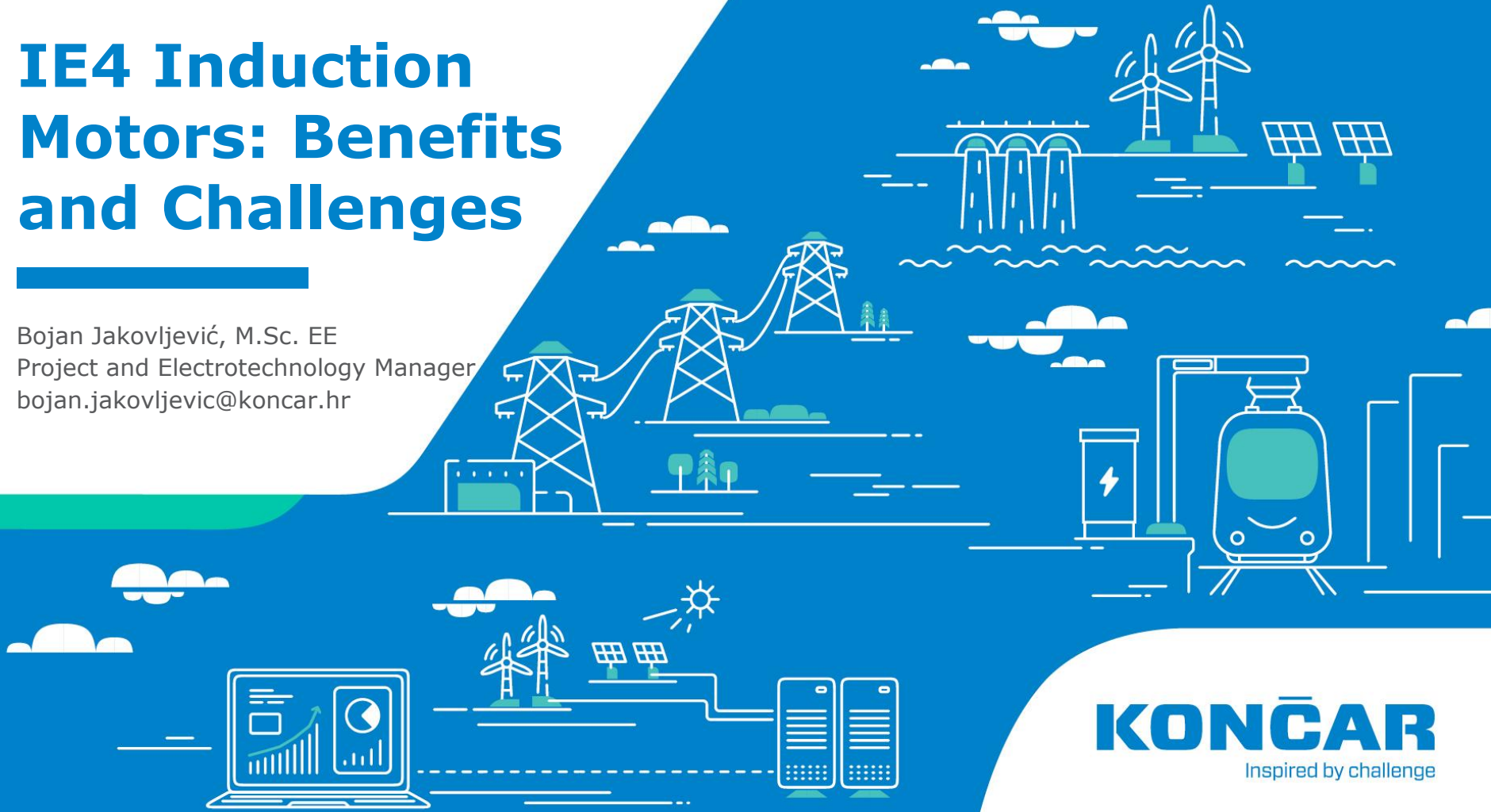
IE4 Induction Motors: Benefits and Challenges

Bojan Jakovljević, M.Sc. EE
Project and Electrotechnology Manager
bojan.jakovljevic@koncar.hr



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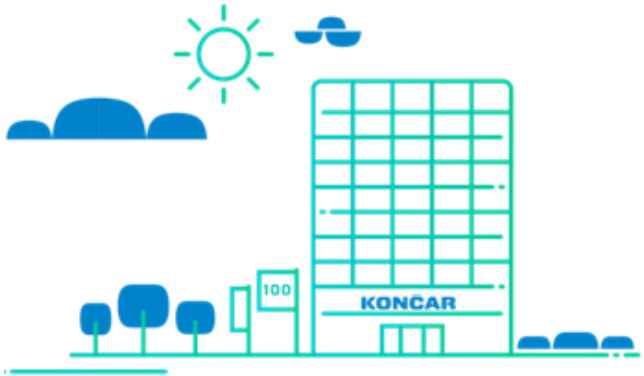
Inspired by challenge

Topics

- Efficiency requirements.
- Replacement of old motors – fast savings calculation.
- IE4 induction motor: benefits and challenges.
- Upgrade of existing induction motors.
- IE4 motors below 75 kW?



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Efficiency requirements

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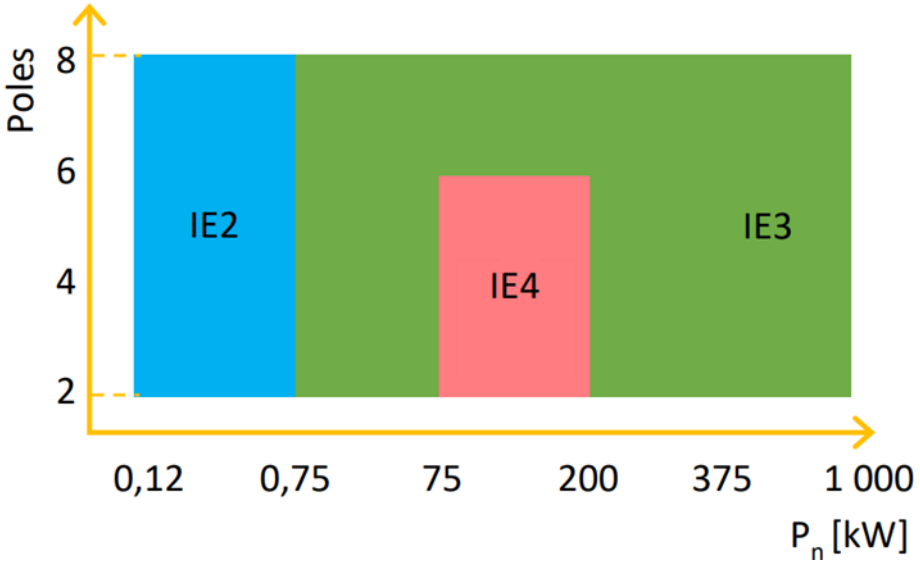
Ecodesign regulation (EU) 2019/1781



- Active since 07/2023.
- Valid for 2,4 and 6 pole motors.
- IE4 For power range 75-200kW.
- Excluded from IE4 requirement:
  - brake motors,
  - Ex eb increased safety motors,
  - other explosion-protected motors.

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Replacement of old motors

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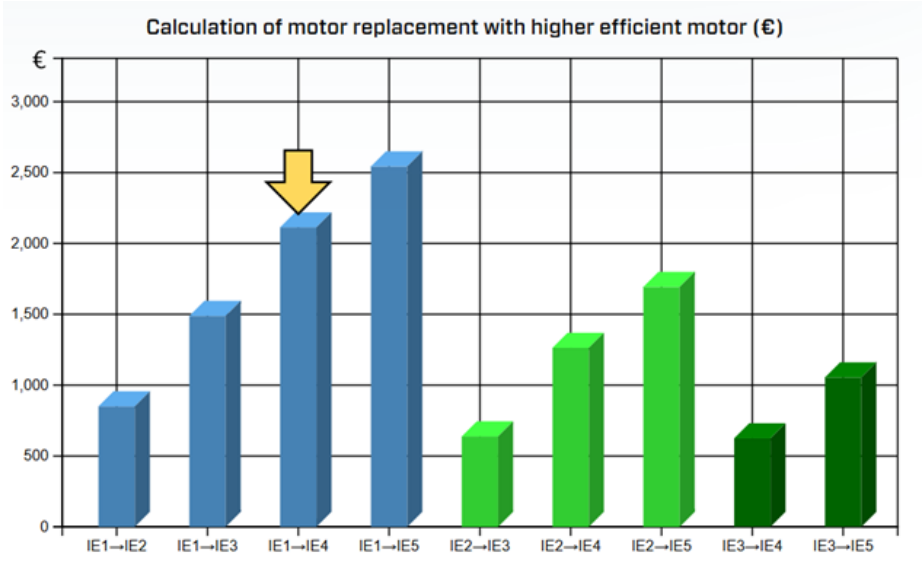
An Investment, Not an Expense!

- The average non-household electricity price in the EU for 2024 is €0.1867 per kWh (Source: Eurostat).
- Based on two work shifts totaling 4000 running hours per year for a 4 pole, 75 kW motor.
- If old IE1 motor is replaced with new IE4 motor complete return on investment is achieved in just **3 years and 9 months**.

Yearly savings for a 2 p=4, 75 kW motor under different replacement scenarios. Source: savings calculator.



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IE4 induction motor benefits and challenges

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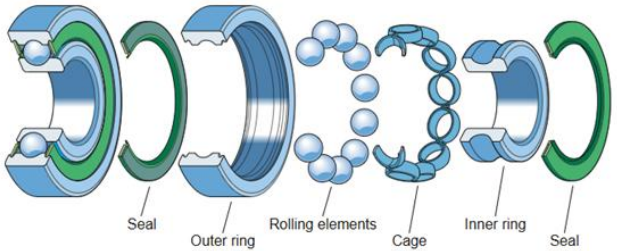
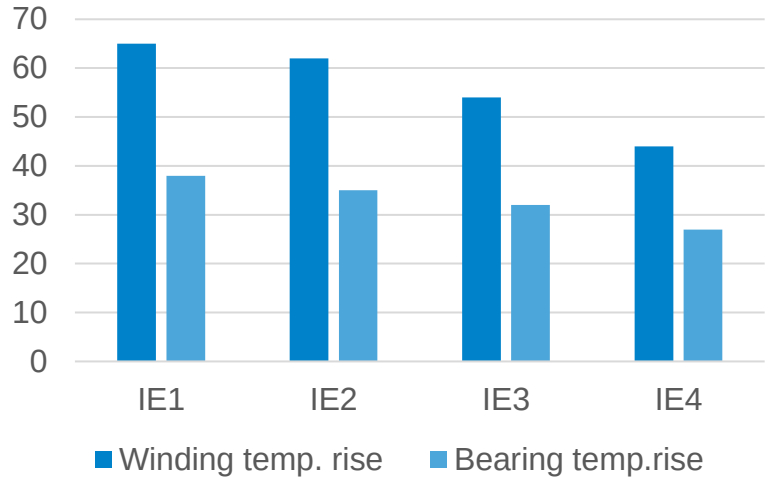
Increased bearing lifetime

- Extremely low bearing and winding temperatures. Bearing grease lifetime for a IE4 75kW motor increases by 40% compared to IE1 motor.





- Grease life doubles for every 15 °C reduction in temperature. Source: Evolution - technology magazine from SKF (Reductions below 55 °C do not provide the same benefit.).

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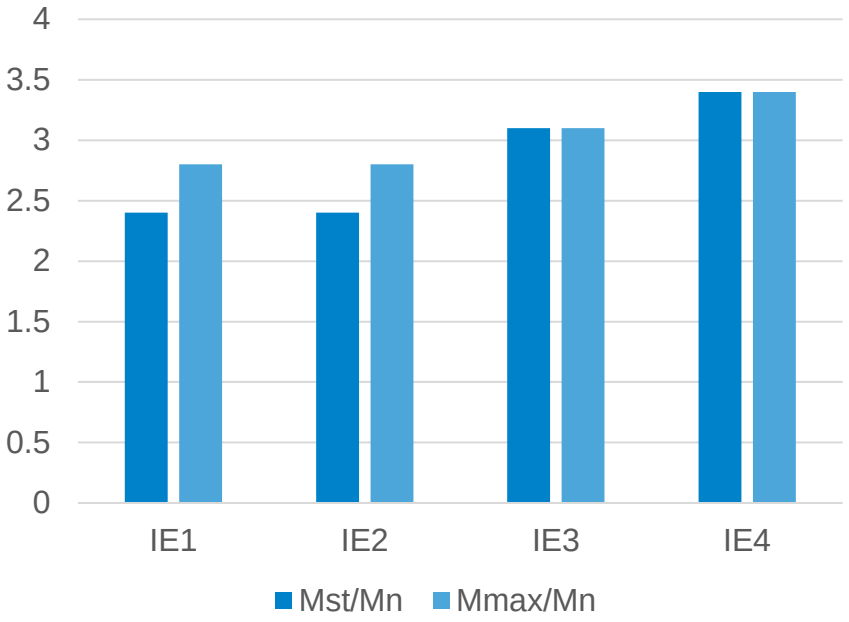
Increased motor performance



- Higher overload capability (20-30%).
- Higher maximum (Mmax) and starting torque (Mst) values.
- Higher resistance to voltage dips.

Mst – starting torque | Mmax – maximum torque | Mn – nominal torque

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Usual induction motor points of failure

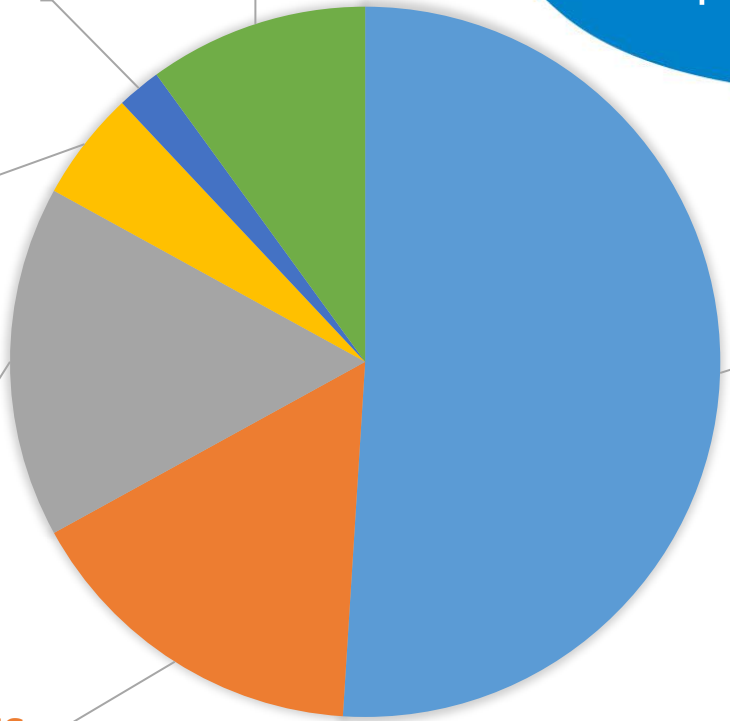
COUPLING WITH MACHINE
2%

1. BAD COUPLING / ALIGNMNENT OF SHAFTS
2. BAD MOTOR MOUNTING

OTHER
10%

ROTOR BARS
5%

1. NUMBER OF STARTS
2. OVERLOAD
3. VOLTAGE DIPS



BEARINGS
51%

1. NOT ENOUGH GREASE
2. TOO MUCH GREASE
3. WRONG GREASE TYPE
4. BAD COUPLING WITH LOAD
5. OVERLOAD
6. VIBRATIONS
7. OVERHEATING

EXTERNAL CONDITIONS
16%

1. HIGH AMBIENT TEMPERATURE
2. HEAT FROM OTHER SOURCES
3. AIR HUMIDITY
4. RESIDUES IN HOUSING RIBS

WINDING
16%

1. OVERLOAD
2. OVERHEATING

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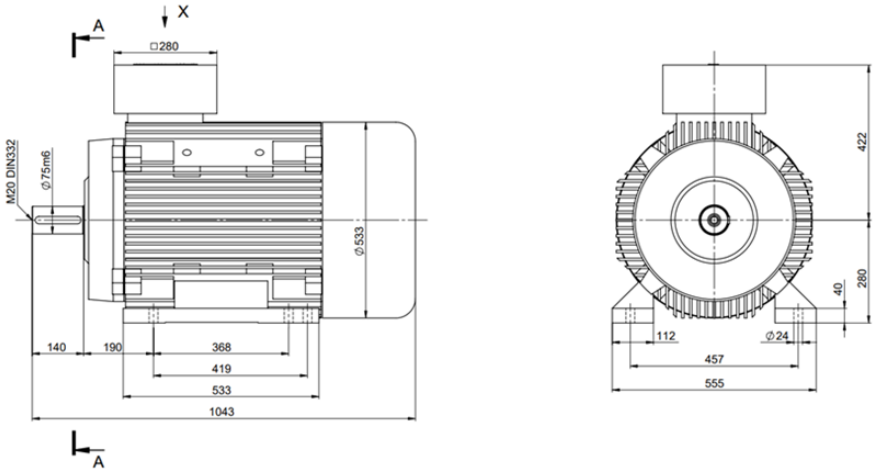
Same main mechanical dimensions



- Note: on some motor types housing is longer
- IE1-2-3 L=1043mm (75kW 2p=4)
  IE4 L=1160mm (75kW 2p=4)

- Same shaft dimensions.
- Same flange and foot dimensions.
- Same mounting and coupling to machine.
- Same maintenance operations and parts (bearings size for example).

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A VSD is not necessary but can provide additional benefits

- Better efficiency on partial loads and speeds.
- Possibility to further optimise drive for even more savings.
- Starting point for cost effective predictive maintenance.

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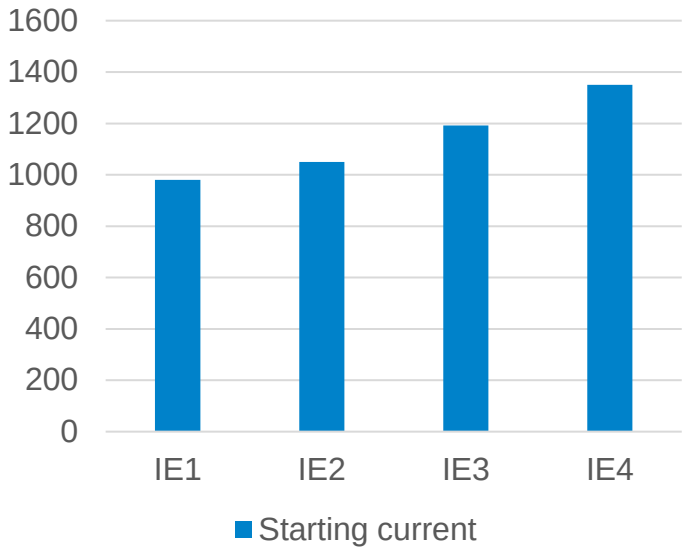
Increased starting current

- should be taken into account when selecting protective devices.
- Use star/delta starting for DOL operation.
- With a soft starter or variable-speed drive, there is essentially no inrush current - starting current is typically 50% higher than nominal.



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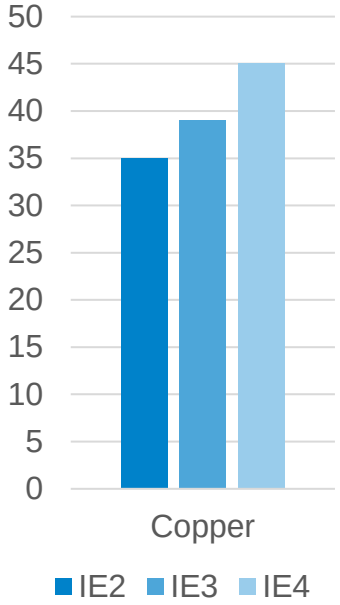
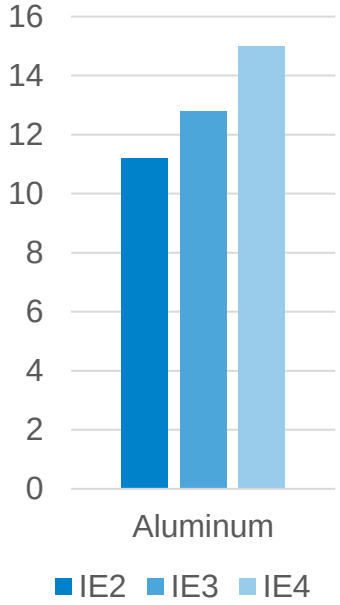
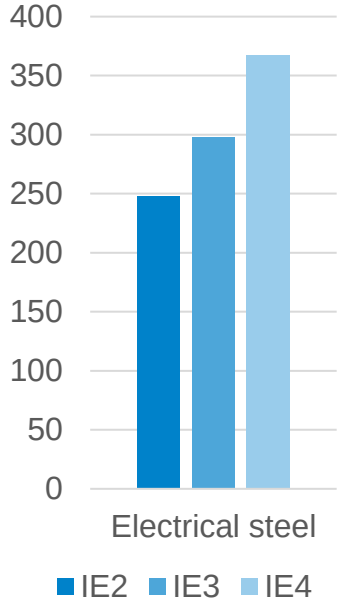
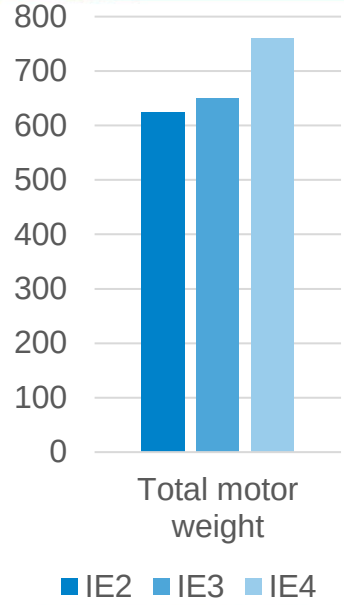
Comparison of used active materials – IE4 with Al rotor









- For 75kW 2p=4 induction motor

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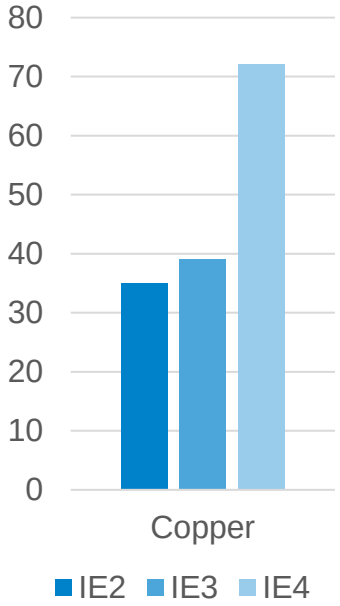
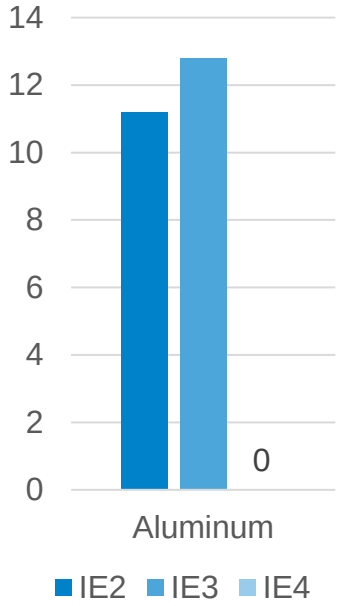
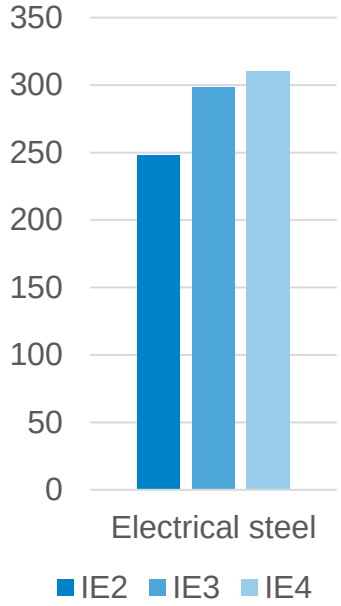
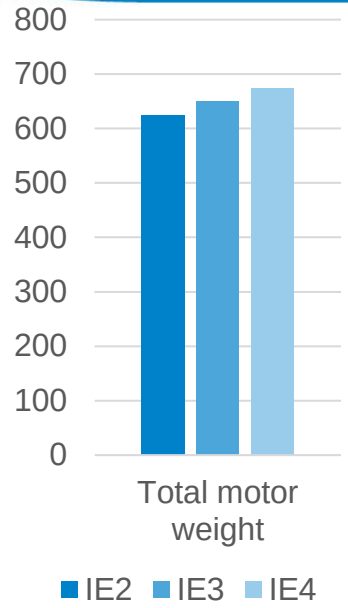
Comparison of used active materials – IE4 with Cu rotor









- For 75kW 2p=4 induction motor

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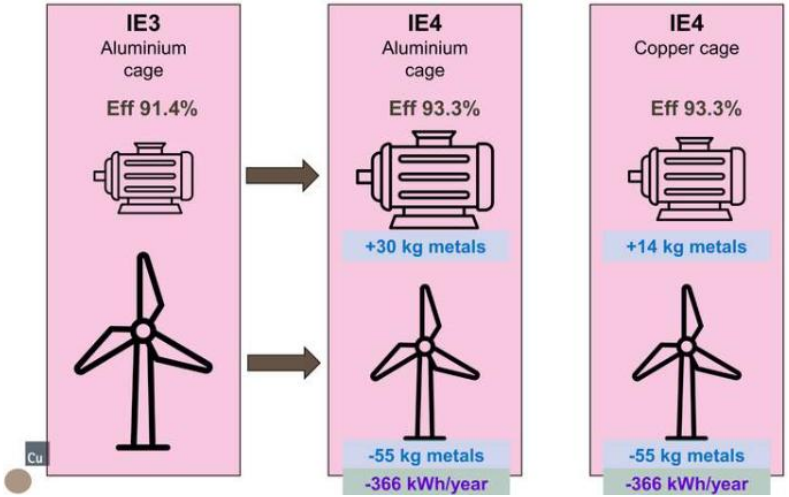
On system level material consumption is reduced

- Consider the entire system, including energy generation and distribution.
- Lower energy losses at the point of use reduce the energy required for distribution and generation, ultimately decreasing the need for additional generation assets.
- See the full study: The Environmental Impact of Every MWh of Electricity Losses over the next 20 Years in the EU (ICA) - Its Relevance for Motor MEPS



Motor use assumption: 1750 hours/year
11kW 2p=4 motor

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Life cycle cost is reduced

- IE4 motors are 20–30% more expensive than IE3 motors due to the use of more and higher-quality materials.
- If we compare a 75 kW IE4 motor to its IE3 equivalent, the additional cost is repaid in just two years.
- An IE4 motor may also have longer maintenance intervals, yielding further savings on spare parts.

Typical life cycle costs of a motor installation for 25 years. Source link.

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25-Year Energy Cost Comparison

Motor type	Efficiency	25 year energy cost
IE1	91,0%	€ 1,538,736
IE4	96,2%	€ 1,455,561
Savings		**€ 83,175** **€ 3,327 / year**

Motor type	Efficiency	25 year energy cost
IE3	94,9%	€ 1,475,501
IE4	96,2%	€ 1,455,561
Savings		**€ 19,940** **€ 798 / year**

- If possible, invest more upfront and purchase a machine with an IE4 motor rather than IE3. Also, whenever possible, replace old motors.

- Average 2024: €0.1867 per KWh (Source: Eurostat).

- Based on 4000 running hours per year. 4 pole 75kW motor.

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Upgrade of existing motors?

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Alternative to purchasing a completely new motor

- Replace the rotor with a copper rotor of the same dimensions during regular maintenance.
- A rotor made of a different cage material can be purchased from the motor manufacturer.
- Efficiency will improve, though it may not reach IE4.
- This is much cheaper than buying a new motor.
- The old aluminum rotor and shaft can be recycled.

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Comparison of measured values

IE3 2p=4 with aluminum rotor		
Output power	P2 (kW)	15
Voltage	U (V)	400
Frequency	f (Hz)	50
Current	I (A)	29
Power factor	CosPhi	0,81
Rotation speed	n (rpm)	1471
Efficiency	η (%)	92,1 (IE3)

IE4 2p=4 Upgraded with copper rotor		
Output power	P2 (kW)	15
Voltage	U (V)	400
Frequency	f (Hz)	50
Current	I (A)	28,3
Power factor	CosPhi	0,815
Rotation speed	n (rpm)	1482
Efficiency	η (%)	93,87 (IE4 93,9%)

Cu rotor instead of Al rotor + optimised air gap and cooling fan.
Only rotor is replaced on original motor during regular maintenance.
The winding can still be optimized.

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IE4 motors below 75kW?

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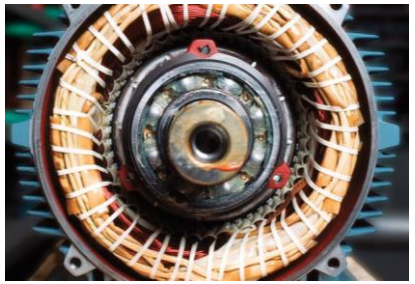
It is possible to produce IE4 motors below 75kW

- Technically more challenging than in larger units (75–200 kW).
- IE4 can be achieved by using copper rotors and optimizing motor cooling and winding.
- This was proven in a previous IE3 upgrade example.



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Conclusion

- Replacement of old motors with IE4 induction motors is great investment with short ROI.
- IE4 induction motor benefits by far outweight all challenges.
- It might be possible to upgrade existing older motors to higher efficiency ratings with new copper rotoros instead of current aluminum rotors (by using same stator).
- It is possible to produce IE4 motors below 75 kW.

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Questions?

Cu International Copper Association Europe

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