EU-MORE

EUropean MOtor REnovation initiative

21st Mar 2024 / T2 Electric motor industry

Trends in motor technologies,

and why old electric motors should be replaced faster – presented by the EU-MORE project

Tomas Jezdinsky (ECI)

This project has been co-funded by the European Climate Infrastructure and Environment Executive Agency under the LIFE call, LIFE-2021-CET-POLICY, with grant agreement N° 101076631.

Intro

Project runtime (30 months) 2022-2025

EU-MORE

EU-MORE is an acronym for
EUropean MOtor
REnovation initiative

This LIFE-Project aims to speed up replacement of old, inefficient electric motors in industry and the service sector.

Electric motors tend to stay in service for 30 to 40 years, which is much longer than generally assumed.

With swift action, this replacement rate could be improved.

In the EU, replacing old motors faster would free up additional energy savings, on top of the savings potential of existing regulations, with all the associated benefits.

LIFE project funded under grant agreement N° 101076631

EU-MORE project partners

- ISR – University of Coimbra
- ECI – European Copper Institute
- IEECP – Institute of European Energy and Climate Policy
- AEA – Austrian Energy Agency
- CRES – Centre for Renewable Energy Sources and Saving
- Fraunhofer Institute for Systems and Innovation Research

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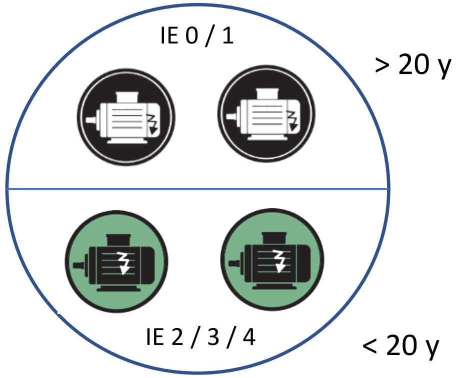
What is the problem?

Electric motors > 50% of EU electricity consumption

A total of 8 billion motors in EU (1)

EU-MORE addresses **motors > 0.75 kW** representing a large share of the total consumption



Swiss survey: 50% of the concerned motors are > 20 y old

Figures for EU are lacking, but situation is expected to be similar

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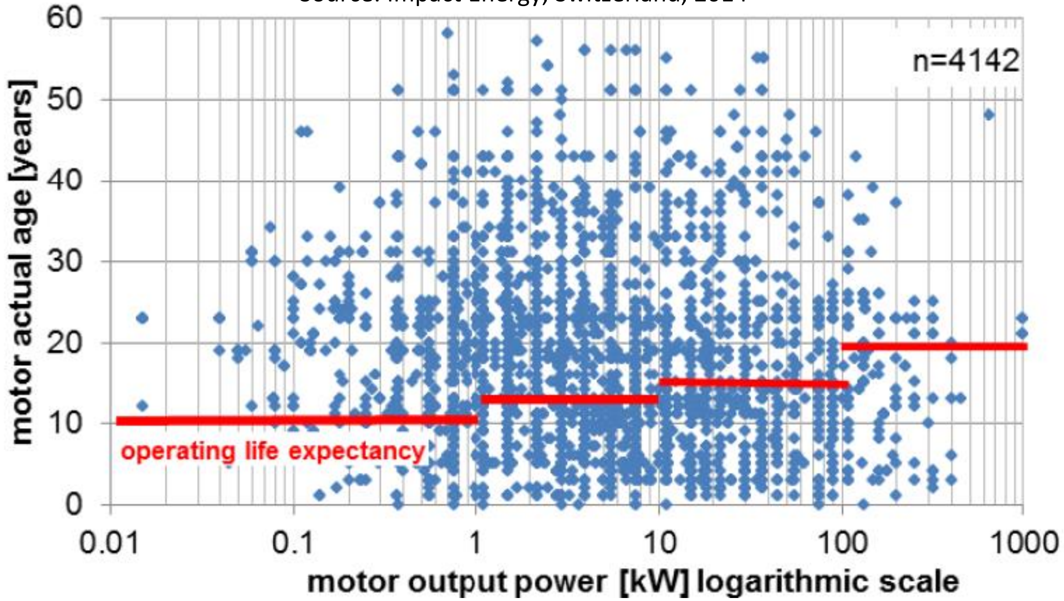
Motor Lifetime

The average lifetime of motors (including repairs) in previous EU studies have been estimated to be:

1.0 – 7.5 kW:	12 years
7.5 – 75 kW:	15 years
75 – 250 kW:	20 years

- In 2013 the Swiss Energy Agency S.A.F.E. assessed 4124 separate motor systems in 18 factories.
- The analysis shows that 56% of all motors and their respective systems were older than their expected operating lifetime (some 2x age).

Source: Impact Energy, Switzerland, 2014



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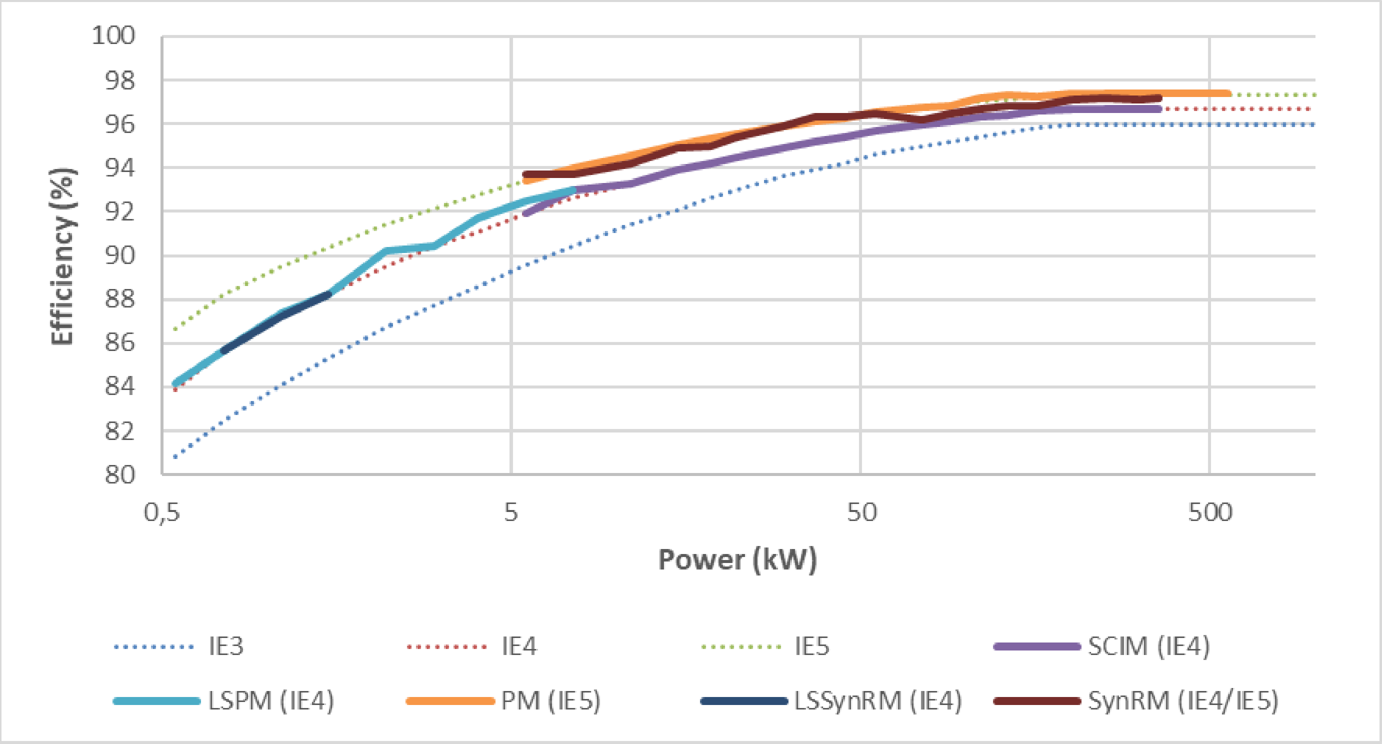
Motor efficiency trends

- Many countries implementing Minimum Energy Performance Standards (MEPS) for motors, has led to great improvements in the energy efficiency of motors
- Now reaching well above IE3, Super- and Ultra-Premium Efficiency Motors (IE4 & IE5)
- Induction motors with IE4 efficiency widely available on the market. Technologies such as permanent magnet motors (PMM) and synchronous reluctance motors (SynRM) even possible to exceed IE4 and IE5 efficiency



Source: ISR-UC based on catalogue data

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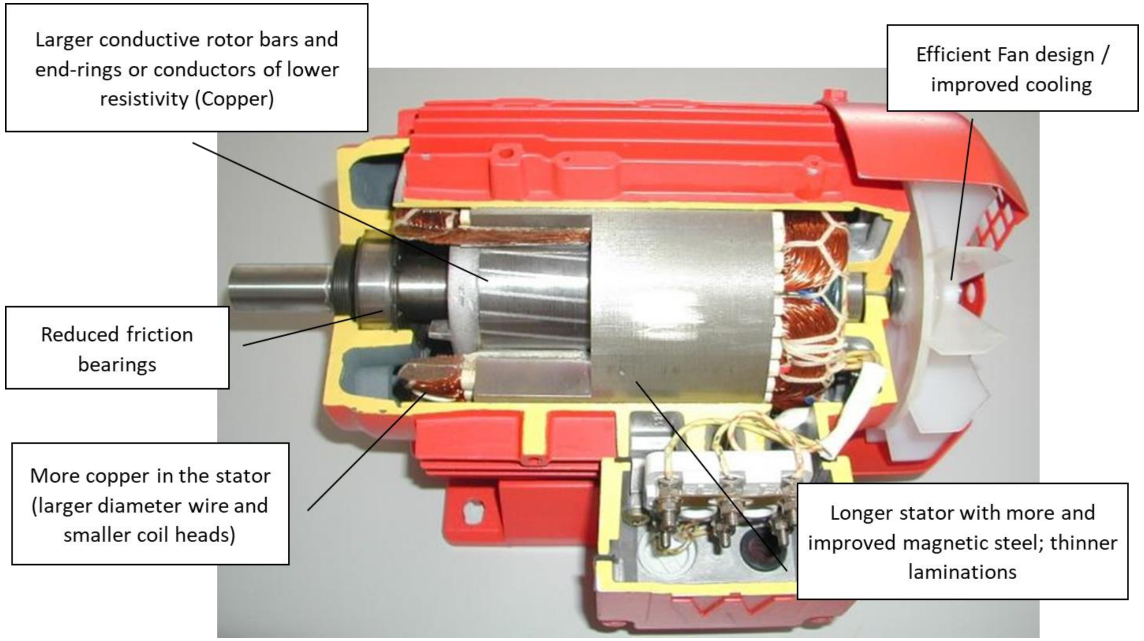
Induction motor efficiency improvements

Efficiency improvements are typically achieved with

- superior magnetic materials
- larger magnetic circuits with thinner laminations
- larger copper/aluminium cross-sections in the stator and rotor windings
- tighter tolerances
- better quality control and optimized design

Lower losses generally result in a lower operating temperature, leading to improved reliability.



Source: ISR-UC

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Hairpin windings to increase slot fill factor

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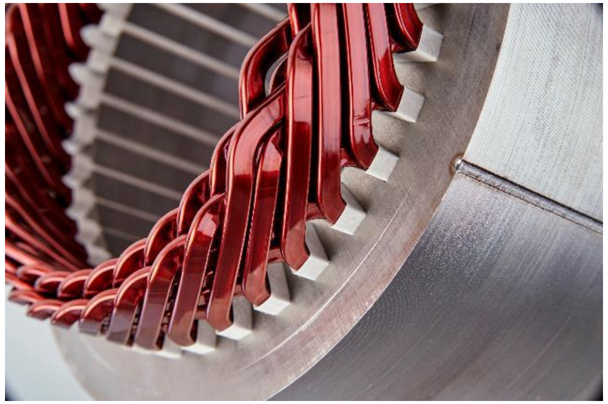
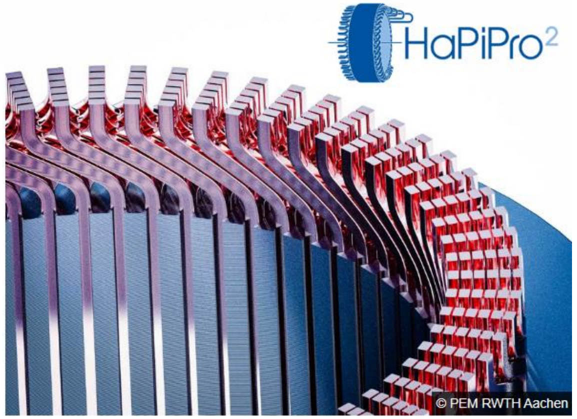
- In hairpin windings, the conductor segments are pre-formed into U-shapes or hairpin-like structures to fit precisely within the stator slots.
- The use of hairpin windings effectively reduces the amount of inactive copper extending out of the stator core by reducing the size of the winding end-turns. The reduction of the magnetic core length is also possible leading to additional savings.
- Improved winding techniques will shorten rotor and stator lengths, reducing the amount of raw materials used and improving performance, especially efficiency.
- These novel winding techniques will help manufacturers to comply with future circular economy requirements by minimizing the raw material content





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Line-Start Permanent Magnet Motors

Courtesy: M. Caner Akuner
Marmara University · Dept. of Mechatronic Engineering

- LSPM have permanent magnets fitted into the squirrel cage rotor, giving them the ability to start by direct coupling to an AC power source – avoiding the use of a Variable Speed Drive – whilst having very high efficiency during synchronous running
- One of the main advantages of these “hybrid” motors is their interchangeability with induction motors. Their design enables them to keep the same output /frame ratio as standard IM motors
- Do not require electronic motion control, since they are able to start from standstill with a fixed-frequency supply.

There two main disadvantages of these motors:

- They cost about twice as much as IE3 induction motors for the same power.
- The starting torque can come with substantial oscillations, which can damage the mechanical loads.

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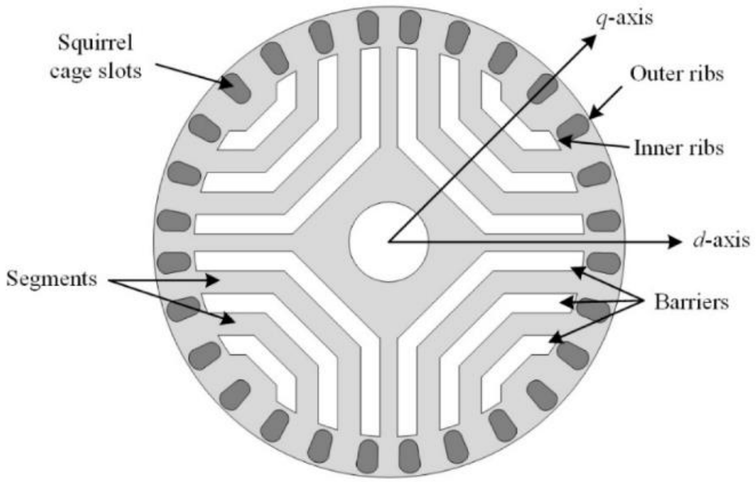
Line-Start Synchronous Reluctance Motors

- Line-Start Synchronous Reluctance Motor (LSSynRM) combines a squirrel cage rotor (for starting) with a synchronous reluctance rotor. The cage is inserted in the air barriers of the reluctance rotor. Commonly, the air barriers are filled with aluminium in a die cast process and the terminals of the cage are short circuited by an end-ring.
- After an asynchronous start-up, the motor synchronizes with the working frequency and runs synchronously at constant speed regardless of the load, much like a synchronous reluctance motor.
- This reduces the rotor losses compared to squirrel cage induction motors
- The lower rotor losses also result in lower bearing temperatures, which will increase the lifetime of the bearings



Source: ISR-UC

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COMPARISON OF MOTOR TECHNOLOGIES

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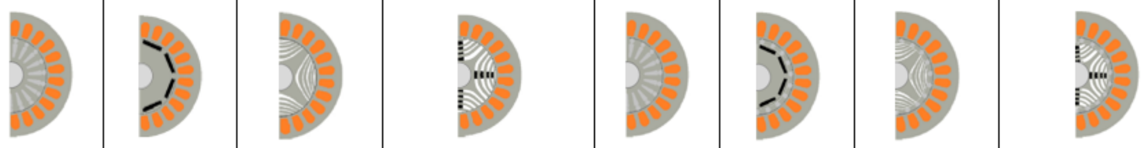
Indicator/Feature		(Optimized Supply Voltage and Frequency)				(Rated Supply Voltage and Frequency)			
		SCIM	PMSM	SynRM	PMSynRM	SCIM	Line-Start PMSM	Line-Start SynRM	Line-Start PMSynRM
Cross-sectional topology with identification of active materials: • orange areas: copper • light grey areas: aluminum • dark grey areas: steel • black areas: permanent magnets									
Line-start capability without VSD		yes	no	no	no	yes	yes	yes	yes
Requires VSD		yes	yes	yes	yes	no	no	no	no
Possibility of using an electronic soft-starter or Y-D starter		n.a.	n.a.	n.a.	n.a.	yes	no	no	no
Motor cost		$	$$$	$	$$	$	$$$	$$	$$
VSD cost		$	$	$$	$	n.a.	n.a.	n.a.	n.a.
Rated efficiency of the motor (best available technology)		•••	•••••	••••	••••	•••	••••	•••	••••
Typical efficiency class range		IE1–IE4	IE4–IE5	IE3–IE5	IE4–IE5	IE1–IE4	IE3–IE4	IE3–IE4	IE4–IE5
Rated power factor of the motor		•••	••••	•	•••	•••	••••	•	••••
Efficiency at partial torque and/or speed		•••	••••	••••	••••	••	••••	•••	•••
Motor reliability and robustness		•••••	••••	•••••	••••	•••••	••	•••••	••
Power density (kW/kg) for standard frame sizes		••	•••••	•••	••••	••	••••	•••	••••
Overload capacity		•••••	•••	•••••	•••	•••••	•••	••••	•••
Field weakening		••••	•••	•••••	•••	n.a.	n.a.	n.a.	n.a.
Very high-speed capability		••••	•••	•••••	•••	n.a.	n.a.	n.a.	n.a.
Thermal limitations		••••	••	•••••	•••	••••	••	•••••	•••
Useful lifetime		•••••	••••	•••••	••••	•••••	••••	•••••	••••
Technology maturity		•••••	••••	•••	••	•••••	•••	•	•
Active materials and parts	Electrical steel core	yes	yes	yes	yes	yes	yes	yes	yes
	Cooper winding	yes	yes	yes	yes	yes	yes	yes	yes
	Cooper or aluminum cage	yes	no	no	no	yes	yes	yes	yes
	Ferrite PMs in the rotor	no	no	no	yes	no	yes	no	yes
	Rare-earth PMs in the rotor	no	yes	no	no	no	yes	no	no

Symbols and abbreviations: "$" denotes lowest costs, "$$$" denotes highest cost, "•••••" denotes high; "•" denotes poor; "n.a." denotes not applicable or not required. Acronyms: SCIM—Squirrel-Cage Induction Motor; PMSM—Permanent-Magnet Synchronous Motor; SynRM—Synchronous Reluctance Motor; PMSynRM—Permanent-Magnet-Assisted Synchronous Reluctance Motor; SRM—Switched Reluctance Motor; PM—Permanent Magnet; VSD—Variable-Speed Drive (AC-AC converter).

Source: ISR-UC

cf EU-MORE report on

MOTOR SYSTEM EFFICIENCY TRENDS

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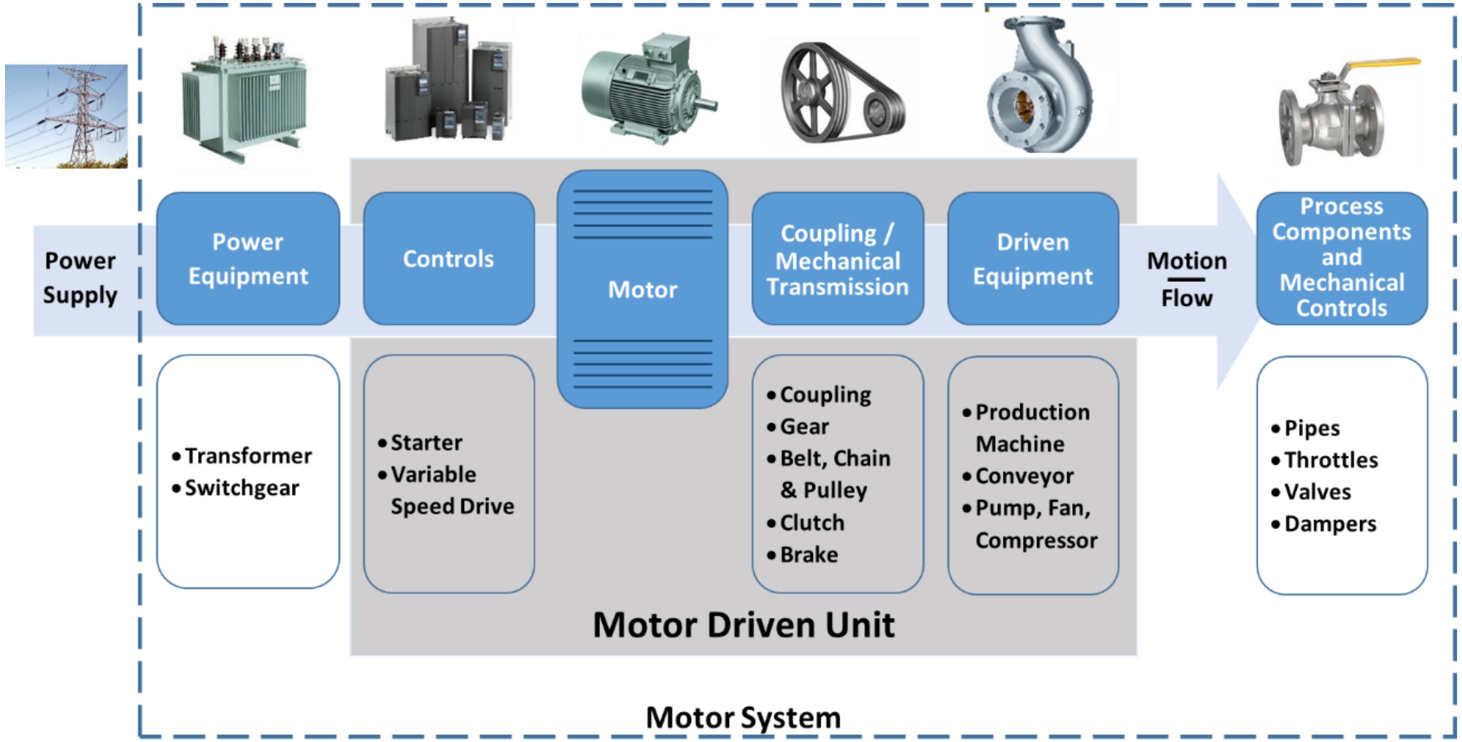
Motor System Efficiency

Each part of the system should be given careful consideration as a source of potential losses:

- power supply quality (high-quality power supply)
- careful attention to harmonics
- system oversizing (proper equipment sizing)
- the transmission and mechanical components (optimised transmission systems)
- the match between the load and the motor (good load management practice



Source: ISR-UC

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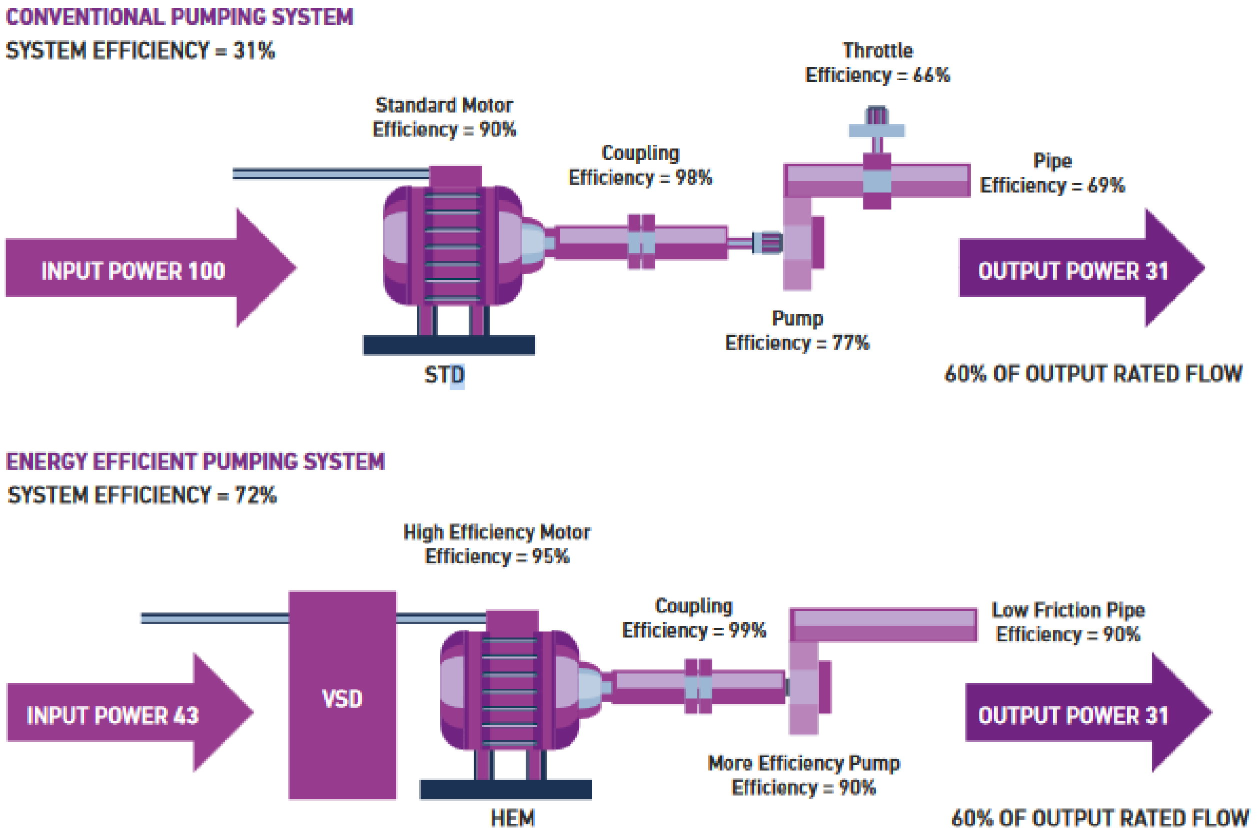
Motor System Efficiency optimization

Possible system improvements,

One example in a pump system:

- Proper motor sizing
- VSD
- Pump upgrade
- Better piping

31% -> 72% overall efficiency



Source: paper by DE ALMEIDA, FERREIRA, & BOTH, 2005

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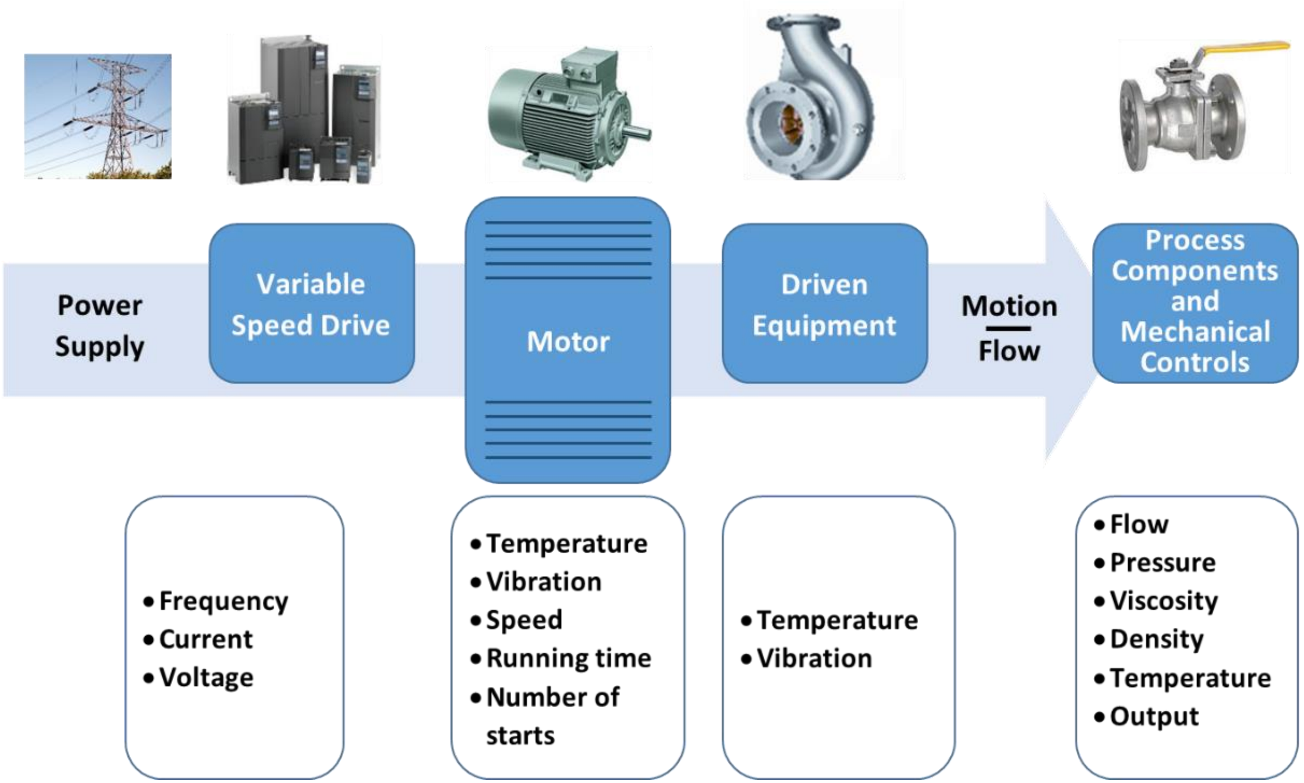
Motor System Digitalization

Application of smart sensors and meters in each part of the motor system can help achieve optimization, both in terms of process improvements and of energy performance

Opportunities for motor system performance improvement:

- Real time data
- Maintenance schedules - based on the observed condition of the equipment (Condition Based Maintenance) or, on the predicted behaviour of the equipment (Predictive Maintenance



Source: KULTERER, DAWODY, WIDERSTROM, & WERKHOVEN, 2022

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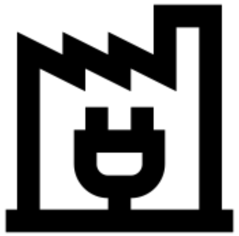
The opportunity: 100 TWh/year

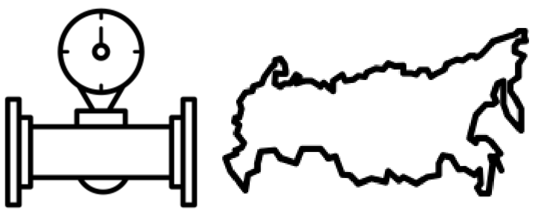
Accelerated motor replacement: replacing old IE0/1/2 motors with new IE3 and above motors + **motor system optimisation**

has an estimated **electricity savings** potential of approximately **100 TWh/y** in the EU-27, which represents:

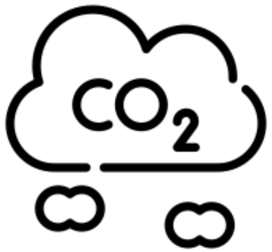


55 average gas fired power plants

electricity consumption of the Netherlands



30% of historic natural gas import from Russia



25 Mton CO2

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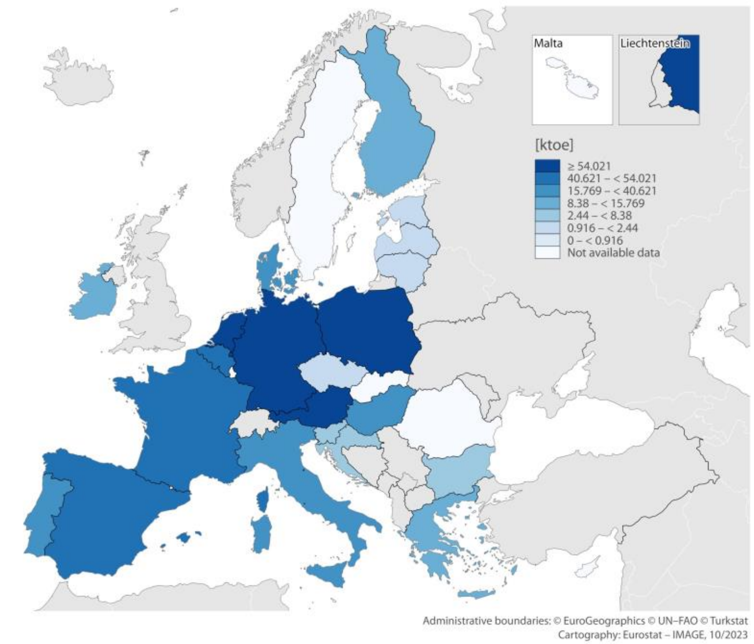
Results of policy review

Overall Policy Measures Impact



Source: IEECP

In EU-MORE we have analyzed in detail 62 policy measures in EU countries

Most are generic and „cross-cutting technologies“:

- **non-financial policy initiative *Learning Networks for Energy Efficiency* in Germany which involves networks of 10 to 15 companies supporting and stimulating each other to improve energy efficiency in their premises.**
- ***OekoBusiness Vienna* program in Austria proved to be successful in raising initial awareness of energy efficiency measures including motor replacement offering a free initial check-up to identify the hidden energy savings potential of industrial and commercial sites.**

A few motor specific:

- ***Energy Efficiency Promotion Plan (PPEC)* in Portugal incorporates a measure to encourage the installation of high-efficiency motors (IE3 or IE4) within the 0.75-400 kW power range.**

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Preliminary policy recommendations

The following are some elements from the first draft – cf final report on EU-MORE website in 2024

- **Mutual trust between policy makers and industrial decision makers is key**
- **Motor replacement could be made mandatory if an energy audit identifies it as an economically beneficial energy savings measure**
- **Voluntary programs might benefit from a carrot-and-stick approach – benefits & penalties**
- **Energy efficiency obligation schemes (EEOS) have proved successful in achieving substantial energy savings in industry with a low direct cost for policy makers**
- **Policy makers at national level should take the requirements of the EU Sustainable Finance Framework into account**

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Barriers to overcome

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PRACTICAL BARRIERS IN INDUSTRY

- A need for quick availability when a motor fails, and many sites have old motors in stock
- Lack of awareness about the co-benefits of energy efficient motors
- Motors are replaced without looking at the system, missing out on the full benefits

ECONOMIC BARRIERS IN INDUSTRY

- Decisions made based on purchase cost instead of life cycle cost, because of split incentives
- Pay-back times of motor replacement are favourable, but not perceived as such because of ignorance or extreme expectations
- Focus on low hanging fruit only following EnEff audits in industry
- Lack of awareness on how to receive funding

BARRIERS AT POLICY LEVEL

- Mandatory EnEff policies only target new motors and lack a leverage for motor replacement
- A lack of data about motor ages in the EU
- A lack of insight in which policies work for accelerating motor renovation in industry
- False perception that life-times should be extended as long as possible in a circular economy, ignoring the full environmental balance

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Main contacts:

Project Coordinator: Joao Fong (ISR-UC), joaofong@isr.uc.pt

Communication: Tomas Jezdinsky (ECI), tomas.jezdinsky@copperalliance.org

www.eu-more.eu

https://www.linkedin.com/company/eu-more/

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