the tool have a different structure and philosophy. Collection of evaluations forms reveals the acceptance of each part

EuroDEEM – motor selector is a standalone database application. Users appreciated using it, but complained about the size of the files to download and having to install it on their computer.

Pumps module – was found to be useful. Many users requested to have a database facility in it. University students (non-professionals) had a number of questions on input required.

Compressed Air Systems was also considered useful. Users, however, once they have used it, do not usually return to it.

Chiller Module – is the most dynamic facility of the tool. It is web based (no need for installation) or standalone, exists in 6 languages, and uses a continuously updated database of certified products. People use it to get information on efficient chillers, or to analyze the chiller technological status. It has lately been placed in the Eurovent website and requests for information are constantly received.

4. Difficulties met – need for development

Developing a software tool is not an easy task. The outcome had to be a working, error-free product. Forming a website of “static” nature (using HTML and downloading files) is quite straightforward. Such a formation gets exceedingly complicated, however, when calculations have to be done within the website.

The organisations participating in the project had, as was expected, different ideas about the outcome and how to achieve it. This presents, of course, advantages - by bringing different ideas together - and disadvantages, time for agreement needed, to the EU cofunded project.

The major problem had to do with being allowed to use databases to compare product of different manufacturers (eg pumps). The difficulties regarding this topic were known before the project started. Progress was, however, slower than we had hoped for. Different manufacturers offer tools on the web helping to size and compare each ones’ products. The manufacturers will not allow, however, using these databases for comparison between similar products of different manufacturers. An exception to that is the motor drive industry which is contributing such data to JRC and allows direct comparison via EuroDEEM. Even chiller manufacturers, who are allowing for such data to be tested and published by Eurovent-Certification, do not allow energy and even more economic comparisons on the Eurovent site.

5. Conclusions

The current project addressed the issue of energy efficient motor driven systems. An easy to use decision support tool for electric motor systems has been developed. The whole tool is placed in its website (www.eu-promot.org) and it can also be downloaded, installed and run on a standalone computer as an offline version.

The project has managed to form a tool/website which combines together

- front-ends with introductory information
- technical calculation modules
- relevant information from EU studies

for

- Electric motors and drives
- Chiller (heat pump) systems
- Compressed air systems
- Pumps

The project has developed a methodology for the energy efficiency evaluation of chillers, using EU-wide accepted chiller databases of Eurovent-Certification. It has also managed to sensitise the pump industry towards the direction of comparing actual pump data. Treatment of pumps and compressed air systems followed an analytical approach.

Wide and effective dissemination of the ProMot decision support tool - to the key actors in the participating countries and, through the web, to the entire EU – has been undertaken. The tool was demonstrated in major international events, shows and conferences as well as in local country meetings and workshops. This led to considerable increase of awareness in exploitation the energy saving possibilities for electric motor systems.

Considerable knowledge has been gained from the execution of the project. The most important is, that database using modules are preferred by end-users as a means to choose a specific product and also to determine the state of the art of the market. Some manufacturers, on the other hand are hesitant to allow use of the databases to perform energy comparisons between products. Significant work is needed to remove this barrier.

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