PEER-REVIEWED PAPER

Megatrends supporting energy efficiency and requirements for effective implementation

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Abstract

This paper aims to clarify upcoming energy efficiency related development in the next 15 years, mainly on a general level but also help end users understand the development and changes in energy intensive industry. There are a few key megatrends linked to energy efficiency:

1. Governments' target to cut correlation between economic growth and primary energy use and to improve energy security.
2. Global competition, where companies in countries with high energy costs have to compensate the energy related competitive disadvantage with more intelligent energy usage.
3. Growing importance of regional trade unions (NAFTA, MERCOSUR, ASEA; EU, EurAsEC) in energy politics and usage of energy trade as a political instrument.

Energy efficiency (EE) is the element that addresses all above mentioned megatrends. While the impact of EE to life time costs is self-evident on micro-level, on macro-level EE has an impact to energy security and infrastructure investments. Reduced energy consumption diminishes energy prices [1] and improves the trade balance [2]. Also, it positively influences energy security and reduces investment needs in new power generation capacity, in transmission and distribution grid investments and grid balancing. All these elements have an impact to the industrial competitive situation, especially in Europe where energy prices for industry are 2–3 fold compared to the USA.

Monitoring energy consumption on an everyday basis is essential to managing energy costs and improving the productivity and competitiveness of European enterprises. Running old inefficient equipment is a general practice, in the domestic, commercial and industry sector. Several examples prove that a demand-side market does not focus on life time costs in purchasing electrical motors but concentrates on capital expenditures instead [3]. This market failure must be fixed with supply-side regulation, as is done in the form of MEPS in many countries and regions. Examples from the USA and EU provide clear evidence that for a change in market behavior, voluntary EE agreements do not suffice but mandatory regulation is needed. [4]

Regulation shall be ambitious and drive technological progress. In this sense European legislation lags behind the US.

The drawback is that MEPS cover only new products. An extensive study [5] in the USA focusing on installed base and user behavior in motor market shows that for every new motor sold 3 to 5 motors are repaired. As a consequence ANSI approved EASA standard AR100-2010, "recommended practice for the repair of rotating electrical apparatus" ensuring that the efficiency of motors remains at a good level after rewinding.

Existing MEPS have differences in power ranges, voltage levels, and in other details. These differences are technical barriers for global motor trade. Therefore international standardization organizations, industrial federations and governments should take action towards unified energy efficiency regulation.

Introduction

Energy efficiency is still of vital importance albeit the price of energy shows a downward trend because of shale oil and shale gas findings. Shale is found only in certain parts of the world and it has been most actively utilized in the USA. This, in turn, leads to a disparity in energy prices between Europe and the USA.

In order to remain competitive, European industry has to embrace energy efficiency measures. Or energy intensive industries will leave Europe for such countries that can offer cheap energy. This problem will be addressed in the section "Changing energy policy landscape".

A Minimum Energy Performance Standard (MEPS) has been taken into use in a number of countries to help the end users choose the right kind of motor for their applications. These standards are, however, different in different parts of the world, which makes it hard to follow this well-intended path. The MEPS dilemma is discussed in the section "Varying MEPS requirements".

Motors can only be run for a certain number of hours, after which they have to be replaced by new (and more efficient) motors or rewound or otherwise brought up to prolonging their life cycle. In the section "Rewinding old motors gives only partial relief" we take a look at how motors are given a second life.

Regulation is regarded by many market participants as something negative. Yet, with regulation a push towards higher efficiency equipment can be created. For instance in the USA the level of new motors has been set to IE3, whereas in Europe the required level is only IE2. This, coupled with lower energy prices, plays to the advantage of American companies. In the section "Regulation plays key role in energy efficiency" it is argued why we need regulation.

Changing energy policy landscape

During the past few years, energy policy landscape has changed. Major contributors to this change are, among others:

- shale gas boom in the USA that has made local energy very attractive for energy intensive industry;
- China's growing energy dependence and energy demand;
- merit order effect and its negative impact to new power plant investment.

These factors are driving a few megatrends in the global energy landscape. Next, we will discuss three of them.

- Governments' target to cut correlation between economic growth and primary energy use and to improve energy security.
- Global competition, where companies in countries with high energy costs have to compensate the energy related competitive disadvantage with more intelligent energy usage.
- Growing importance of regional trade unions (NAFTA, MERCOSUR, ASEA; EU, EurAsEC) in energy politics and usage of energy trade as a political instrument.

All these are related to energy efficiency. And energy efficiency is the only common factor in addressing all of them.

Population growth, increasing living standards and urbanization are driving energy consumption. According to IEA WEO 2013, primary energy consumption will grow 1,2 %–1,3 %/a during the next 15 years. But electricity demand will grow nearby twice so fast. [6]

In Europe, growth based on a growing population is very limited but to manage all social, environmental and economic challenges and problems we are facing, economic growth is needed. However, this is possible only when

- European industry is competitive.
- Climate and other environmental boundary conditions are dealt with.

To accomplish this, the connection between economic growth and energy consumption must be cutout. This is already happening but mainly thanks to relocation of energy intensive industry to non-EU countries. This is not the right approach, because it jeopardizes the European industrial base.

A few years ago, during the pre-shale gas boom era, the main concern was to prepare economies to energy scarcity and to sky-rocketing energy prices. This launched energy saving programs and other actions towards better GDP/TWh-ratios. This also emphasized climate worries. But the unconventional gas and oil boom particularly in the USA changed the picture. Now it is about the competitiveness of European energy intensive industry. Industry in the USA enjoys remarkable energy price advances: On average, electricity prices in the USA are half of those in the EU and gas prices are one third.

The shale gas boom has also reduced USA energy related emissions dramatically. Power generation related specific emissions are expected to reduce nearby one quarter until 2030. [7]

The European Union is updating its energy targets for 2030 and beyond. This is happening when customs unions and Economic communities are becoming more important trade policy actors and bilateral agreements are more and more common and WTO is losing its importance as common trade policy base. While NAFTA and also MERCOSUR are reaching self-sufficient position on energy markets and maybe also becoming net – exporters like EurASEC, the European Union remains primary energy importer paying a high financial but also political price.

But what is the common factor in this development? It is energy efficiency. Energy efficiency addresses all energy security, competitiveness and economical security related issues. It reduces direct costs for the industry and energy prices while diminishing aggregated energy demand. It also reduces investment need for new generation and transmission/distribution infrastructure and dependence on imported energy. It improves trade balance and reduces emissions. Changes in the energy supply, demand and security policies all underline the central position of energy efficiency on micro and macro level.

Varying MEPS requirements

Existing Minimum Energy Performance Standards (MEPS) have differences in specifications that form technical barriers for global trade. International industrial and standardization organizations and governments should take action towards a unified EE-regulation.

GLOBAL DIFFERENCES MEAN GLOBAL DIFFICULTIES

At this moment MEPS are valid only for motors and the scope and the coverage for different types of motors in the countries globally are totally different. For example the basic idea in the USA and NEMA (National Electrical Manufacturers Association) regions was to include all motors into the plan and then make exceptions for special types of motors. On the contrary, in the European Union the basic idea was very narrow which means that new motor types will be included into the MEPS classification only one by one. It would be interesting to see what the final form of MEPS in China will be; what motor types will be included there in the first wave. Of course the same question is relevant to other big markets too.

Figure 1 shows a list of the existing and near future MEPS globally. As seen from the figure, the power ranges for MEPS vary a lot and so does the time for enforcement and implementation of policies according to various power ranges and motor types. Many countries do not have any kind of MEPS, so all types of motors are legally available in these markets.

The next step in the EU energy efficiency policy will be a system efficiency approach for motor driven systems, where motors, VSDs and the actual load equipment will be taken into account when making efficiency classes or actually putting limits to losses in the systems.

All these variations in the MEPS form serious challenges to international companies that use motors in their factories. It gets even more difficult for OEMs who use motors in the products they manufacture to global markets.

In this situation of varying local MEPS it is problematic to organize global purchasing because depending on the locations of their manufacturing units different types of motors have to be used. Moreover the need for country specific products will cause extra costs to OEMs and other manufacturers.

EFFICIENCY CLASSES

Motor manufacturers and later also VSD manufacturers may have to make small series of products which fit into some local MEPS requirements. Thus the danger arises that this situation may affect same way as local production protectionism if only certain types of products are allowed in the local MEPS.

There is no system in place to control that the motor users are following the new MEPS at their manufacturing sites. It has not been defined which authority should monitor these MEPS in the countries.

Only the availability of products in the markets can be controlled, so motors with lower than the minimum IE class cannot be sold. This also applies to the motors in the OEM products and later the same goes for the VSDs and other equipment which are defined in the MEPS.

But especially in the EU the situation in 2015 will be interesting when the next MEPS step comes into force: should the motor represent a minimum of IE3 class or can also an IE2 motor be used with a VSD? The IE2 motors will still be available in the markets. So how and who will control that IE2 motors are not put into use as DOL (direct-on-line) without a VSD in the production sites?

Moreover there will be a clear danger that old poor efficiency motors will be repaired and taken into use in new applications, too. There are indicators in the USA that some kind of black market business for repaired IE1–IE2 class motors already exists. [8]

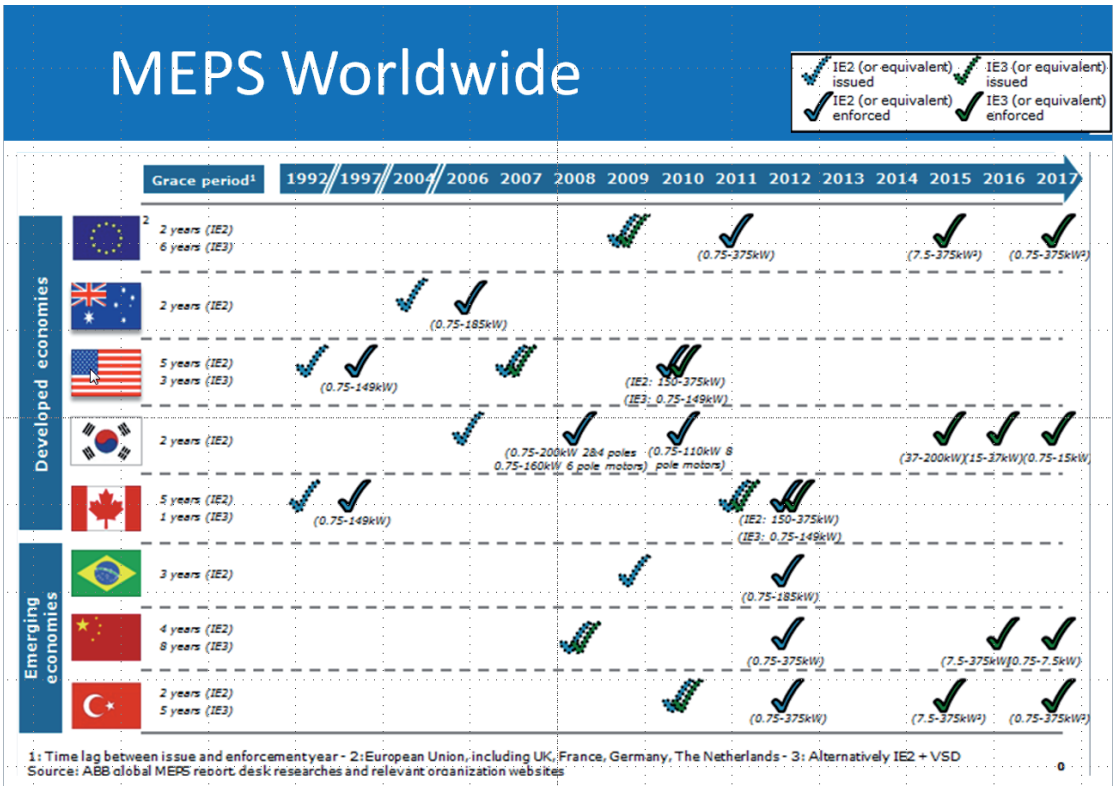

Figure 1. MEPS Worldwide (ISR – University of Coimbra, June 11, 2013).

Table 1. Rewinding practices of electric motors in the US. [5]

HP Category	Mean Lifetime Operating Hrs	Mean Annual Operating Hrs	% of Units Failed/Year	% of Failed Units Rewound
1–5	40,000	2,745	7	20
6–20	40,000	3,391	8	61
21–50	40,000	4,067	10	81
51–100	40,000	5,329	13	90
101–200	40,000	5,200	13	91
201–500	40,000	6,132	15	91
501–1000	40,000	7,186	18	91
1001+	40,000	7,436	19	91

Rewinding old motors gives only partial relief

Today Minimum Efficiency Performance Standards (MEPS) for electric motors cover the majority of the markets for new low voltage motors. Many countries are preparing MEPS for LV motors and China as a front runner will introduce the first MEPS for high voltage motors, followed by US and EU in the near future.

However to realize the full potential of energy efficiency in electric motor driven systems, more attention should be paid to the installed motor population as well. The global motor population (above 0.75 kW) is estimated to be roughly 300,000,000 million units (2010) growing 10 % annually. [9] Additionally according to the American Council for Energy-Efficient Economy (ACEEE) estimates that for every new motor sold, five motors are repaired and 25–30 % are rewound during the motor lifespan. So, despite the good progress in regulatory world new motors are not penetrating in full scale to the majority of motor population, installed base and repairs.

In many cases rewinding will not restore the motor's original optimized efficiency level. [10] Of course there are cases where the efficiency can be even improved with rewinding. But generally in literature it is estimated that rewinding drops the efficiency of a motor from one to three percent. It is estimated that the price for rewinding is 40–60 % of the price of a new motor, depending on the local labour costs. [11] Especially in low cost countries and during tough economic times rewinding is be the first choice in many companies.

In the US there is already a voluntary standard available, AR100-2010 recommended practice, for the repair of rotating electrical apparatus. The standard gives guidelines also for rewinding in order to assuring the quality of rewinding. Table 1 shows that the rewinding of the failed unit reaches a remarkable level starting from 21 HP. In the higher output ranges nine out of ten units are rewound in case of failure. The motors within the above mentioned output ranges also exhibit the highest annual operating hours, which means that with high quality rewinding or replacement with higher efficiency motors the biggest savings in electricity consumption can be reached.

In the electrical motor repair market the utilization of higher efficiency replacements, high quality rewinding or system upgrade, e.g. installing a VSD, face the same barriers as in the new motor market. Energy efficiency does not stand high enough in the purchasing criteria of electric motor buyers. Instead, it comes only after reliability, availability, safety and price.

Regulation plays key role in energy efficiency

Regulation plays the key role when energy efficient products are rolled out. The timeline of low voltage motors regulation tells quite simply that that the US and NEMA regions lead the development (Figure 3). They have implemented already in 2011 mandatory IE3 (Premium efficiency) level regulation for motors while the EU only half a year later took first steps to IE2 (High efficiency).

EU LAGS BEHIND THE US

Why is regulation so important? We need to understand the volume base first. In the low voltage motor markets more than 48 million motors where shipped globally in 2012 (IHS). The motor market can be roughly divided in three areas (Figure 4). Here the US and Americas form one, EU and MEA (Middle East and Africa) makes the second and China and other Asian countries make the last third area.

If we now look at the US motor market, there are more than 10 million units shipped annually. Based on IHS statistics, regulation clearly works and the main purchase volume of new motors has moved to IE3 motors. At the same time EU markets are moving from IE1 to IE2. Having more than 10 million motors with efficiency gain of 2–3 % not only helps end users to save energy and be more competitive in the market place but also helps the whole society to use energy more efficiently and limit CO_2 emissions. Based on a rough calculation this effect can be 20–30 TWh every year compared to low regulation countries. [12]

To understand this transition from existing installation base of LV motors, many of those still at the IE0 level, we can look at an IHS statistic and forecast from 2010 to 2017 (Figure 3). Lifetime expectancy for LV motors is 15–20 years. Based on a recent study in Switzerland (Brunner 2013) [13] more than half the analyzed motors in industry where even older, some 40–50 years. It is interesting to realize that even though there have been IE4 motors on the market already in 2010 their

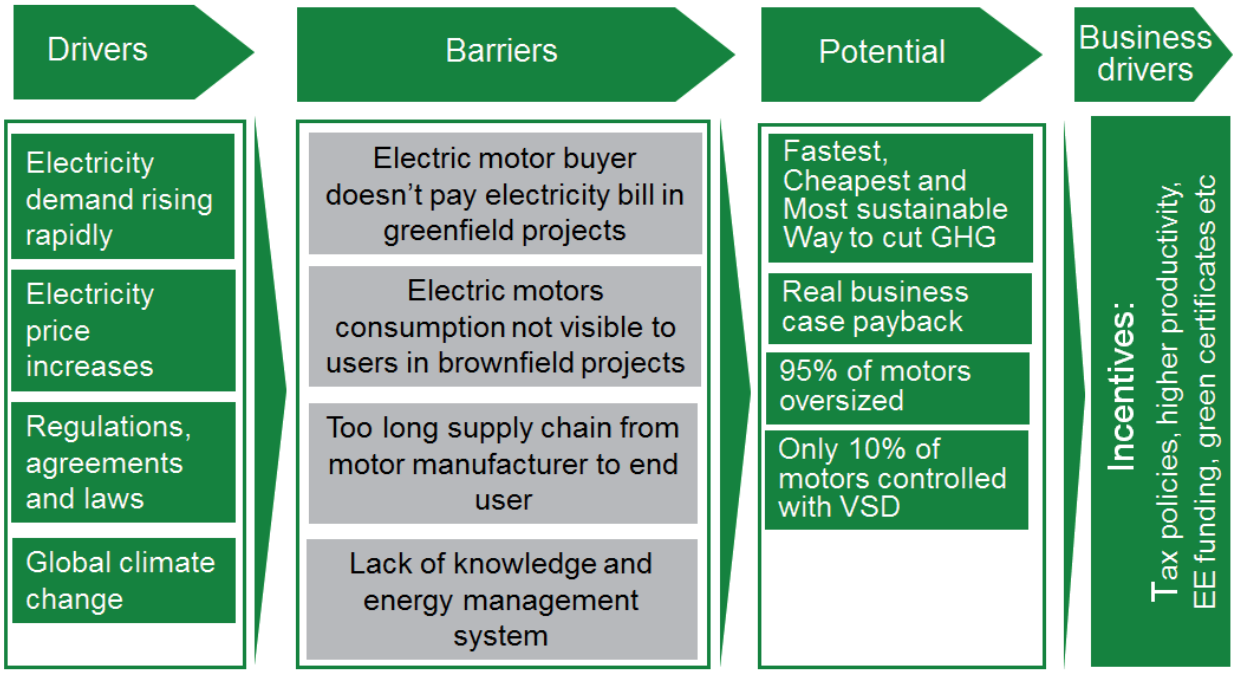

Figure 2. Barriers to buying new motors (Jyrki Leino 2013).

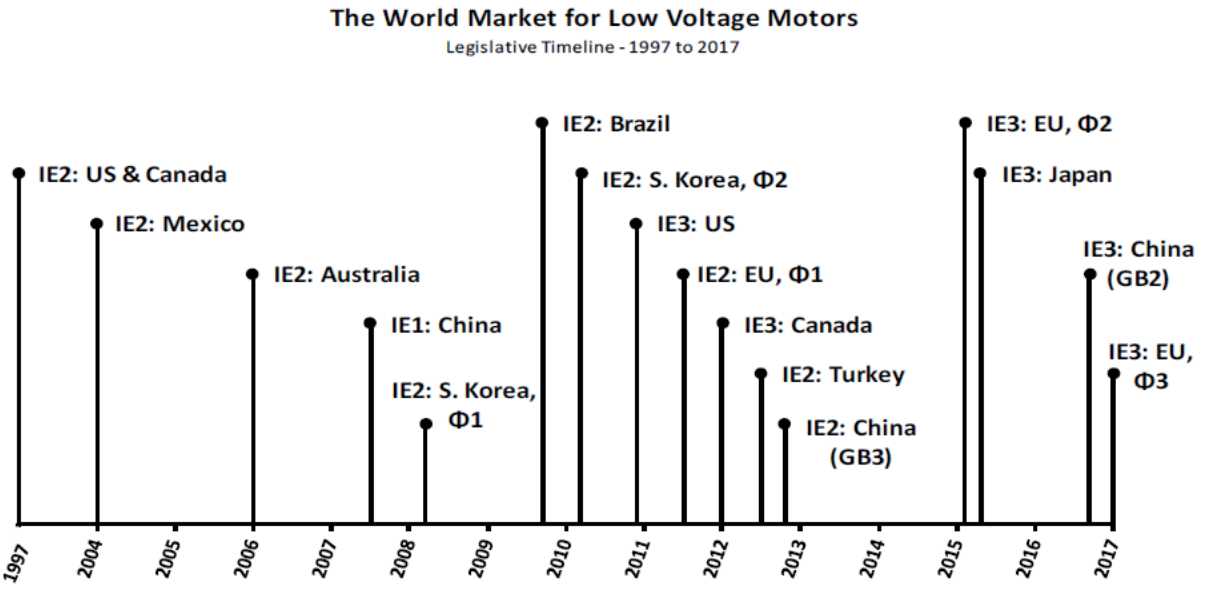

Figure 3. Regulation timeline for LV motors 1997–2017 (IHS 2013).

market share has been and still is very low. This is especially hard to understand when one knows that that 95 % or more of motor life cycle costs are pure energy consumption (Brunner 2013). Here IE4 motors would clearly save the most. Looking more closely at Figure 3 we see that the US regulation to IE3 has taken effect on 2011 and 2012. IE1 volumes are slowly going down partly because of EU regulation and development in China.

Many countries support voluntary energy efficiency agreements to limit energy consumption, mainly in industry. Coming back to Figure 3 we do not see any aggressive move to high efficiency motors in any markets. Voluntary agreements are one way to promote energy efficiency and boost investments but statistically they have not proved to be very effective compared to regulation.

REGULATION REQUIRED FOR HIGH EFFICIENCY MOTORS

Let us take a look at the Figure 5 with different eyeglasses, this time with the motor manufacturers'. As we see, there are a variety of motor efficiency classes available. To be able to manu-

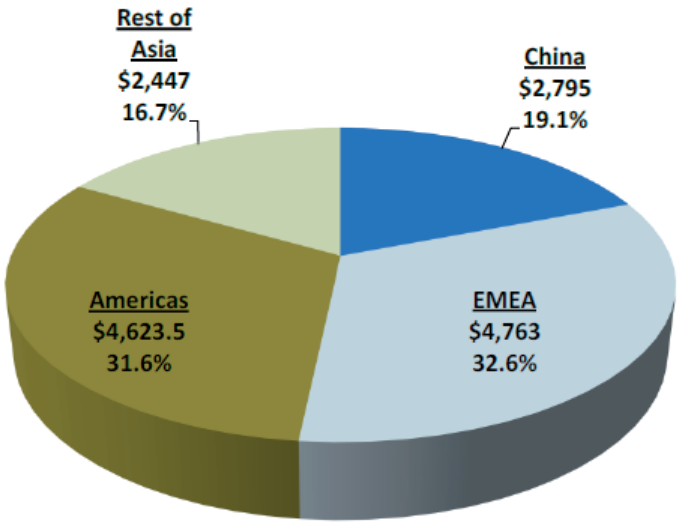

Figure 4. 2012 Global low voltage motor market in MUSD (IHS 2013).

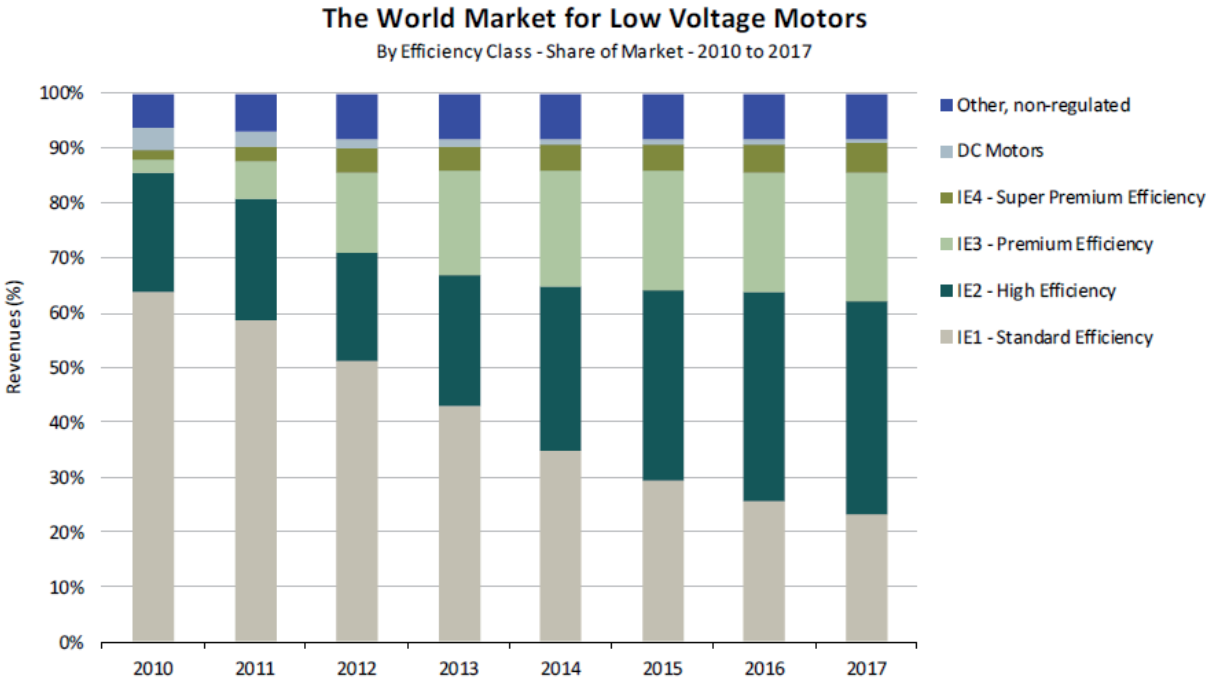

Figure 5. The World market of LV motors 2010–2017 [IHS 2013].

facture high efficiency IE4 motors one needs constant R&D to limit motor losses and innovate. Permanent magnet motors and synchronous reluctance motors are part of this development, the race for higher efficiency. At the same time many low cost motor manufacturers are active within the IE1 and IE2 areas where the sales price of the motor is the lowest. In Europe and the US there are many motor manufacturers focusing on high technology products that tackle the price competition with high efficiency and high reliability.

Successful launching of high efficiency motors regulation helps remarkably in creating a local market for this kind of motors. The market pull boosted with regulation has helped US motor manufacturers in recent years. In the EU motor manufacturers are offering high efficiency motors but low cost, low efficiency motors are preferred by the markets. This kind of fragmented development is a huge risk for local manufacturing.

Regulation development in US has been active. Europe is many years behind the US development. The worst case scenario from the EU perspective is if China changes gears and starts to implement high efficiency regulation faster than is expected in Figure 1. In this scenario the EU would be the only market for low cost, low efficiency motors. This situation would be unsustainable for European motor manufacturers.

Conclusions

From this study it can be concluded that motor markets do no work like the efficient market hypothesis presumes. In an ideal world end users would choose energy efficient motors that help in saving energy, thus relieving a company's cost pressures that stem to a large part – especially in the manufacturing industry – from electricity. This is on micro level. The joint behaviour of many companies produces the macro level, where energy efficient equipment alleviates the pressure on electricity distribution networks and even diminishes the need for building new power plants.

The declining energy prices, due to shale gas, give US companies an edge over European companies that have to pay a higher price for their energy. This could be fought with a widespread usage of energy efficient motors, but instead Europe lags behind the US in regulating the markets. In Europe only IE2 class motors are mandatory whereas the USA mandates the use of IE3 motors.

Also problematic to a wide scale adoption of new motors are the differences in Minimum Efficiency Performance Standards (MEPS). The MEPS are different in different parts of the world which makes multinational companies' international sourcing difficult. Also motor manufacturers suffer from having to pursue the national guidelines which compel them to produce smaller series.

Used motors are often rewound instead of buying new more efficient motors. Especially when low efficiency motors are given a new life, the resulting savings can be marginal.

Market regulation is often regarded as interfering with the markets. We have shown, however, that regulation can boost the demand for higher efficiency motors. This in turn has positive effects to, besides the individual companies' finances, also to national economies. Less imported energy translates into better trade balances and less energy consumption means less infrastructure investments. It has been seen in practice that voluntary energy saving initiatives work only to a certain degree. For more results, more regulation is needed.

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