The “**Paris Agreement**” is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC) dealing with greenhouse gases emissions mitigation, adaptation and finance starting in the year 2020. After the European Union ratified the agreement in October 2016, there were enough countries that had ratified the agreement that produce enough of the world's greenhouse gases for the agreement to enter into force. **It will take effect on 4 November 2016**. (Wikipedia, Paris Agreement, 6 Oct 2016)

Global Overview

Conrad U. Brunner

Motor Summit 2016, Zurich

11 October 2016

Trebević Mountain

Energy Efficient Motor Systems

1. The Future
2. The Present
3. The Open Questions

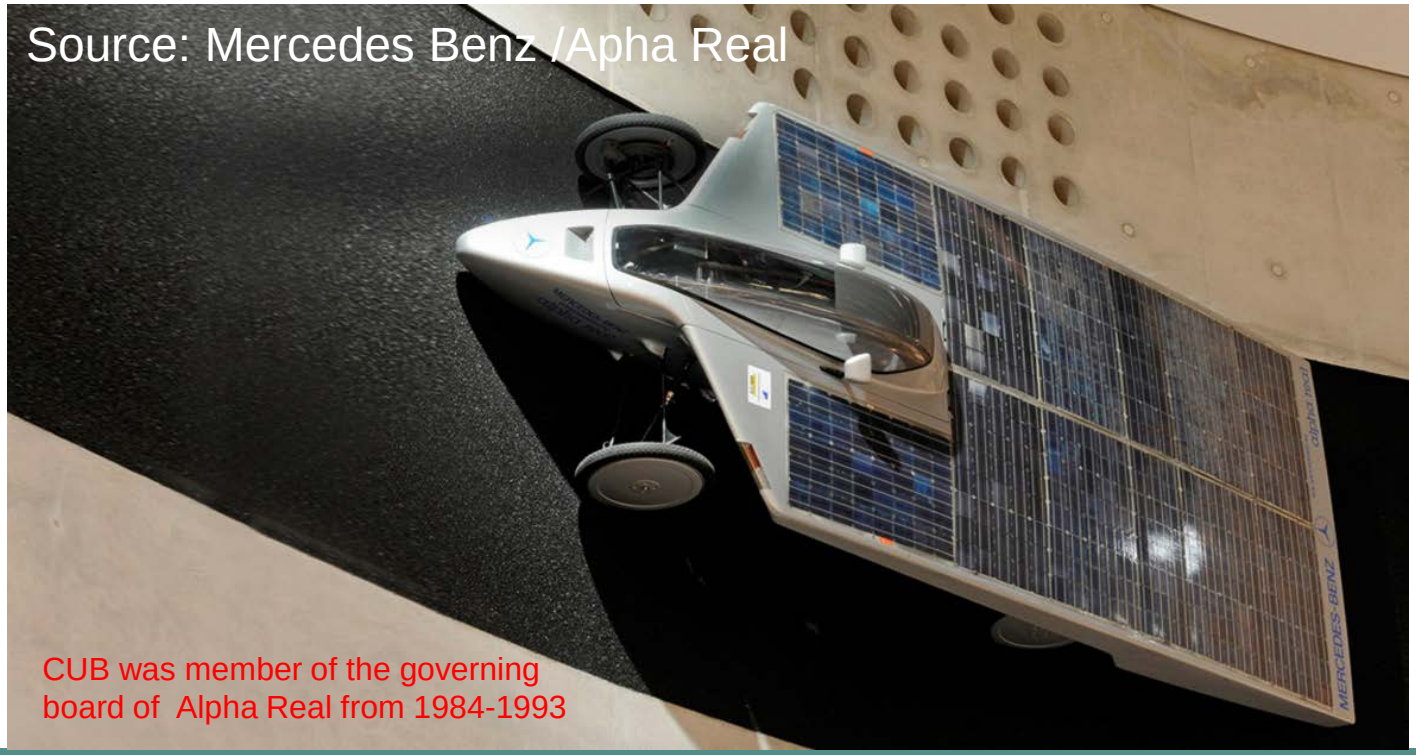
The Future

Three big dreams of mankind today:

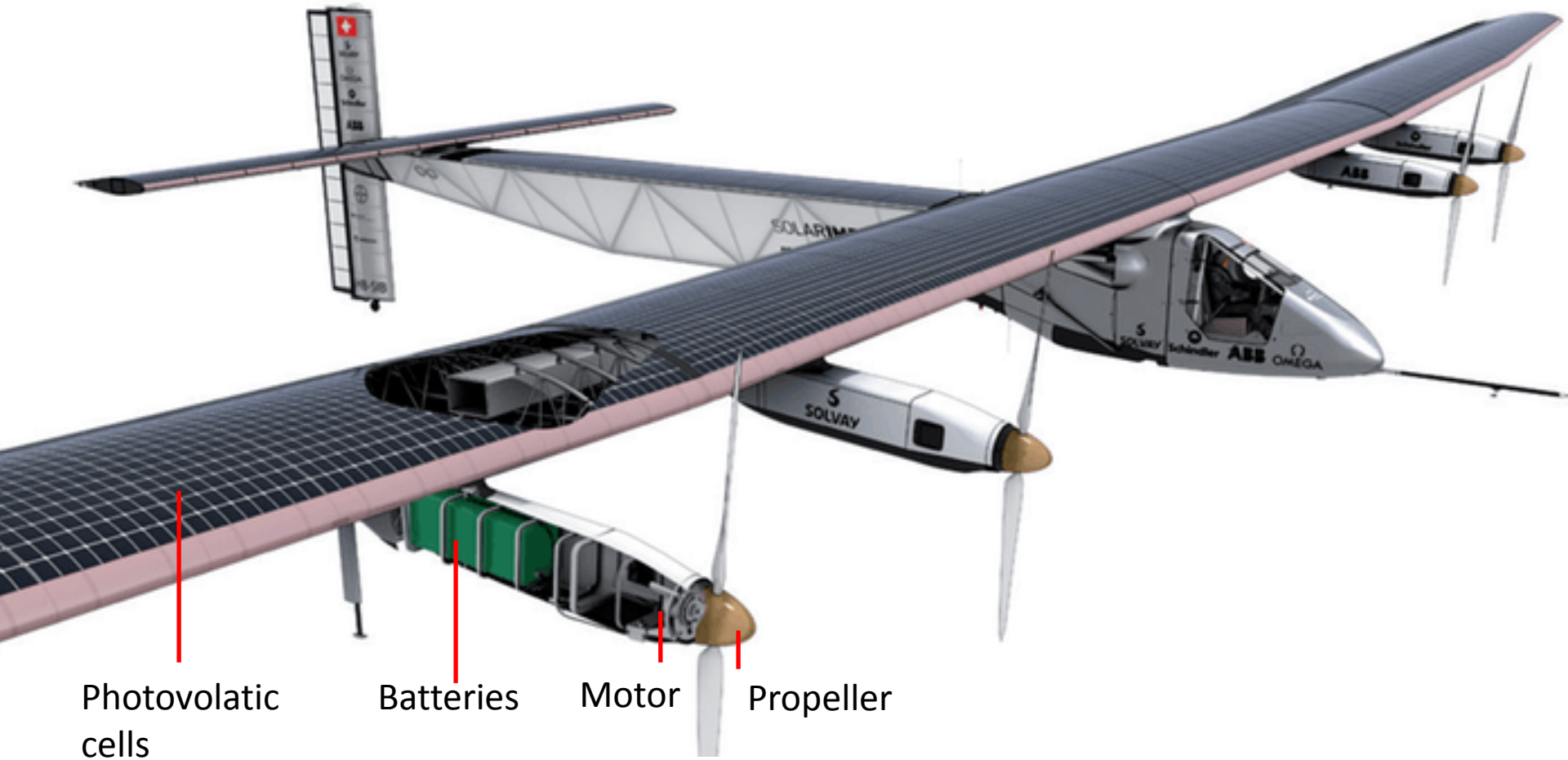
1. Flying without kerosene
2. Driving without gasoline
3. Power production without coal

Mercedes-Benz / Alpha Real (1985)

- “Tour de Sol Centennial Rally” from Lake Constance to Lake Geneva
- Two electric motors of the car were fed by 432 solar cells
- 2 DC motors with 1.8 kW
- Top speed 70 km/h



Solar Impuls 2



Source: ETEL and Solar Impuls

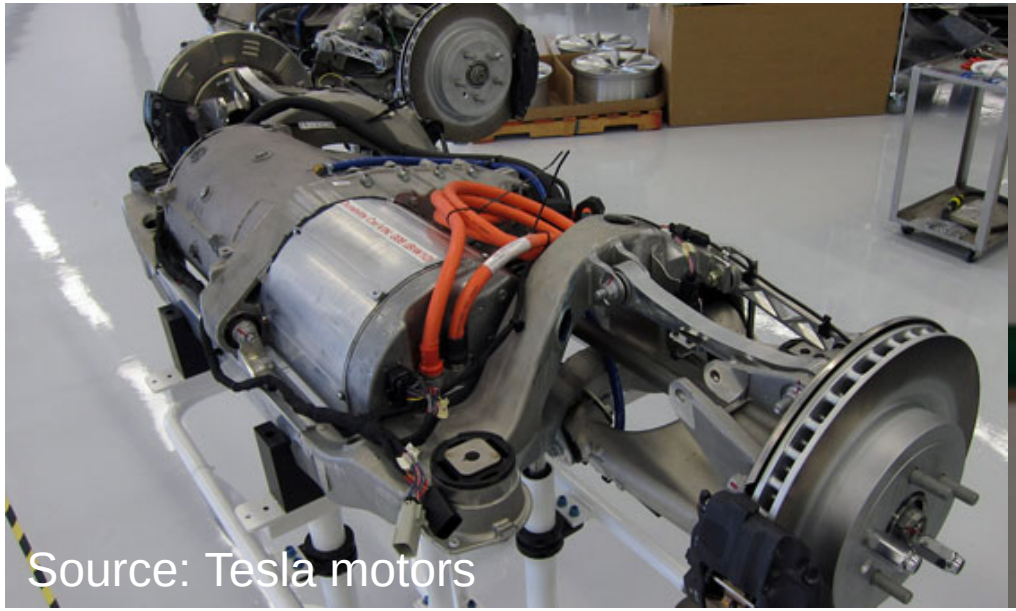
Solar Impuls 2

- 13.5 kW Permanent Magnet motor made by ETEL, Neuchâtel Switzerland
- Torque motor with 94-95% efficiency
- Direct drive: maximum speed 4’900 rpm
- Reduction gear
- Two-bladed propeller with 4 m diameter, 525 rpm

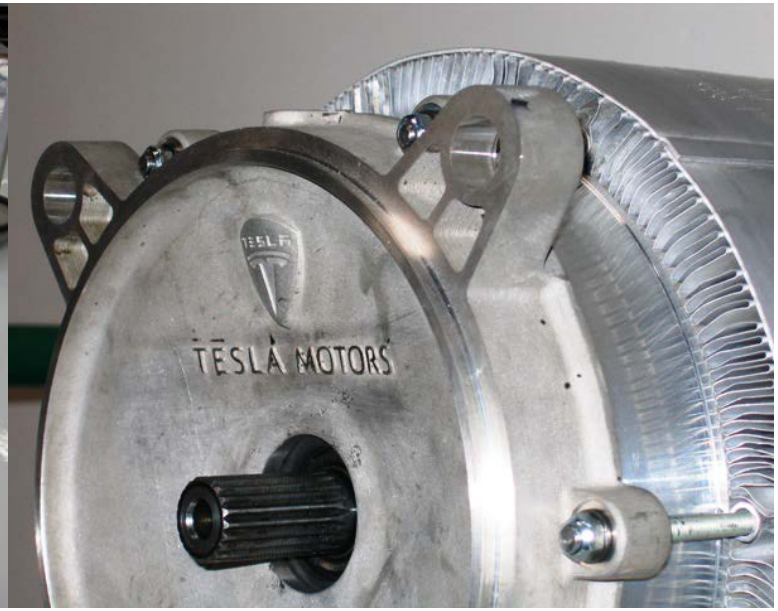
Source: ETEL

TESLA S

- 3-phase 4-pole AC induction motor
- 235 kW up to 396 kW electric motor
- Copper rotor
- Water cooling
- Variable frequency drive
- Wide torque band



Source: Tesla motors

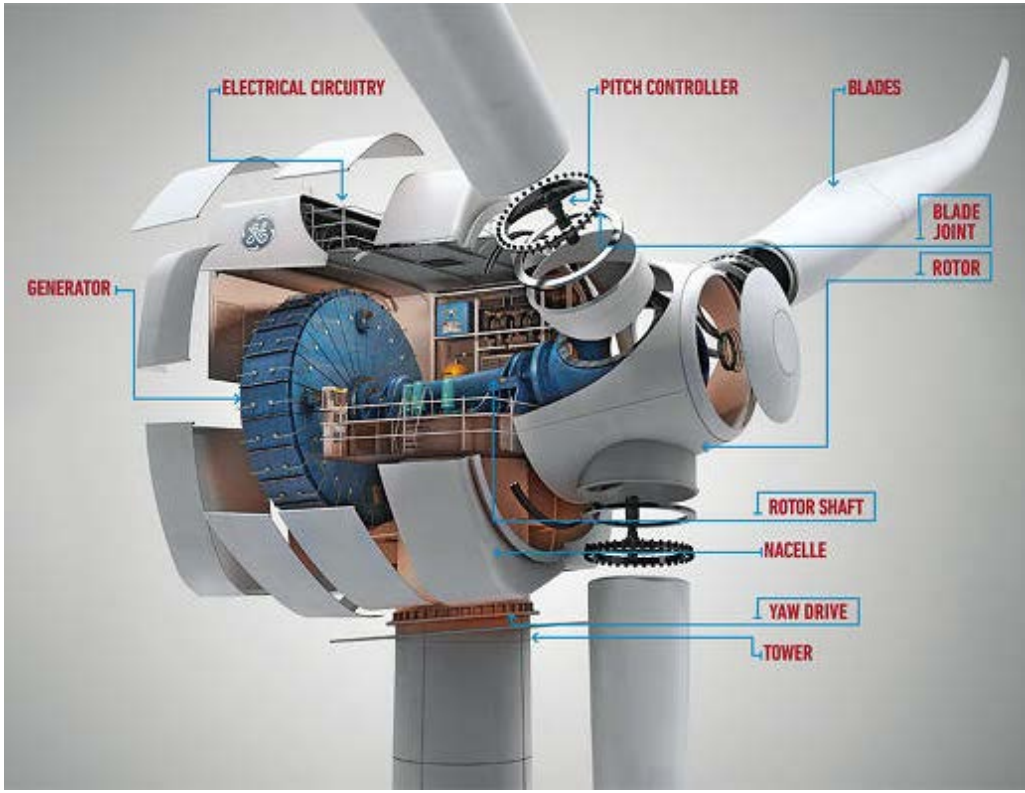


Wind Turbine 6 MW

Source: Thyssen Krupp

Wind turbine

- Synchronous, Permanent Magnet Direct Drive Generator
- Multi-MW power up to 7 MW
- Efficiency up to 98 %
  (also at 20 % load)
- 150 to 400 rpm using a single or 2-stage gear
  future gear concepts can be 500 rpm or more



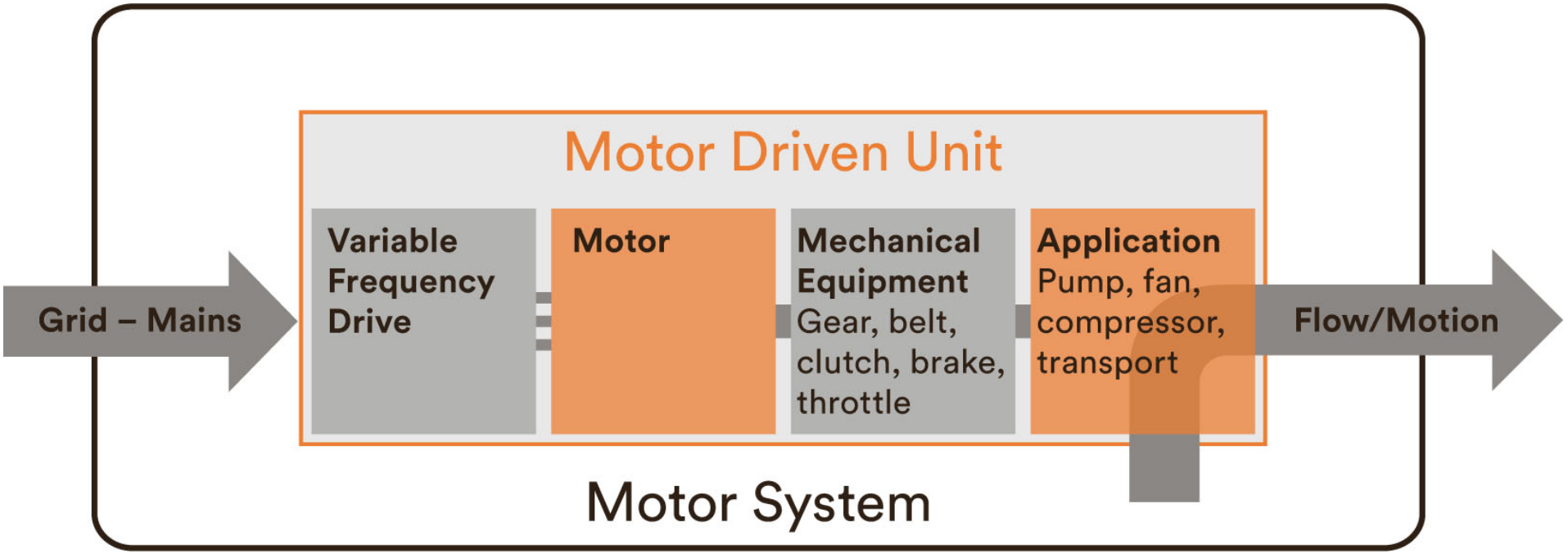
Source: GE

Where is the future?

Size	Type
1.8 kW	DC motor
13. 5 kW	PM motor
250 kW	Copper Rotor motor
6’000 kW	PM generator

Motor Driven Units

►becoming more important



System efficiency is the product of the efficiencies of all components.

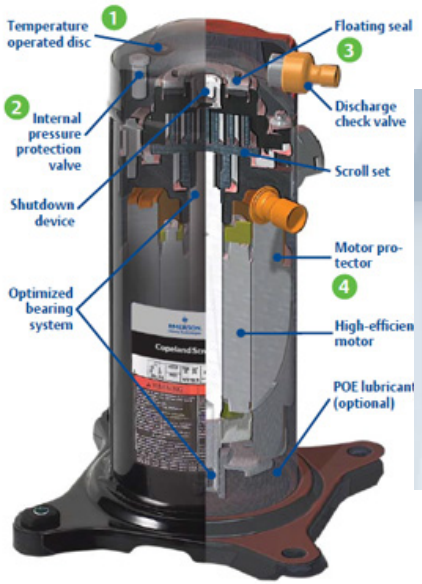
Misunderstanding:
Only the best components make for an optimum system.

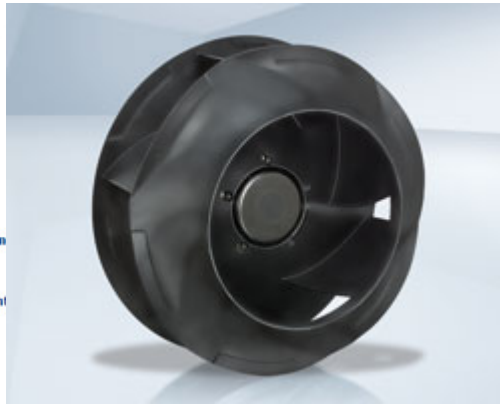
Cost/benefit and life cycle analysis can help to decide

Integrated small products (< 5 kW)

The advantage:

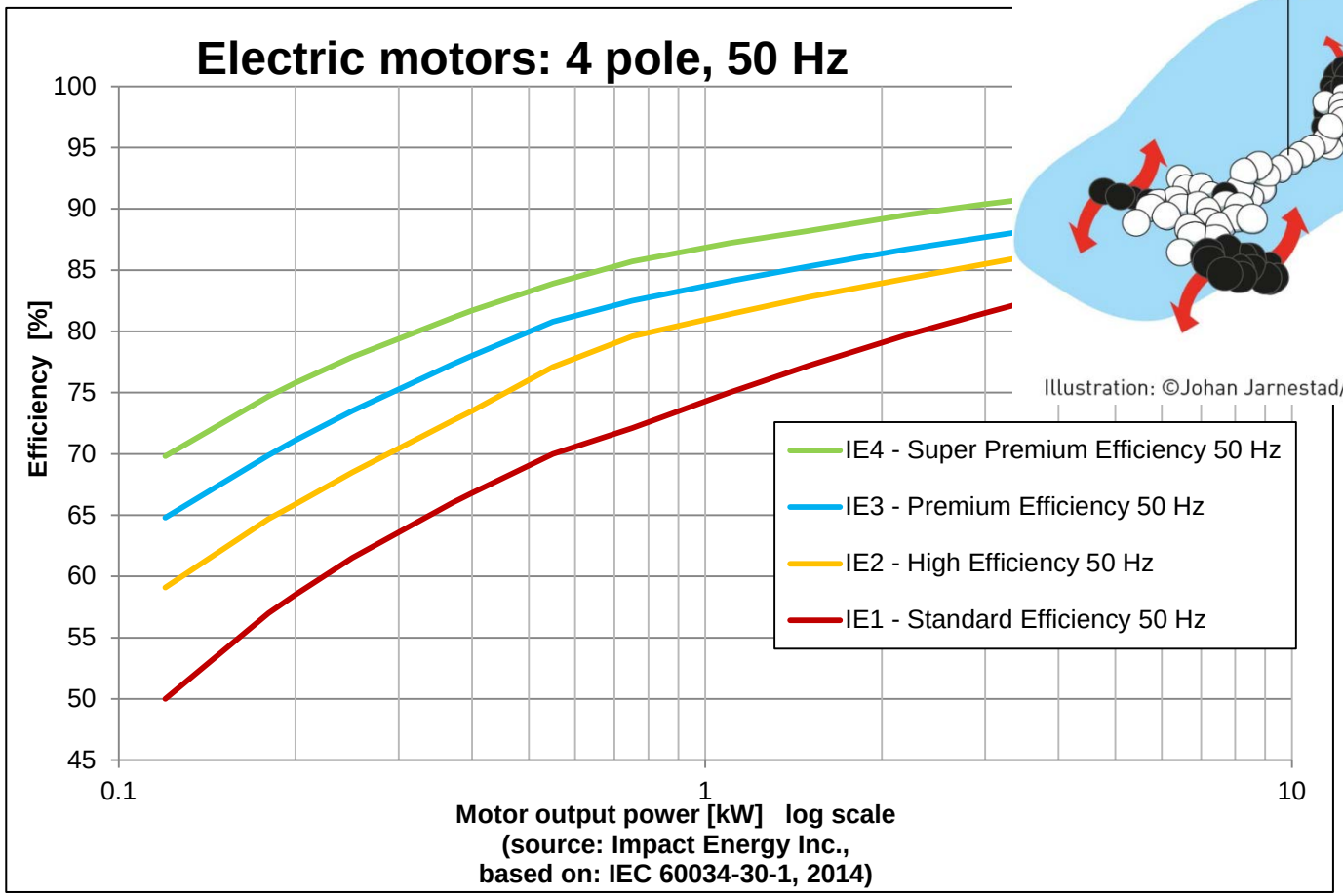
- Smaller
- Lighter
- Cheaper
- More efficient
- Less heat
- Variable load
- More performant
- Only for small machines?





Sources: Copeland, ebmpapst, Grundfos, Wilo

Efficiencies in the small motor world



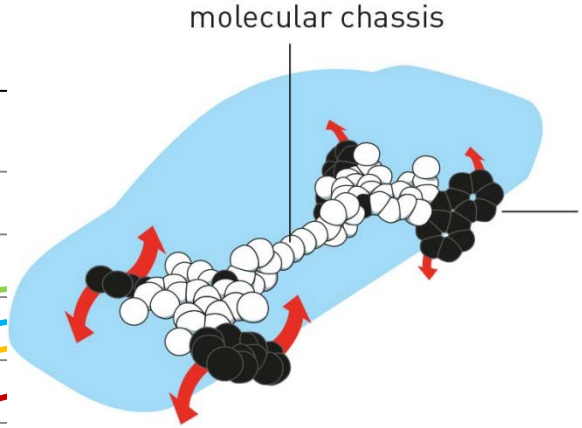
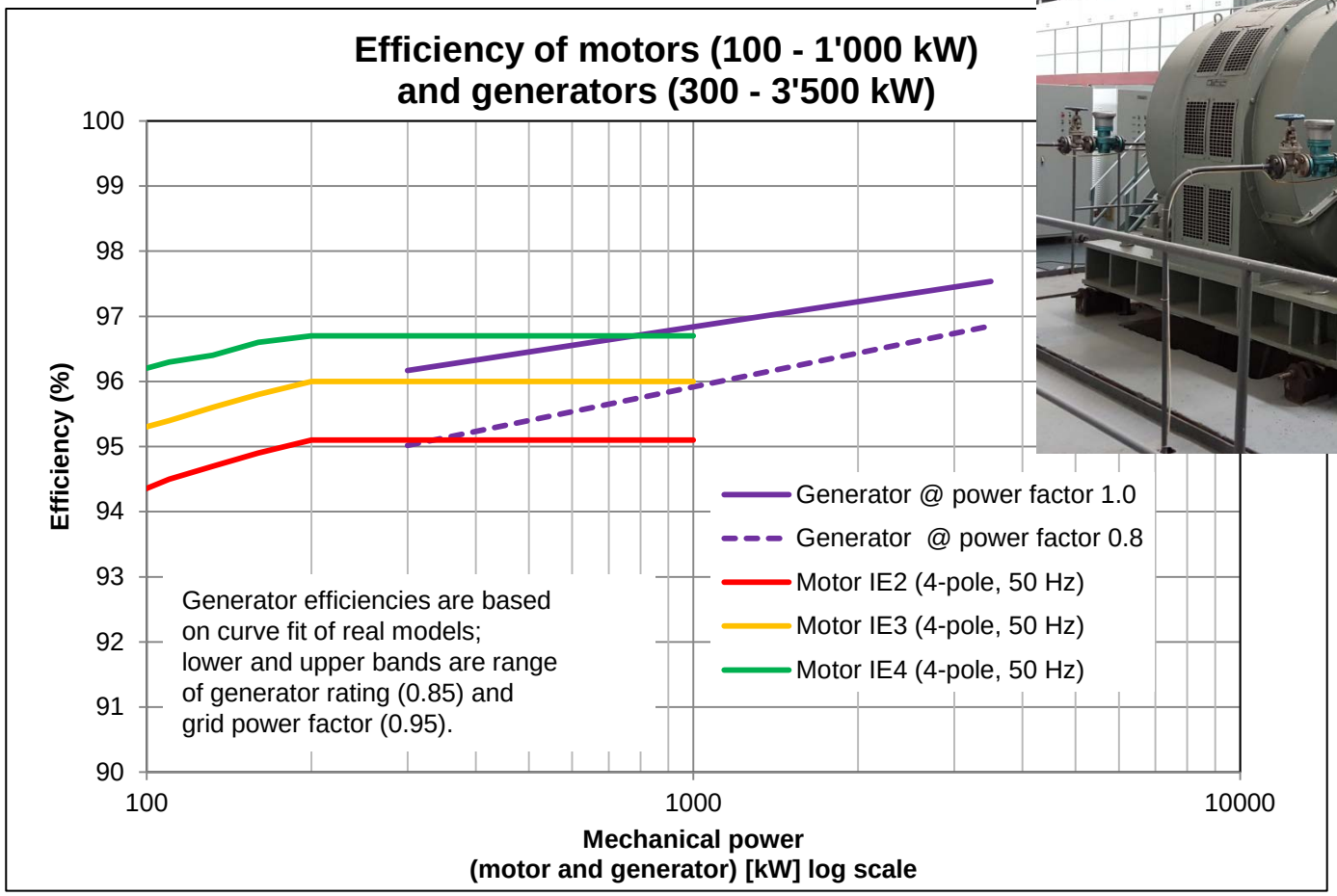


Illustration: ©Johan Jarnestad/The Royal Swedish Academy of Sciences

Efficiencies of big machines > 100 kW

Source: SEARI



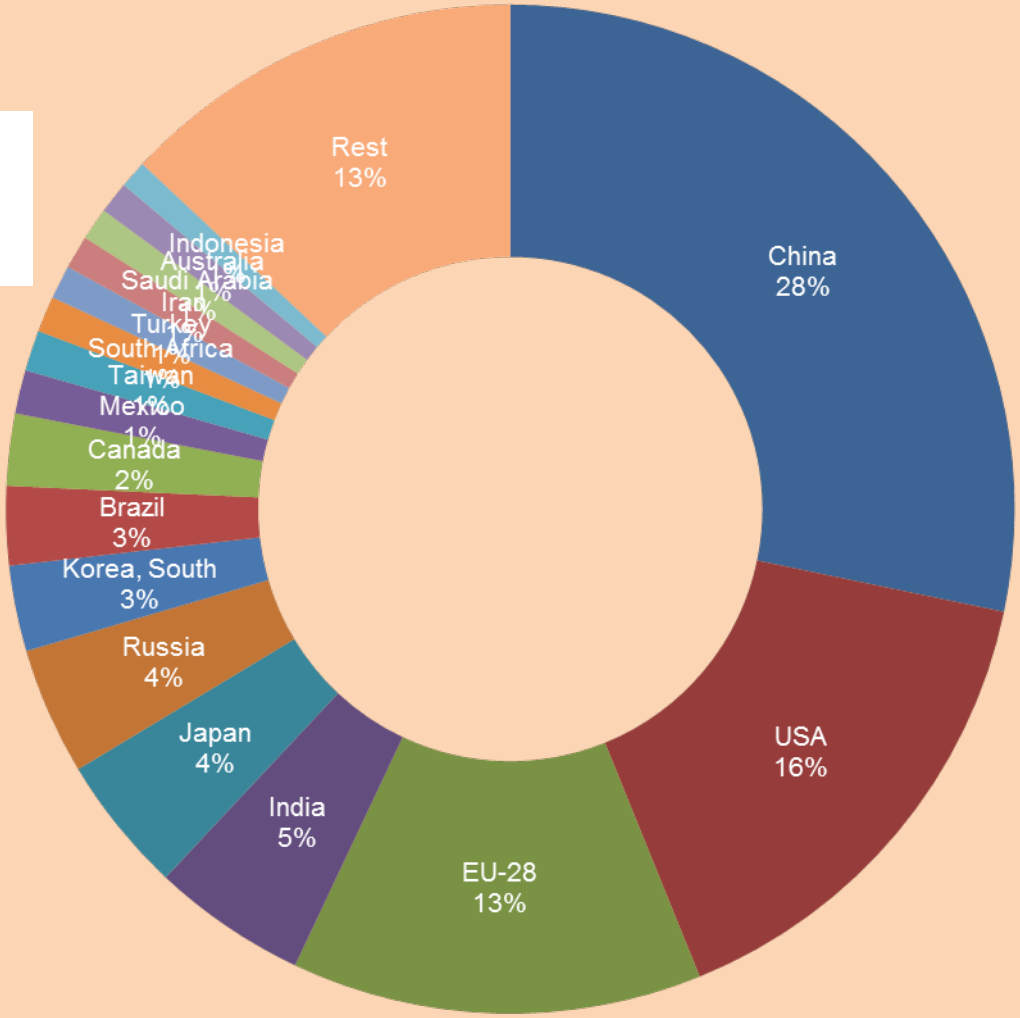
Source: IEC TC 2 WG31: Conrad U. Brunner, Günther Krei, Martin Doppelbauer

The Present

Electricity used in motors

47.2% of the total global electric energy consumption of 19’836 TWh/a is in motors

75.6% of the total global electric energy consumption in motors is
in countries with MEPS

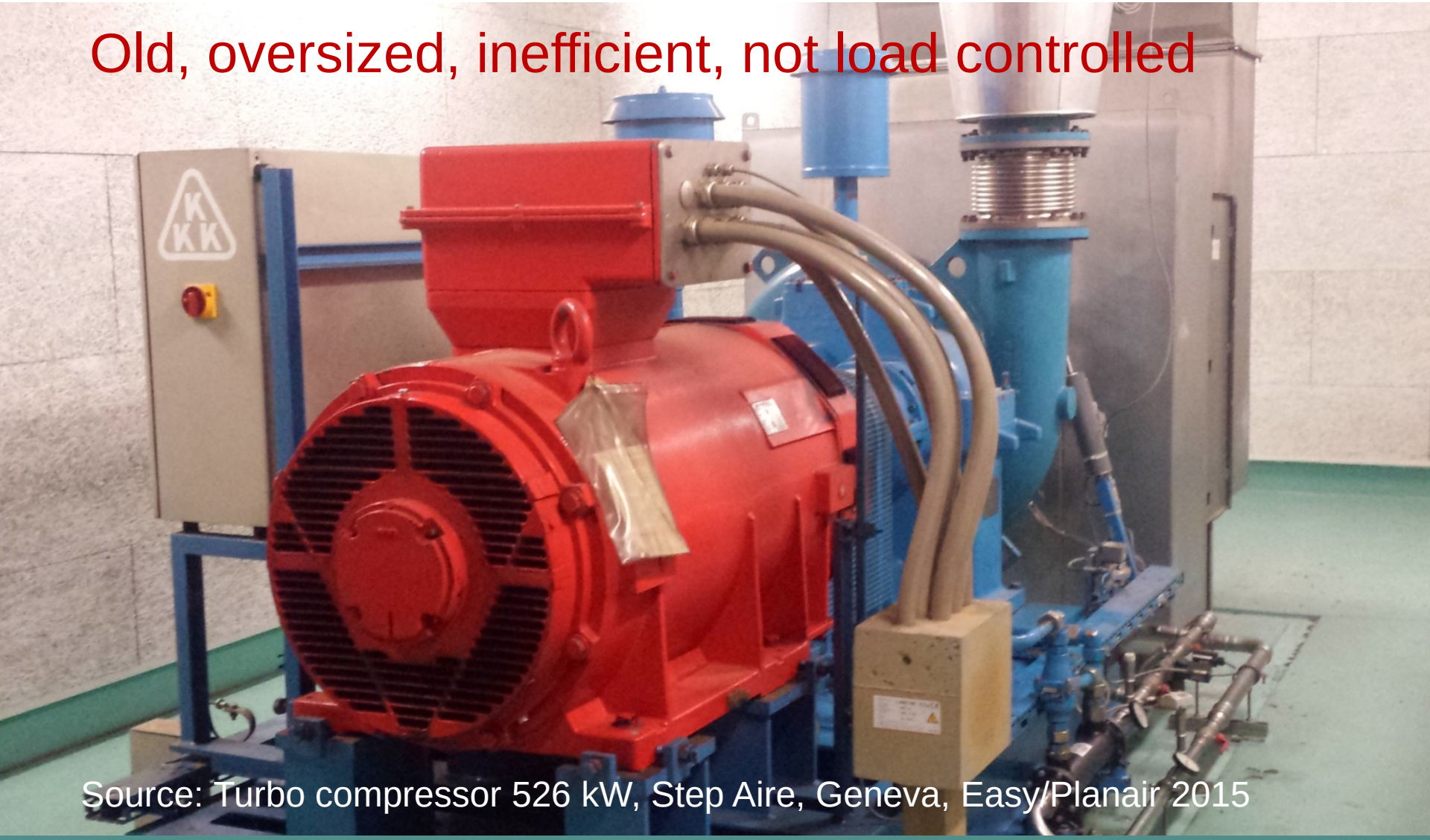


Total electricity in motor systems 9’370 TWh/a

Source: Impact Energy 2016 based on IEA data for 2014

Present: our daily business

Old, oversized, inefficient, not load controlled



Source: Turbo compressor 526 kW, Step Aire, Geneva, Easy/Planair 2015

The present

Efficiency Levels 3-phase induction motors (Low Voltage < 1000 V)	Efficiency Classes IEC 60034-30-1, 2014 Global classes IE-Code *	Testing Standard IEC 60034-2-1, 2014 incl. stray load losses	Performance Standard Mandatory MEPS *** National Policy Requirement
Super Premium Efficiency	IE4	Preferred Method **	
Premium Efficiency	IE3	Summation of losses with load test:	Canada (0.75 - 150 kW) Israel (7.5 - 375 kW) Mexico (0.75 - 375 kW) USA (0.75 - 375 kW) South Korea (37 - 375 kW) Switzerland (7.5 - 375)**** Turkey (7.5 - 375 kW)**** Japan (Toprunner) EU 28 (7.5 - 375 kW)****
High Efficiency	IE2	Additional losses P_{LL} determined from residual loss	Australia (0.75 - 185 kW)***** Brazil (0.75 - 185 kW) Canada (151 - 375 kW) China (0.75 - 375) Israel (0.75 - 5.5 kW) Saudi Arabia (0.75 - 375 kW) South Korea (0.75 - 30 kW) New Zealand (0.75 - 185 kW) Taiwan (0.75 - 200 kW) Turkey (0.75 - 7.5 kW)
Standard Efficiency	IE1		Costa Rica Chile (0.75 - 7.5 kW)

07. Okt 16
Impact Energy Inc.
© EMSA 2016

*) Output power: 0.12 kW - 1000 kW, 50 and 60 Hz, line operated 2-, 4-, 6- and 8-poles

**) for 3-phase machines direct online, < 1 kV, rated output power < 1000 kW

***) Minimum Energy Performance Standard

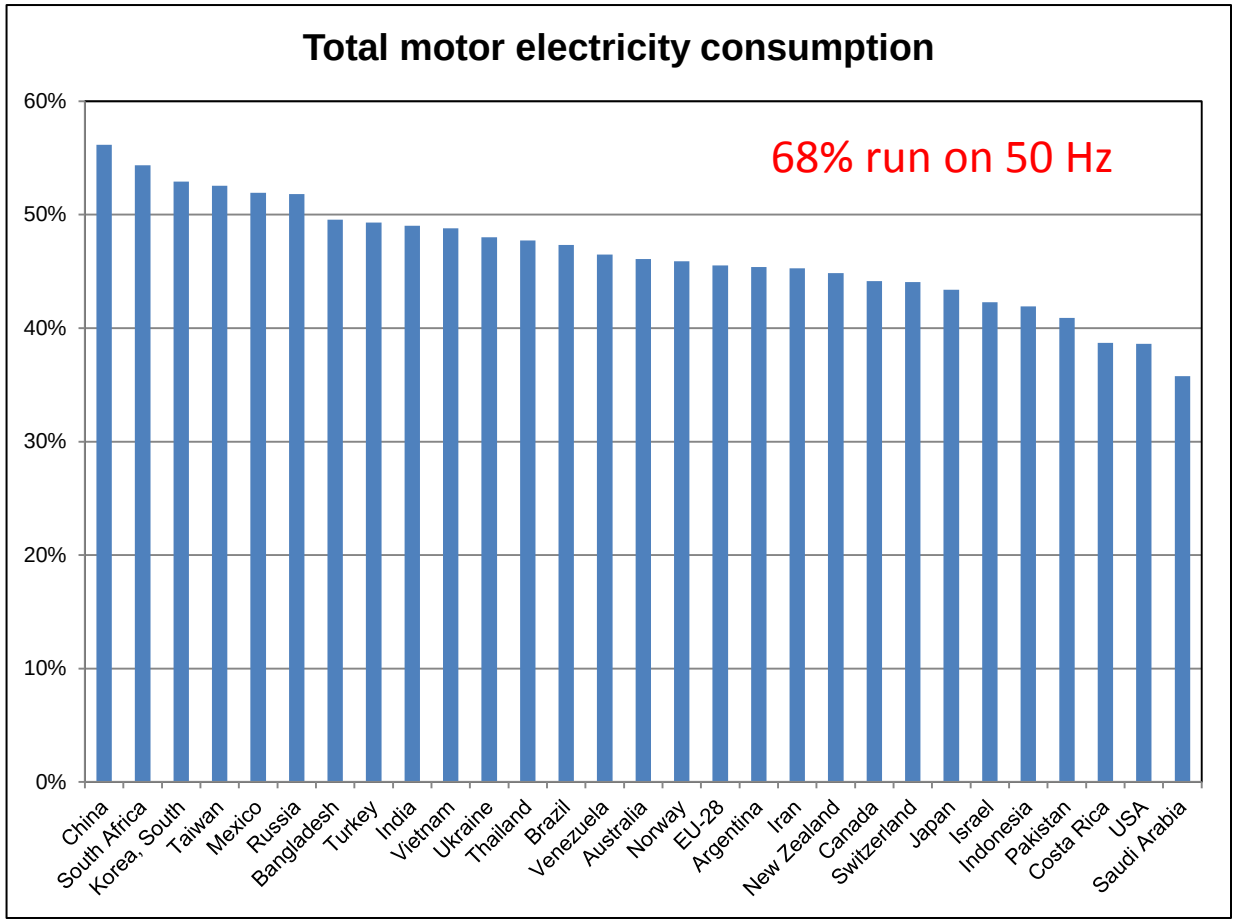
****) European Union, Turkey, Switzerland: IE3 or IE2 + VFD; 2017 above 0.75 kW

*****) Australia adoption of IE Standards pending

Electricity share of motors

Countries who use the largest share of electricity for motor systems:

1. China
2. South Africa
3. Taiwan
4. Mexico
5. Russia



Average: 47.2%
Source: Impact Energy 2016 based on IEA data for 2014

IEC standards are ready

Performance and tolerances	IEC	60034-1
Testing for fixed speed motors	IEC	60034-2-1
Testing for variable speed motors	IEC	60034-2-3
Efficiency classes for fixed speed motors	IEC	60034-30-1
Efficiency classes for converter fed motors	IEC TS	60034-30-2
Requirements for motor, converter and applications	IEC	61800-9-1*
Testing & Efficiency classes for converters	IEC	61800-9-2*

*) FDIS: Final Draft International Standard

MEPS - progress is slow

- Fraction of global electricity demand covered by MEPS
  - Motors 76%
  - Pumps 58%
  - Fans 41%
  - Compressors 28%
  - VFD 0%

Source: Maarten van Werkhoven, Rita Werle, et al.:
Policy Guidelines for Motor Driven Units, part 1, 2016

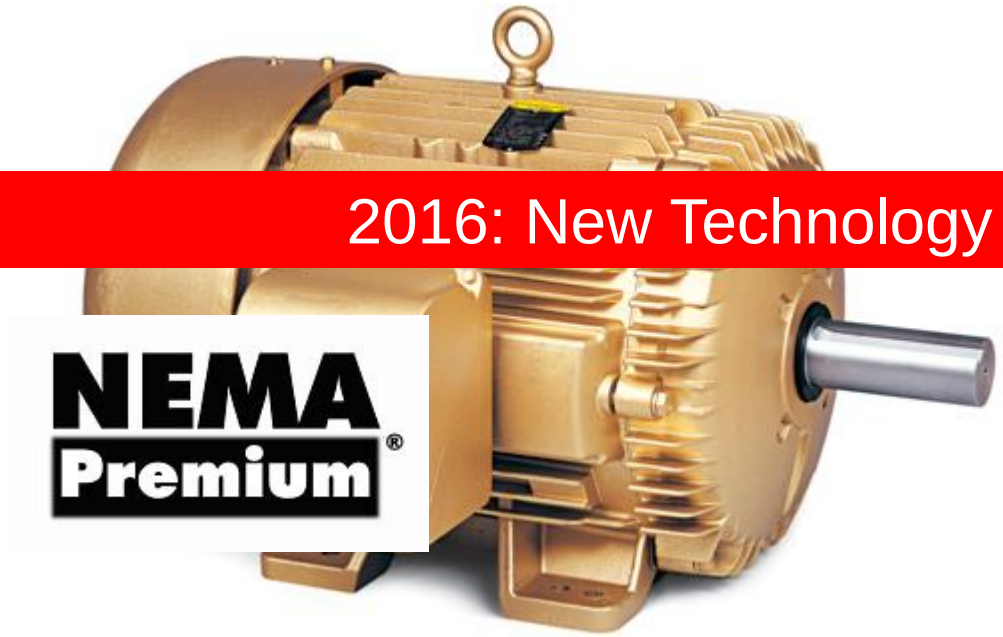
The Open Question

The fundamental question:

How can we save:

- the most energy
- with the least cost - over time
- for the benefit of the society and the environment

Two pioneers in 2001



Baldor NEMA Premium

Nokia 6100

2016: New Technology leaders are in Asia

The open question Nr. 1:

a) Shall we go with few machines in the market to the peak of performance

(IE4, IE5)?

or

b) Should we try to bring as many countries as possible at least to the next plateau of performance

(IE2, IE3)?

The open question nr. 2

Where is the optimum?

a) Shall we go higher and higher with motor efficiency?

or

b) Should we check the entire system's performance only , not look at the efficiency of the components anymore?

Systems integration:

- **Technical optimum**:
  - operating cycle
  - starting inertia
- **Economic optimum**:
  - hours of operation
  - price of electricity
- **Ecological optimum**
  - durability

Thank you

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