ENGINEERING TOMORROW

Thought leadership

# System philosophy in efficiency optimization


*Abstract*

*A system approach in efficiency optimization delivers the most rewarding efficiency improvements.
This article presents the concept of Efficiency First, where energy saved is regarded as the first fuel, an energy source in itself.
It goes on to describe a system philosophy to significantly reducing energy consumption in applications, where the focus is on system efficiency and not only on component efficiency.*


## Powering a better tomorrow for the global energy supply

In the united effort to preserve global security of energy supply and protect the climate, the industrial sector is justifiably under intense scrutiny as a significant energy consumer. Focus on energy consumption, and therefore energy efficiency, is inextricably bound to security of supply. This article presents the concept of Efficiency First, where energy saved is regarded as an energy source in itself. It goes on to describe how energy consumption can be significantly reduced with a focus on system efficiency and not only on component efficiency.

## Energy efficiency as an energy source

Taking a holistic approach, the principle of reducing consumption has just as great a role to play in ensuring a sustainable energy supply in the future as converting from fossil fuel to renewable energy sources or expanding energy supply capacity. Energy efficiency is not only crucial in reducing $CO_2$ emissions and production costs. It is also a key enabler in ensuring a stable supply, because it contributes to avoiding expansions of the grid. What is not consumed is not transported, saving on expansion and maintenance of the associated infrastructure. Improving energy efficiency does require an up-front investment. However, in many cases this investment is more cost-effective or valuable than the equivalent supply-side resources.

Therefore it makes sense to talk about energy efficiency as an energy source, the first source. This approach goes under the name of Efficiency First.

Some of the key ways in which Efficiency First can contribute to more cost-effective, competitive energy choices are[1]:

- Enabling efficiency investments to compete on a level playing field with energy supply investments, in the national energy markets
- Removing barriers to investments in efficiency
- Monitoring progress on targeted initiatives such as the Ecodesign Directive, the Energy Performance of Buildings Directive and the Energy Efficiency Directive
- Taking account of energy efficiency in policy development and planning, and avoiding unnecessary investments in fossil fuel infrastructure

When the capacity of industrial facilities is upgraded with an Efficiency First approach, system efficiency optimization becomes the first alternative in sourcing energy, and increasing energy consumption becomes the last. Incentive and motivation to optimize system efficiency will decouple increased capacity from increased energy consumption. In many countries the link between increased GDP and increased energy consumption has already been broken. To achieve the best possible results with Efficiency First, the prerequisites are:

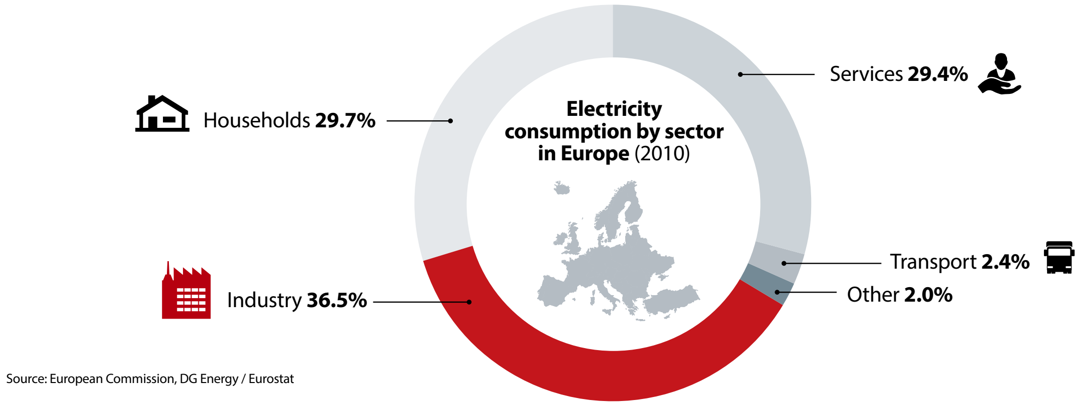
- Benchmarking tools to compare the efficiencies of different systems and solutions
- Motor and control system independence of the AC drives, ensuring freedom to achieve the best possible combination of components for optimal system efficiency

[1] *Efficiency First: Key points for the Energy Union Communication, The Regulatory Assistance Project, February 2015*

## Component versus system thinking

Why all the focus on industry? In 2010, the industrial sector was the biggest electricity consumer in Europe[2], with a share of 36.5 per cent of the total consumption (Fig. 1), equivalent to 1.036 TWh (1.036 billion kWh).[3] Almost two-thirds of this total, or 650 TWh, was used by electric motors and electric motor systems.[4] In the tertiary sector, a part of services, the total electricity consumption of motor systems is around 200 TWh.[5]

*Figure 1: Electricity consumption by sector in Europe (2010)*



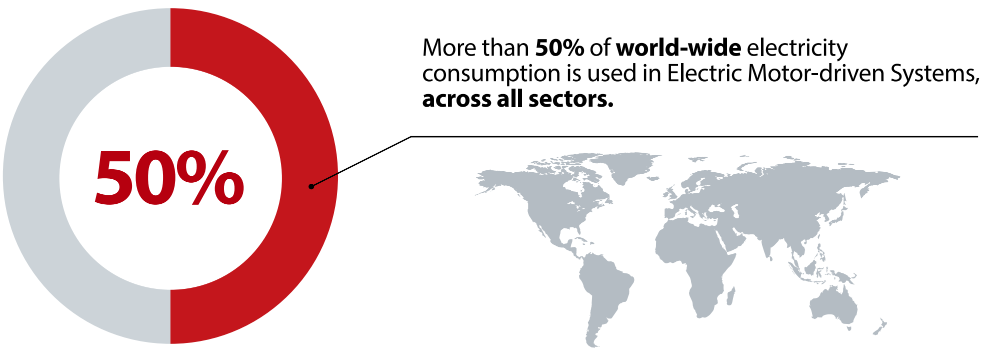

### Within the Industry sector, electric motors account for the majority of the electricity demand.

In China, industry is the largest electricity-consuming sector in the entire economy, responsible for over two thirds of total electricity demand. Electric motors account for 60-70 percent of the industrial electricity demand, which creates a strong case for optimizing electric motor systems – for instance through variable speed drives, or AC drives, which the International Energy Agency (IEA) suggests should be made mandatory. The situation is very similar when looking at India where the industrial sector accounts for more than 40 percent of the total electricity demand.[6]

### Electric Motor-driven Systems consume more than 50% of global end-use electricity

Typically the electric motor is a component in a motor system, responsible for the conversion of electrical power into mechanical power. In turn, this mechanical power drives equipment such as fans, pumps or compressors. Analysis by the IEA shows that Electric Motor-driven Systems consume 6000 TWh/year in the industrial sector alone, and account for more than 50 percent of world-wide end-use electricity consumption.[7]
Electric Motor-driven Systems are therefore the largest single consumer of end-use electricity and therefore a prime target for coordinated government policies on a global scale.

*Figure 2: More than 50% of world-wide electricity consumption is used in Electric Motor-driven Systems*




To date, political regulation of industrial energy consumption has only partly addressed the energy efficiency and energy-saving potential of motor driven systems. The present initiatives all address efficiency at the component level, setting Minimum Performance Levels for motors, pumps, fans and other single pieces of equipment.

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[2] *Energy-Efficiency with Electric Drive Systems*, ZVEI- German Electrical and Electronic Manufacturers' Association, April 2015
[3] *Energy markets in the EU*, European Commission, DG Energy / Eurostat
[4] Bauernhansel, Mandel, Wahren, Kasprowicz & Miehe, *Energieeffizienz in Deutschland*, May 2013
[5] EUP Lot 11 Motors Final Report [6] International Energy Agency, *World Energy Outlook Special Report on Energy and Climate*, December 2015, pages 77-79
[6] International Energy Agency, World Energy Outlook Special Report on Energy and Climate, December 2015, pages 77-79
[7] *World Energy Outlook*, International Energy Agency, November 2016

According to ZVEI, the German Electrical and Electronic Manufacturers' Association[8], efficiency improvement at the component level can address about 10% of the total savings potential. Using variable speed in applications with pumps, fans, and compressors can address about 30% of the total savings potential. However, the largest potential for energy savings lies in system level optimization, where 60% of the total savings potential can be addressed.

A large untapped potential for energy saving awaits nations in the form of regulation for a system-based optimization of energy efficiency, rather than for optimization only at the component level.

**What's to win with the system approach?**

Energy efficiency initiatives are by no means equal, and some energy-saving opportunities are clearly more worthwhile to pursue than others. The wide range of energy-reduction strategies fall into three general categories, with differing value. As stated above, the total energy reduction potential is split into three categories, which will now be addressed in more detail.

The origins of energy savings potential in electric motor driven systems are illustrated in Figure 3. The scope of the Extende Product is the motor system, defined as the AC drive, motor, driven machine (for example, fan or pump) and variable load. Figure 4 illustrates the scope of the Extended Product [9, 10].

*Figure 3: Energy savings potential, in industrial terminology*

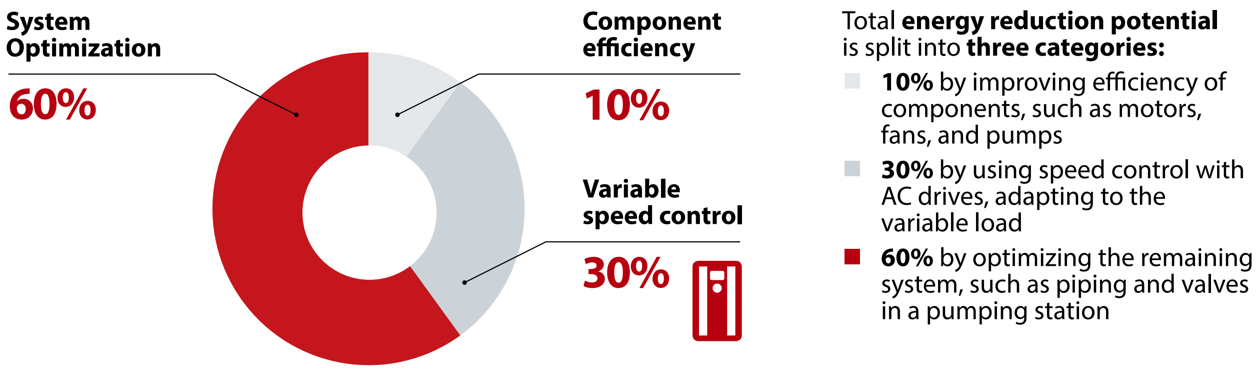
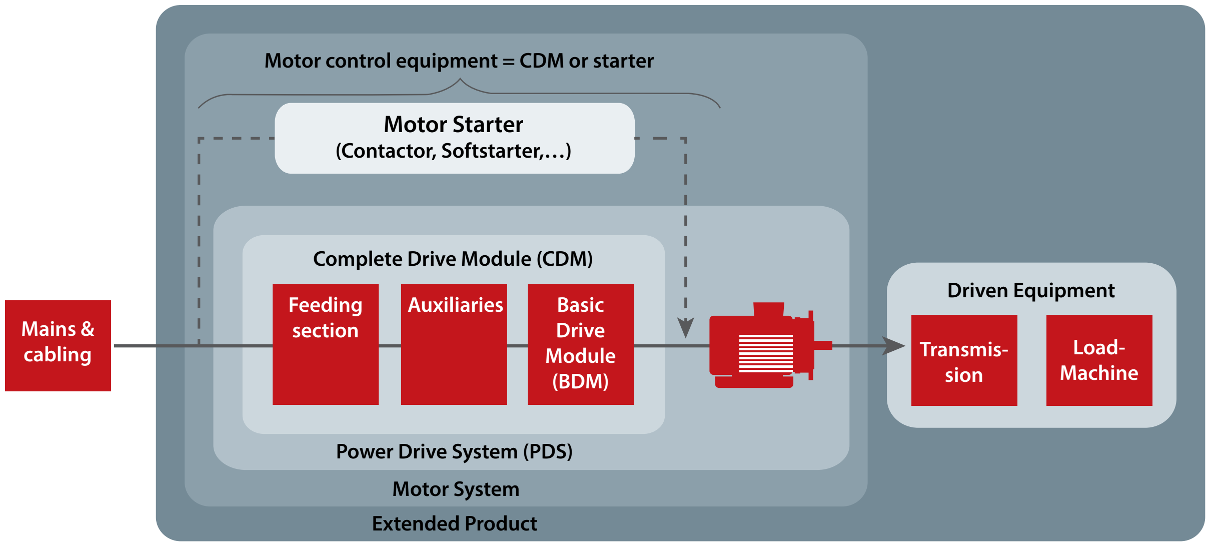



*Figure 4: Scope of the Extended Product*




[8] *Energy-Efficiency with Electric Drive Systems*, ZVEI- German Electrical and Electronic Manufacturers' Association, April 2015
[9] *EN50598-2* Efficiency classes of converters and drive systems
[10] IEC 61800-9-2 Adjustable Speed Electrical Power Drive Systems – Part 9-1 Extended Products and Part 9-2 Classification, not published

An EU pump study under Ecodesign Lot 29[11] demonstrates that efficiency regulation based on the extended product approach has an energy savings potential 7-9 times greater than component efficiency regulation.

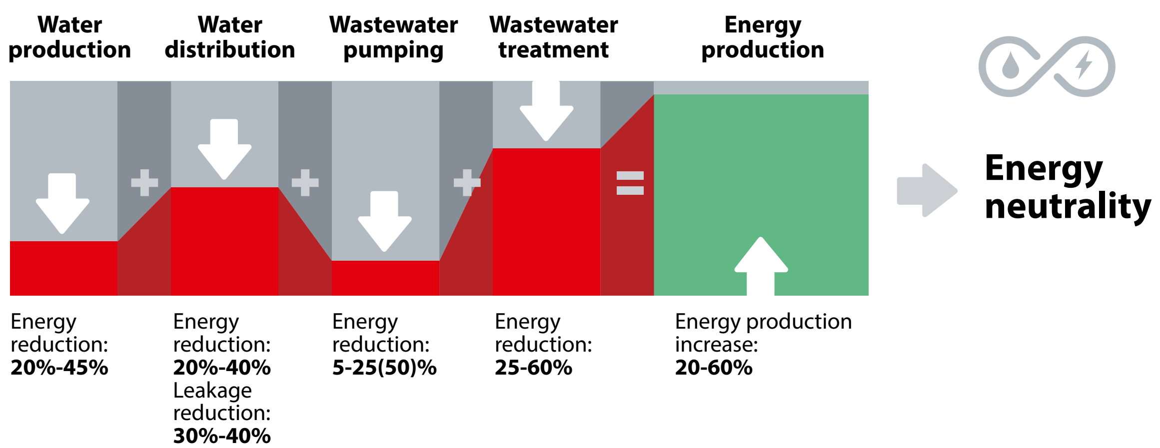
Overall system optimization comprises a multitude of different energy-saving approaches. All these factors influence the overall system efficiency:

- Analysis of the system layout
- The energy sources used
- Central or decentral control
- Degree of partial loading
- Actions which can reduce energy consumption

When choosing which combination of approaches to apply, it is vital to act on the basis of cost-effectiveness over the lifetime of the facility.

The Marselisborg wastewater treatment plant operated by Aarhus Water in Denmark is a textbook example of system optimization at its best. This water utility has optimized its system and processes by reducing energy consumption, maximizing biogas energy production, managing leakages, and reducing maintenance and replacement of pipes. As a result it has achieved energy neutrality, and reduced its proportion of the municipal electricity consumption, which was typically 25-40 percent of the municipal electricity budget, to zero[12].

*Figure 5: Energy neutrality in a water utility*




### Partial load

In particular, partial loading is a critical issue addressed in system optimization but not in component-level optimization. Component efficiency measurements are based on full load. In reality, however, systems operate at varying partial load where the efficiency levels of the components drop dramatically - and this drop is addressed in measures for system optimization.

Since system-level optimization offers the highest energy-saving potential, it makes sense to shift the focus there but not forget component efficiency. Efficient components will aid in providing motivation to improve the Extended Product efficiency and the system efficiency, and in achieving the greatest gains for the global energy supply.

How can we promote the Extended Product and system efficiency approaches? If organizations, regions and businesses can agree on a universal benchmarking standard which takes partial loading into account, it will be easier to compare and assess the efficiencies of different system solutions.

### System efficiency as market differentiator

In the US, pumping system operators will soon be motivated to optimize pump system efficiency by a voluntary labelling scheme. The Hydraulic Institute, a non-profit trade association of pump manufacturers and suppliers, is planning to introduce a voluntary labelling program which enables benchmarking of pump systems.

Using a standardized testing system, manufacturers can differentiate themselves by demonstrating the superior efficiency of their pump systems in terms which are comparable with competing systems. In this way, pumping industry suppliers are effectively motivated to optimize pump system energy efficiency ratings, without the need for government regulation.

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[11] Viegand Maagøe and Van Holsteijn en Kemna B.V., *Ecodesign Pump Review, Study of Commission Regulation (EU) No. 547/2012 incorporating the preparatory studies on 'Lot 28' and 'Lot 29' (Pumps), Final Progress report* December 2015

[12] Hughes, L: *Water Management is Highly Energy Consuming – But It Doesn't Have To Be,* Huffington Post, December 2015

In contrast to the Hydraulic Institute's voluntary labelling program, The Energy Conservation Standards for Pumps uses a mandatory approach. Implementation of this regulation is predicted to reduce US electricity consumption by 1% in the period 2020-2045, due to pump system optimization alone[13]. The standard states: The cumulative reduction in CO2 emissions through 2030 amounts to 2.7 Mt, which is equivalent to the emissions resulting from the annual electricity use of more than 0.37 million homes[14].

**Challenge to legislators and regulators**

Common wisdom amongst leading authorities within research and regulation says that effective regulation has to come in a well-defined order[15]:

1. Component efficiency regulation
2. Once this is in place and completed, The Extended Product approach (the AC drive, motor and driven machine) is implemented
3. Finally, the system approach can be implemented.

Danfoss Drives challenges this approach, as this does not address the "low-hanging fruits" first, although it seems easy from a legislation point of view. We propose to address all three areas in parallel, using well defined and suitable tools in each area. System level optimization can without a doubt deliver the greatest energy savings. Therefore we encourage focus not only on optimizing component efficiency, but also on increasingly improving efficiency at the system level by applying the "Extended Product Approach", addressing the variable speed drive, the motor, the driven application and its variable load.

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[13] *Energy Conservation Program: Energy Conservation Standards for Pumps*, AGENCY: Office of Energy Efficiency and Renewable Energy, Department of Energy, July 2015, page 13

[14] *Energy Conservation Program: Energy Conservation Standards for Pumps*, AGENCY: Office of Energy Efficiency and Renewable Energy, Department of Energy, July 2015, page 14

[15] Electric Motor Systems Annex (EMSA), *Policy Guidelines for Electric Motor Systems, Part 2: Toolkit for Policy Makers*, October 2014

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AGENCY: Office of Energy Efficiency and Renewable Energy, Department of Energy, July 2015

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