Energy Using Product (EuP) Directive Preparatory Study

Lot 11: Motors

Analysis of existing technical and market information

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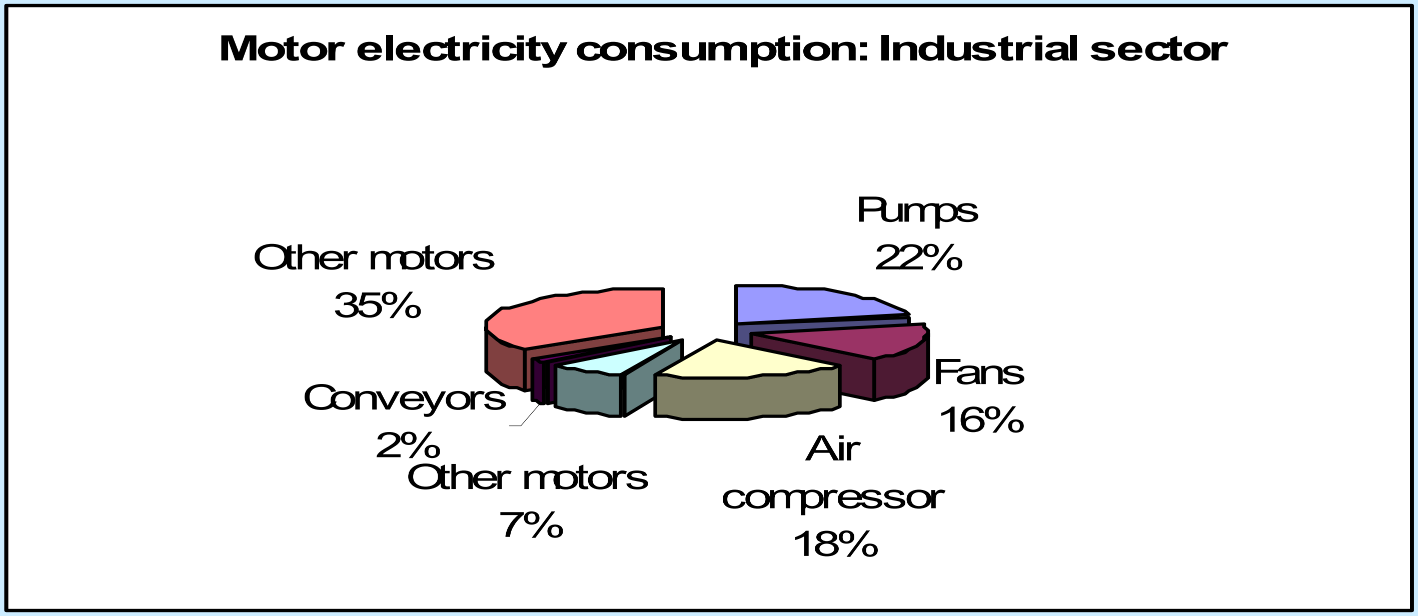
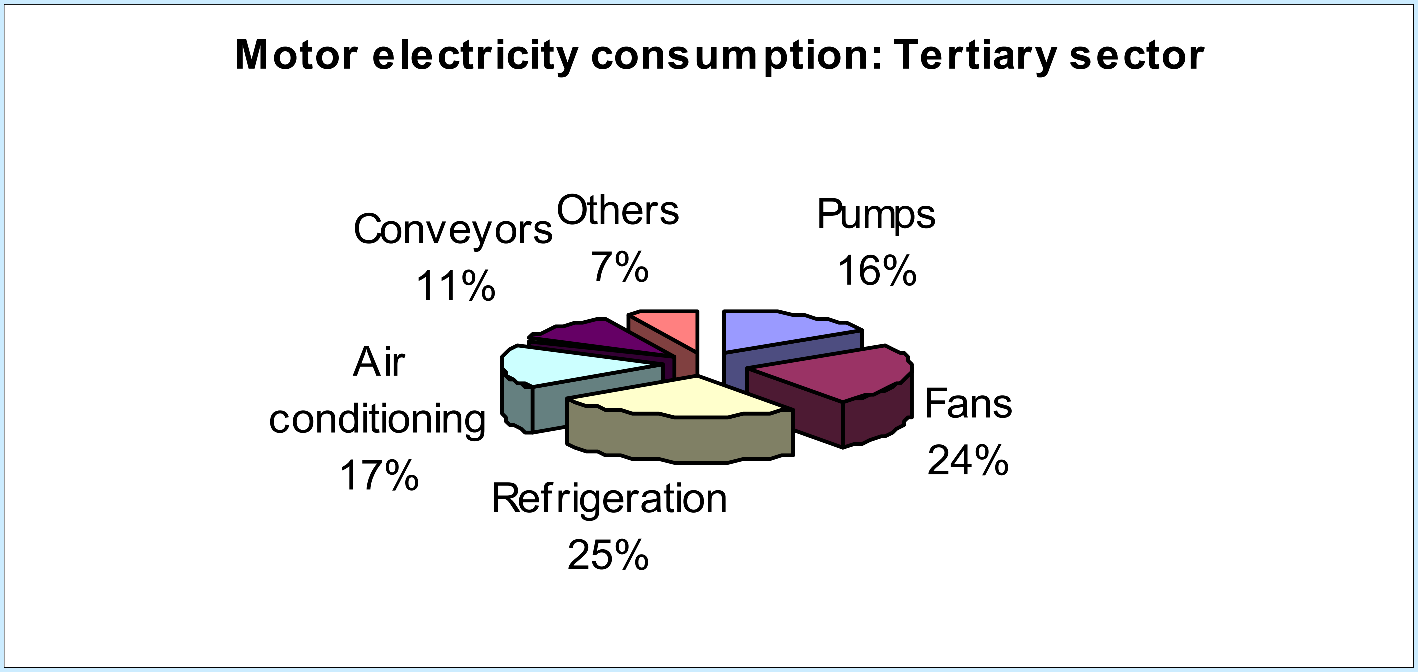
Aníbal T. de Almeida
ISR-University of Coimbra

Relevance of Electric Motors

-In the EU, motor systems are responsible for 69% of the electricity used in the industry and for 38% used in tertiary sector;

-Energy-efficient motor systems can save 200 TWh per year


Motor electricity consumption: Industrial sector
Pumps
22%
Fans
16%
Air
compressor
18%
Other motors
7%
Conveyors
2%
Other motors
35%


Motor electricity consumption: Tertiary sector
Pumps
16%
Fans
24%
Refrigeration
25%
Air
conditioning
17%
Conveyors
11%
Others
7%

- Role of induction motors

Induction motors are by far the most widely used motor in the power range under consideration (1-150 kW), using over 90% of the electricity consumed by all motors in that range.

General purpose induction motors are a commodity type of motor constituting a large majority of the market whose main characteristics are standardised.

This standardisation allows motors to be easily exchanged around he world, by motors made by different manufacturers meeting the same requirements.

- 3-phase induction motors

The integral horsepower motor market is largely dominated by three-phase motors.

Single-phase motors are more expensive and less efficient than equivalent three-phase motors, being mainly used in appliances in residential applications.

Integral single phase motors can be found, mostly in the residential sector in applications such as submersible pumps and machine tools.

These motors typically have a small number of operating hours per year.

- Proposed Primary Functional Parameters:

- Output power (the provided mechanical power (kW));
- Speed/Number of Poles;
- Nominal voltage;
- Frequency;
- Number of phases;
- Efficiency class/nominal value.

- Proposed Secondary Functional Parameters:

- Starting torque;
- Breakdown torque;
- Starting current;
- Current;
- Power factor;
- Insulation class;
- Duty class;
- Case tightness grade;
- Frame size;
- Bearing reference.

Motor Efficiency Testing

For the same load factor and operating hours, motor operating costs depend mainly on the motor efficiency, which is measured and classified according to different efficiency testing standards around the world.

The differences between the main efficiency testing standards, can lead to significantly different motor efficiency values.

Efficiency testing standards

- **IEEE 112-B (2004)**

-North America and Latin America.

-**Direct method** where output power is obtained measuring the torque and rotation speed at different load levels.

-Requires accurate measuring instrumentation, including precision dynamometers, for the different power ranges.

- **IEC 60034-2 (1996)**

-**Indirect method**, avoiding the need to measure Mechanical Power and the associated costs. Mechanical Power is calculated by measuring the electrical input power and the losses.

-All losses are measured using laboratorial tests except stray load losses which are assumed.

-Overestimated efficiency values because the value considered for stray load losses (0.5 % of the full load input power) is not realistic.

-In fact, in the most cases, particularly in the low and medium power motor ranges, stray load losses assume real values well above 0.5%.

- **IEC 61972 (2002)**

-Developed as a possible replacement of IEC 60034-2 allows two methods to determine motor efficiency.

-Direct method (similar to IEEE 112-B);

-Indirect method (assigns variable allowance for SLL).

- **IEC 60034-2 (CDV Ed.4/2, 2006)**

-New version of IEC 60034-2.

-Allows three different test methods to obtain the motor efficiency:

-Direct method (just like IEEE 112-B);

-Indirect method (assigns variable allowance for SLL);

-Eh Star (Indirect measurement of SLL) - This is an inexpensive method with good accuracy where stray load losses are calculated mathematically.

- **C390-98 (2005) [10]**

-Canadian Std.

-Very similar to IEEE 112-B, being used for the definition of minimum energy performance standards (MEPS) in Canada.

- **AS 1359.102**

-Australian Std.

-Gives the possibility to choose between 3 different methods: indirect, direct and calorimetric.

-Indirect method similar to IEC 60034-2, Amd.2.

-Calorimetric method: very accurate but it is very expensive and time consuming.

-Direct method in accordance with IEC 61972.

It is expected that the Australian Standard will shortly collapse to follow the revised international standard IEC 60034-2.

Existing relevant legislation and self regulation inside and outside EU

There are different approaches to motor efficiency voluntary agreements and minimum efficiency standards regulation around the world. North America was the first region to enforce MEPS.

In Canada and the US, the MEPS relating to motors that conform to National Electrical Manufacturers Association (NEMA) requirements are identical, but the Canadian regulation also covers metric motors.

Mexico has recently completed a revision of its MEPS, making the levels equivalent to those in the US and Canada.

Motor efficiency voluntary agreements and regulation around the world

Country/Region	Type of agreement	Market share
U.S.A	Mandatory implementation (EPACT-1997) and voluntary agreement (NEMA Premium)	EPACT (54%) and NEMA Premium (16%)
EU	Voluntary agreement (CEMEP/EU)	EFF1 (7%) and EFF2 (85% for CEMEP agreement members and 66% for non-CEMEP agreement members)
Canada	Mandatory implementation (EPACT-1996) and voluntary agreement (NEMA Premium)	EPACT (54%) and NEMA Premium (16%)
Mexico	Mexico has recently completed a revision of its MEPS, making the levels equivalent to those in the US and Canada.	
Australia	Mandatory implementation (High efficiency-2006) and voluntary agreement (Premium)	Premium (10%), High efficiency (32%), Standard (58%)
New Zealand	Mandatory implementation	-
Brazil	Mandatory implementation (standard efficiency, high efficiency in 2009) and voluntary agreement (high efficiency)	High (15%) and Standard (85%)
China	Mandatory implementation (standard efficiency-2002) and high efficiency in 2010	High (1%) and Standard (99%)
Japan	Voluntary agreements (standard and high efficiency)	High (1%) and Standard (99%)
Korea	Voluntary agreements since 1996 Mandatory implementation (in 2008)	High (10%) and Standard (90%)

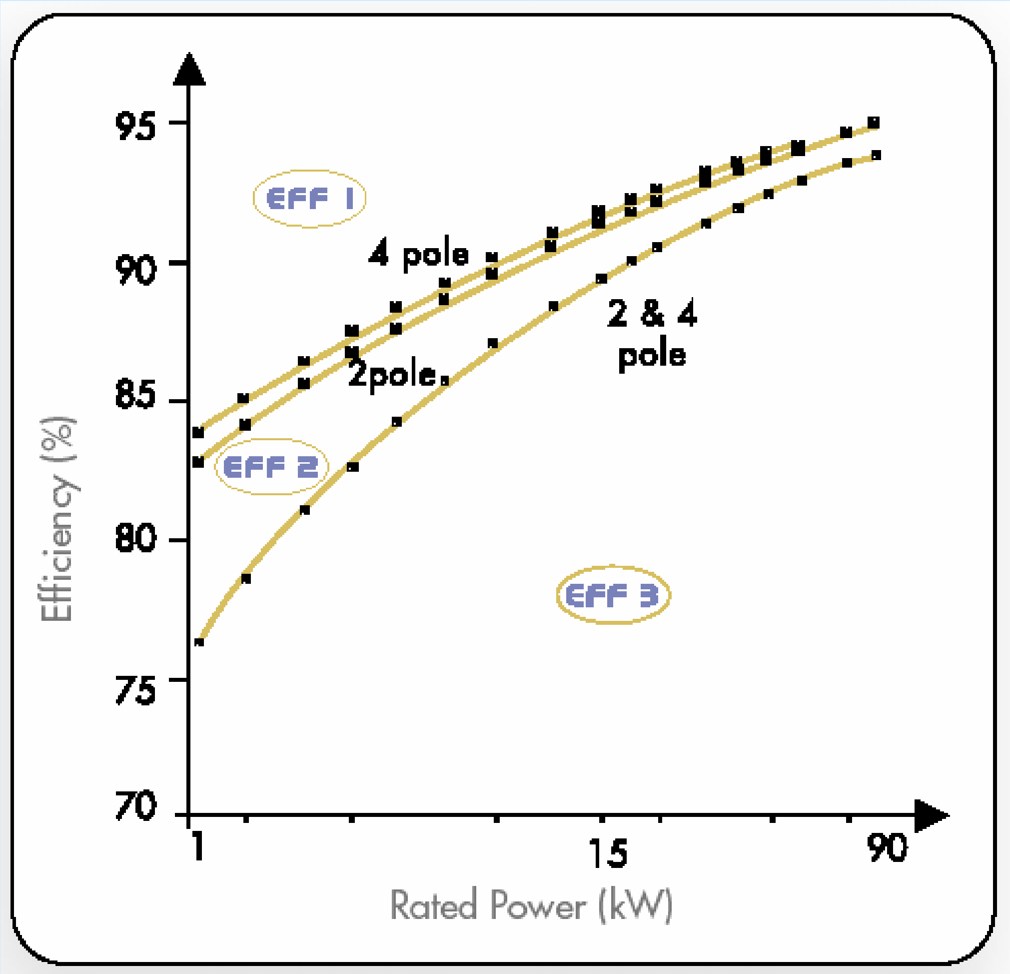
Voluntary agreement EU-CEMEP

-In 1998 a voluntary agreement supported by CEMEP and the European Commission was established and signed by 36 motor manufacturers.

-Motor efficiency classification scheme with three levels for motors:

- EFF1 – High efficiency motors
- EFF2 – Medium efficiency motors
- EFF3 – Low efficiency motors

Motors included in CEMEP/EU agreement:
3-phase AC squirrel-cage induction motors
Rated power: 1.1 kW to 90 kW
Totally enclosed fan ventilated
Line voltage: 400 V
50 Hz
S1 duty class (continuous mode)
Efficiency tested in accordance with IEC 34-2 (indirect method)



Class definition for CEMEP/EU agreements.

There was a voluntary undertaking by motor manufacturers to reduce the sale of motors with the current standard efficiency (EFF3).

Existing relevant environmental legislation outside the EU

-USA Energy Policy Act – EPACT (1992), enforced in October 1997 – requires motors manufactured for sale in USA or imported motors meet minimum efficiency levels. It is a mandatory agreement and has been enforced in 1997.

-EPACT motors constitute 54% of the integral horsepower induction motor market share. Premium motors represent 16%.

Characteristics of the motors included on EPACT

Motors included in EPACT scheme
Polyphase squirrel-cage induction motors, NEMA Design A and B
Rated power 1-200 hp
Single-speed
230/400 Volts
60 Hz
Continuous rated
Tested in accordance with IEEE 112-B
2, 4 and 6 poles
Type of Enclosure: TEFC and ODP

-NEMA – Premium (2002): Because many utilities and industry associations were promoting motors with a higher efficiency that EPACT mandatory levels, the National Electrical Manufacturers Association (NEMA) felt a need to define a classification scheme for premium higher efficiency motors.

-In 2005 NEMA Premium motors constituted 16% of the market share in USA.

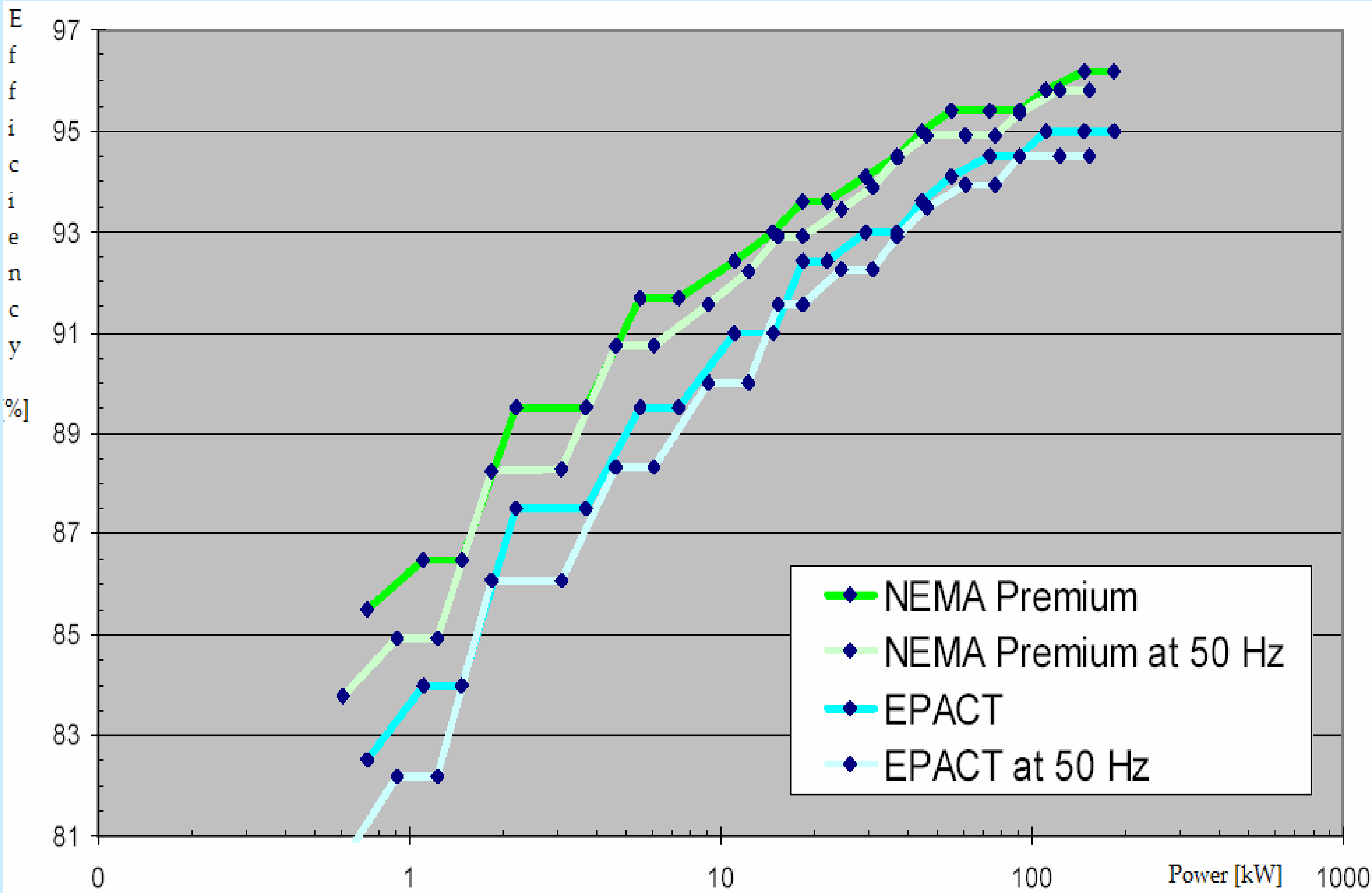
Motors included NEMA Premium scheme
Polyphase squirrel-cage induction motors, NEMA Design A and B
Rated power 1-500 hp
Single-speed
600 Volts or less
60 Hz
Continuous rated
Tested in accordance with IEEE 112-B
General-purpose motors T frame
2, 4 and 6 poles

Comparison of Minimum Efficiency Requirements in Different Parts of the World

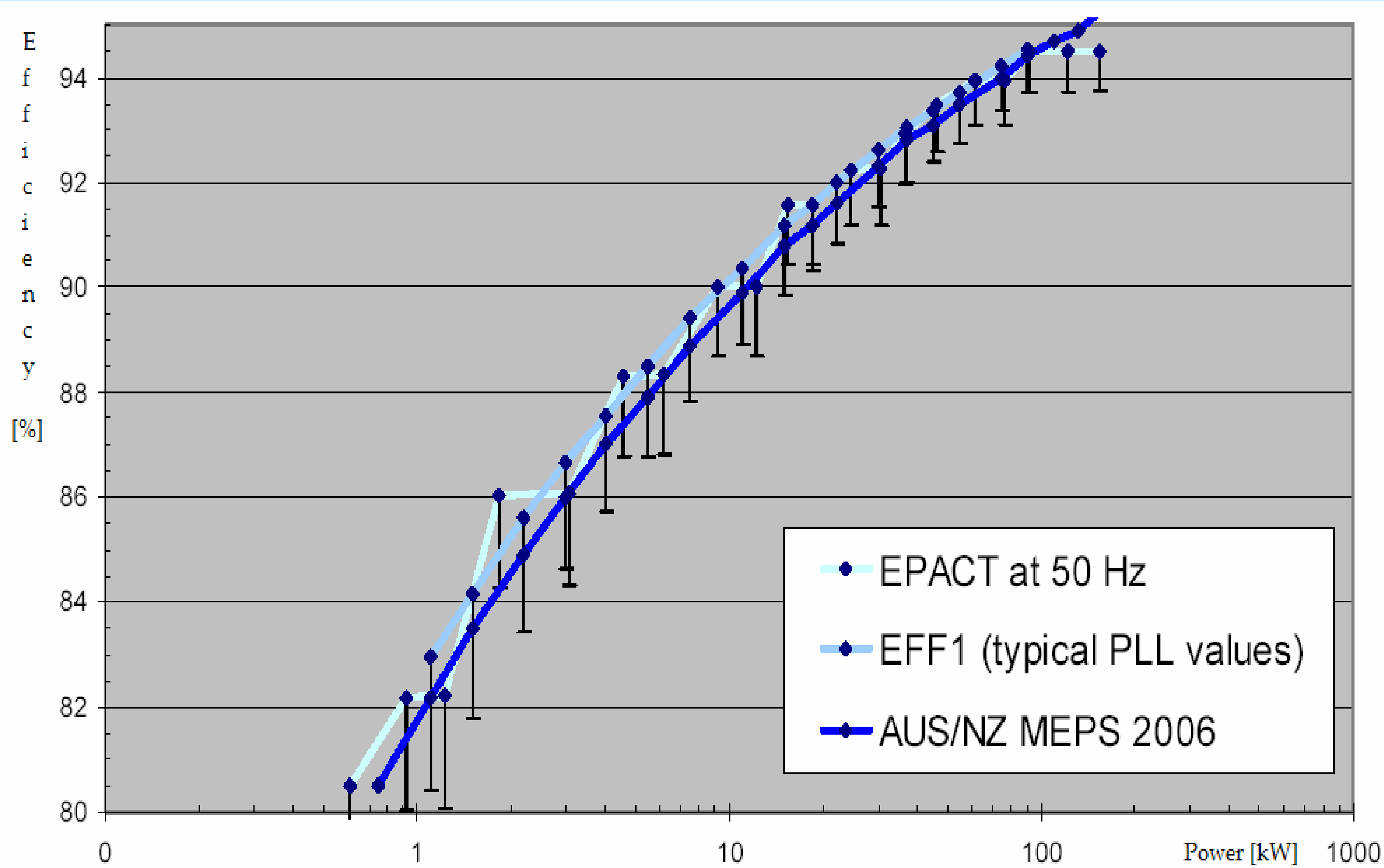
Because of the different efficiency testing standards and frequency it is cumbersome to make comparisons between different requirement levels in standards such as:

- EU/CEMEP (Europe)
- EPACT (North America)
- NEMA Premium (North America)
- MEPS (Australia and New Zeeland)

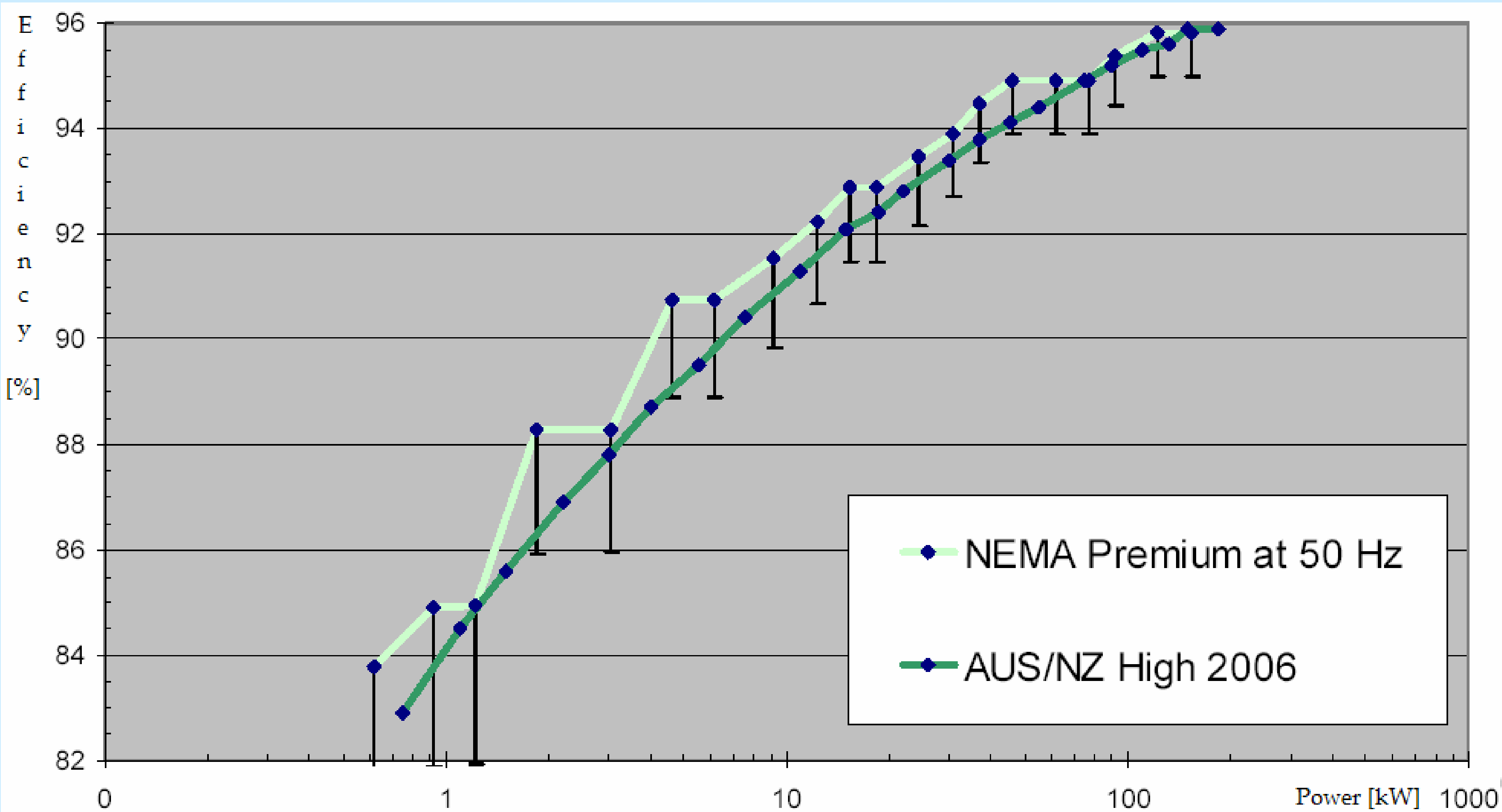
Comparison of 60 Hz efficiency requirements at 50 Hz line frequency (EPACT and NEMA Premium)



Comparison of High Efficiency requirements (EPACT, CEMEP/EU and Australian/New Zeeland MEPS)



Comparison of High Efficiency requirements (NEMA Premium and Australian/New Zeeland high level)



IEC – Draft Standard for harmonization of efficiency classification standards

-Several different energy efficiency classes are currently in use, increasing potential confusion and creating market barriers.

-IEC is now developing a classification standard trying to harmonize different requirements for induction motors efficiency levels covering the following motor types:

- Single-speed three-phase 50 Hz or 60 Hz cage induction motors
- Rated voltage up to 1000 V
- Rated power between 0,75 kW to 200 kW
- S1 duty type (continuous duty)
- 2, 4 and 6 poles
- Degree of protection: IP4X or higher

Efficiency and losses shall be tested in accordance with IEC 60034-2 using the test procedure summation of losses with *stray load losses* determined either from residual loss or from Eh-star test.

Four efficiency classes are being proposed:

- Class A (Premium efficiency)
- Class B (High efficiency)
- Class C (Improved efficiency)
- Class D (Standard efficiency)

Other relevant efficiency standards

Several industries in which the induction motors operate a very large number of hours per year, and in which there are strict requirements on performance and reliability, have created sector specifics standards which address the recommended minimum efficiency levels.

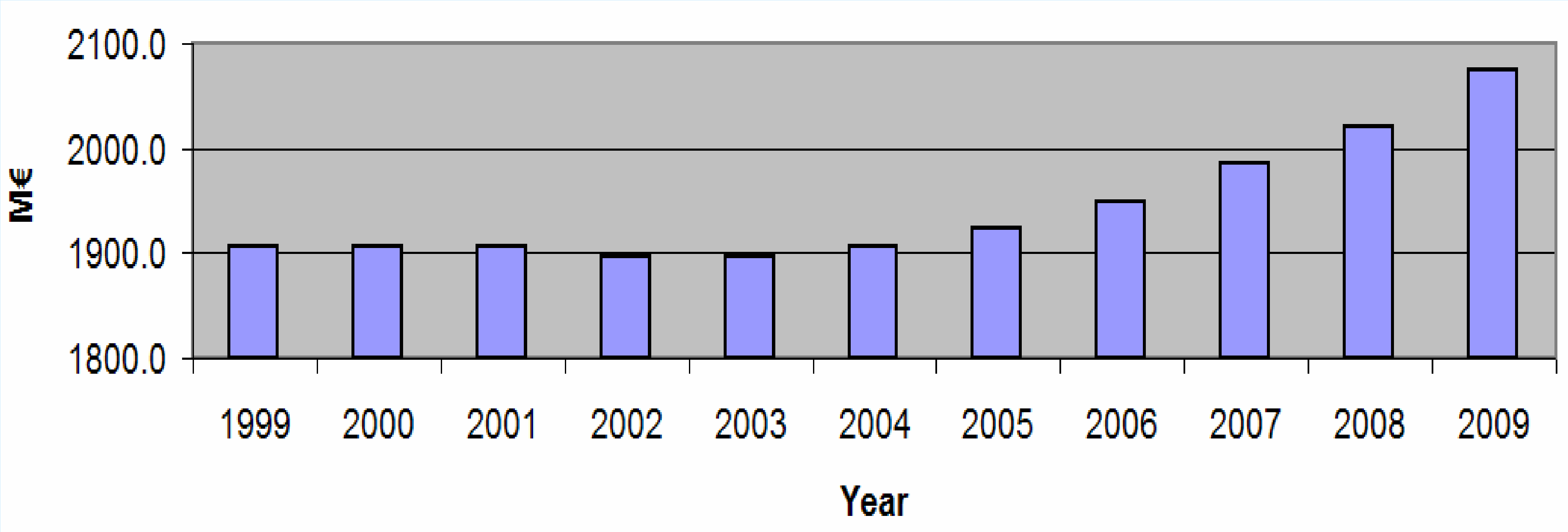
- WIMES 3.03 (Special standard for water industry) – United Kingdom - defines minimum standards of performance and construction of low voltage motors, and was drawn up with the assistance of water companies, manufacturers and suppliers.

- IEEE-841, IEEE Standard for Petroleum and Chemical Industry, - Severe Duty Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors - Up to and Including 370 kW (500 hp), is currently being revised and will adopt NEMA Premium efficiency levels.

2. Economics and market

2.1 Macro data on EU trade, production and apparent consumption

The integral horsepower market is a mature market with expected slight growth in the near future.

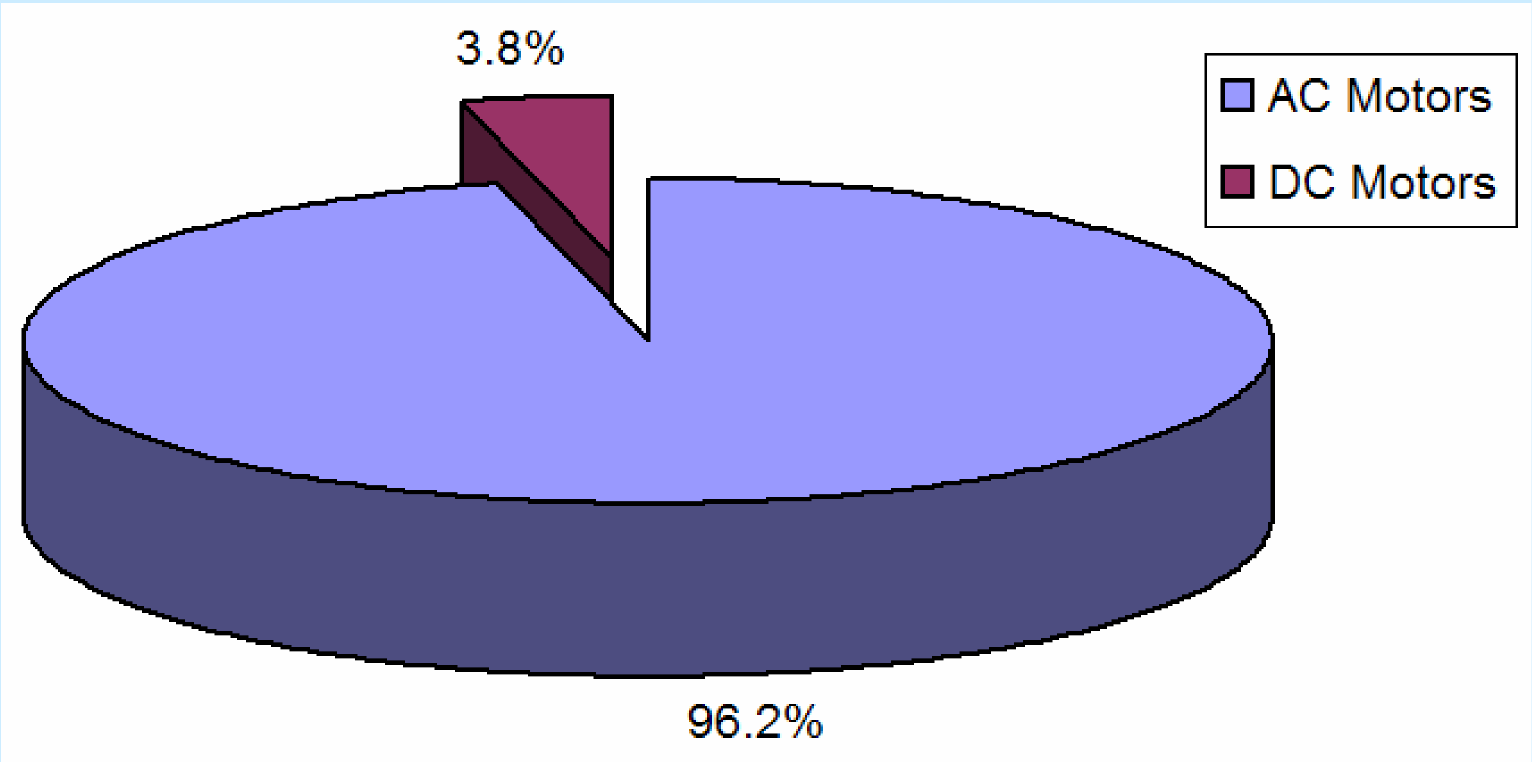


Revenue forecast for integral motors in Europe.

-AC motors largely dominate the sales.

-The trends show that the DC motors market share is projected to see a decline in the next few years.

-The three-phase induction motors can have a high dynamic performance when fed by VSDs, cost less and require much less maintenance.



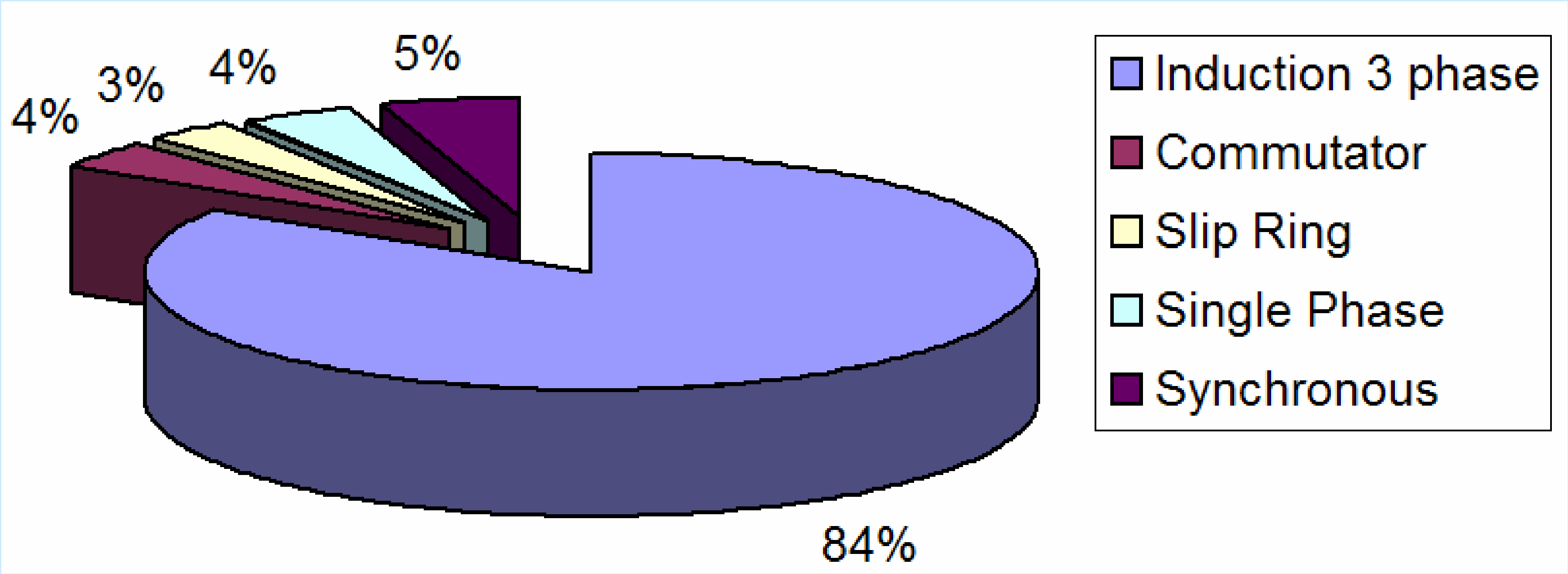
Share of shipments (units) by motor type (integral motors) in Europe (2006).

AC integral motors market Europe:

-Largely dominated by three-phase induction motors.

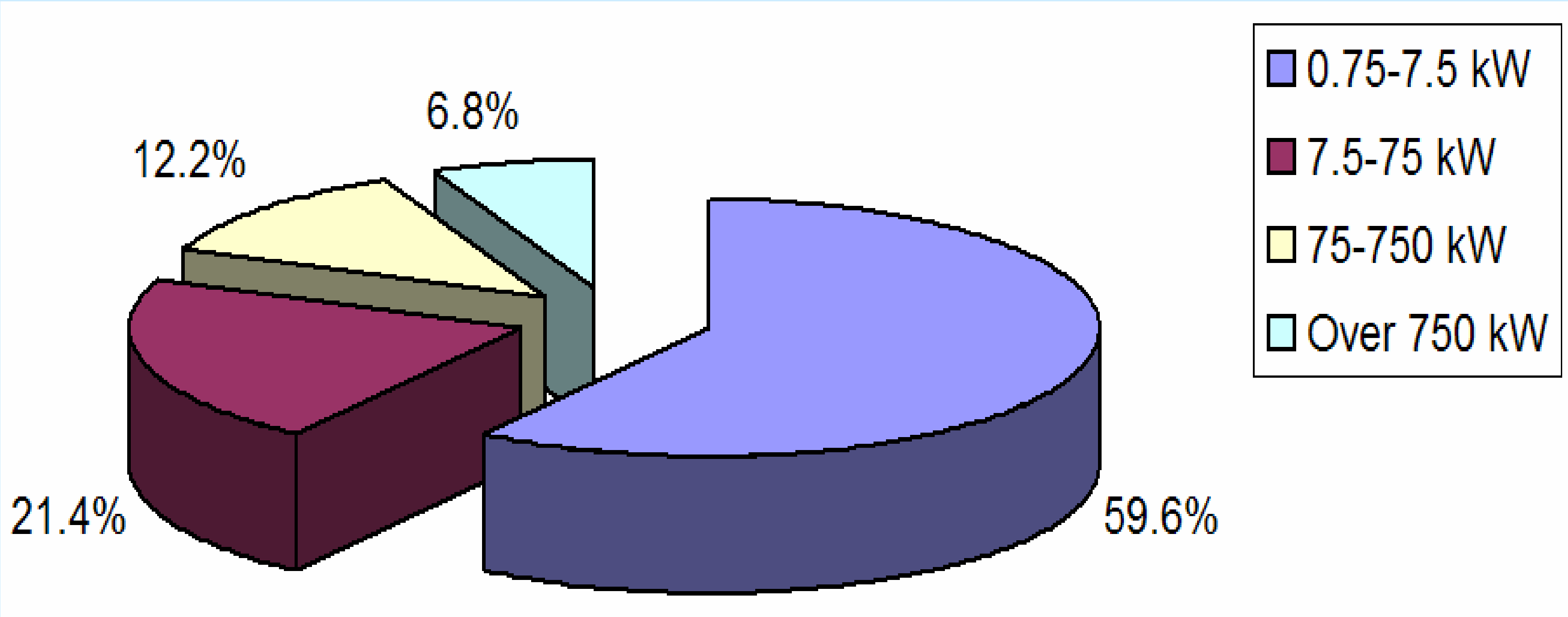
-Single-phase motors represent about 4%.

-0.75-75 kW motors dominate the market (in units).



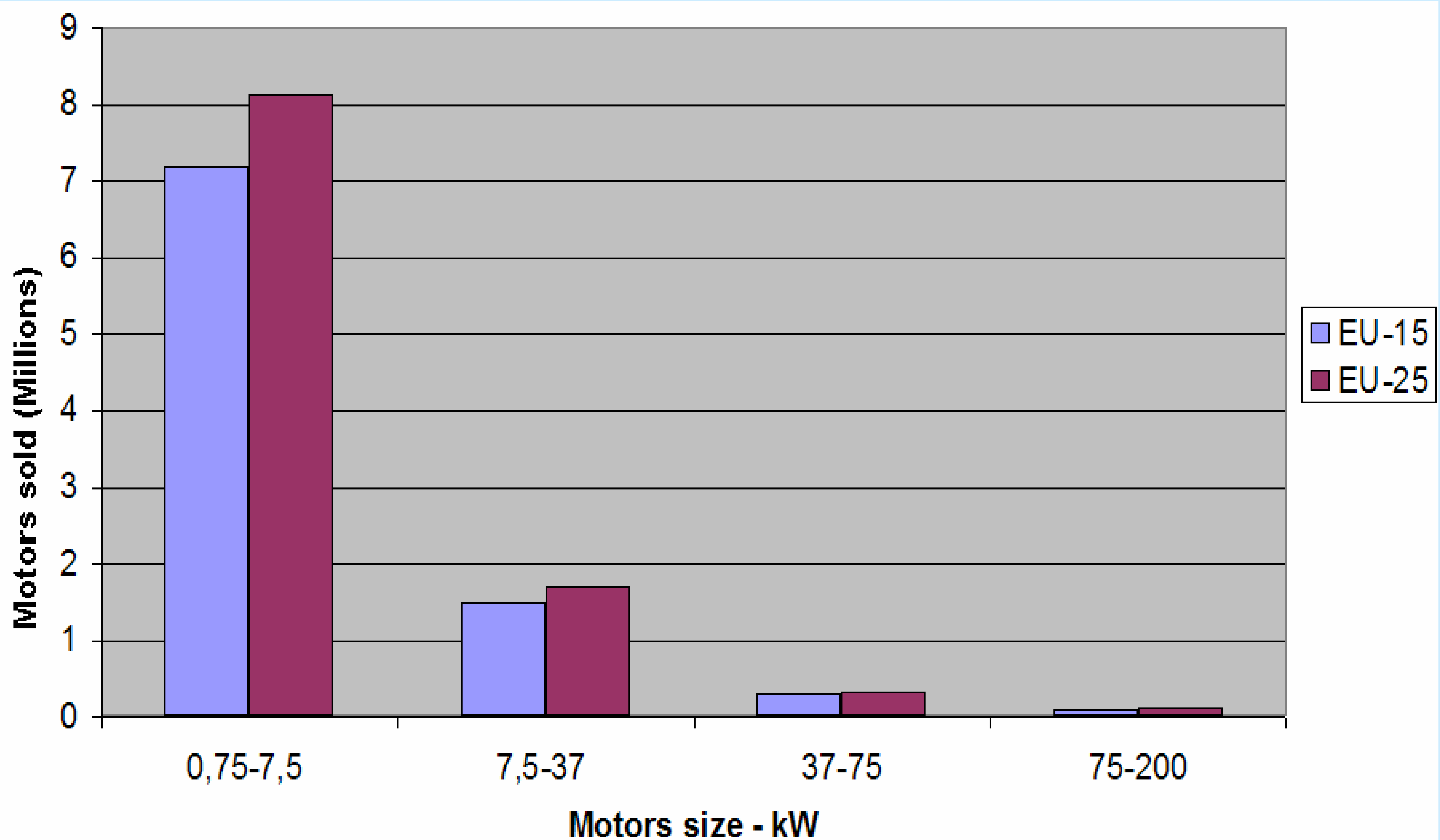
Revenues share of integral AC motors in Europe (2006).

Shipments share (units) of AC integral motors by size in Europe (2006).



EU-15 market information

Power range	Production in EU-15 (Millions units)	Exports* EU-15 (Millions units)	Imports* EU-15 (Millions units)	Market EU-15 (Millions units)	Capacity (GW)
0.75-7.5 kW	6.3	3.1	4	7.20	22.5
7.5-37 kW	1.4	0.7	0.8	1.50	30
37-75 kW	0.3	0.2	0.2	0.30	15.6
75-200 kW	0.08	0.075	0.1	0.10	11.6
Total	8.08	4.075	5.1	9.10	79.6



EU-15 and EU-25 market information (low voltage A. C. motors), 2005.

The low-voltage AC motors market share by number of poles is dominated by **4-pole motors**,

EU-25 market information, 2005

Motor type	**Share (%)**
2-pole	15-35
4-pole	**50-70**
6-pole	7-15
8-pole	1-7

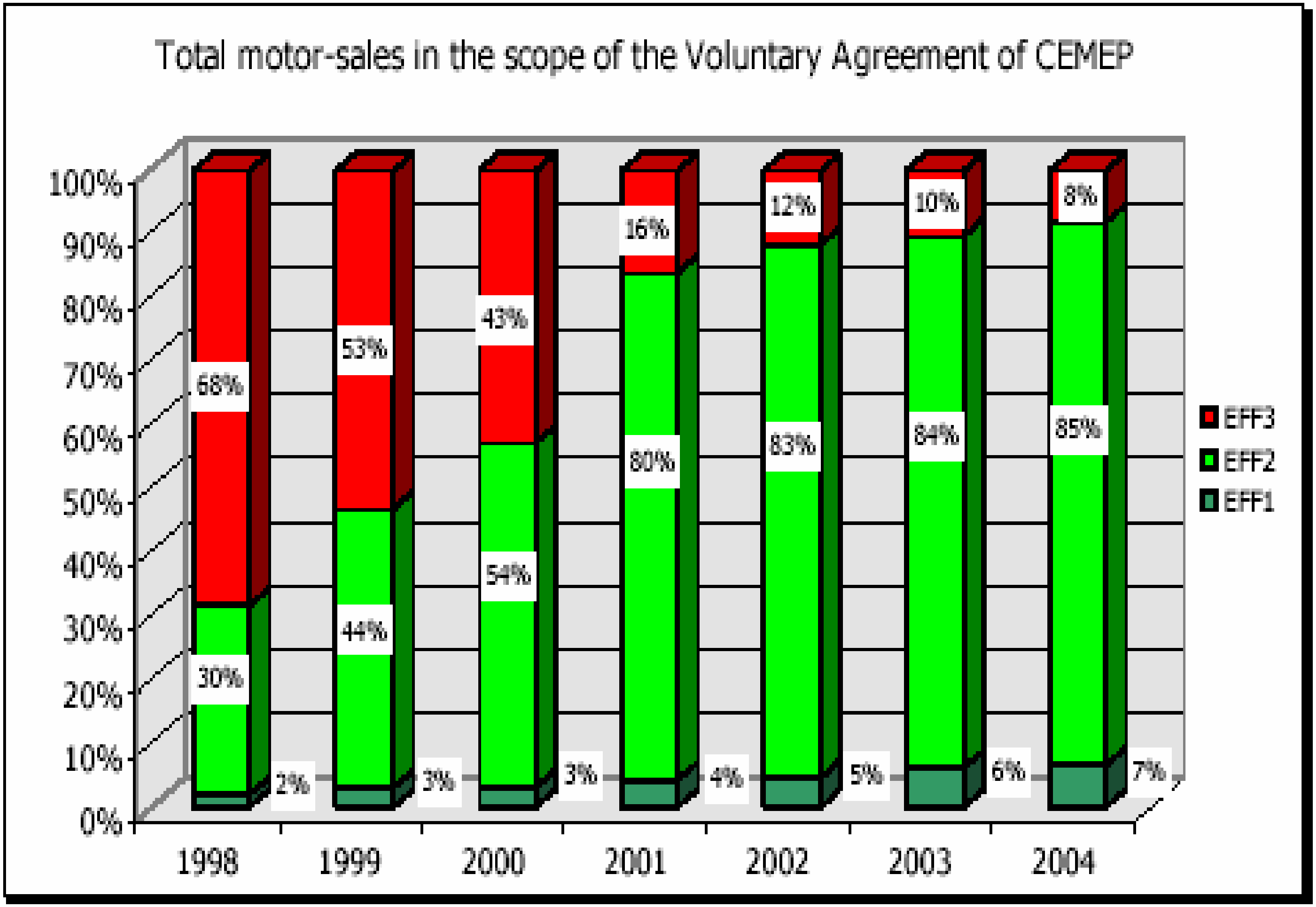
Market trends in the EU

In EU, the original target of CEMEP/EU agreement was to reduce joint sales of EFF3 motors by 50% after agreement period (2003).

- The aim was completely achieved, since EFF3 motor sales decreased from 68% in 1998 to 8% in 2004. Motor manufacturers were able to introduce EFF2 motors with a similar price to EFF3 motors, by improved design, manufacturing and more competitive marketing.

- The penetration of EFF1 efficiency motors is quite small. The main reason for this situation is the fact that the motor market is largely an OEM market, in which OEM purchases represent 80-90 % of the sales.

- This large share of the market combined with the higher EFF1 prices, which typically are 20-30% above EFF2 motors price, leads to a low penetration of EFF1 motors.

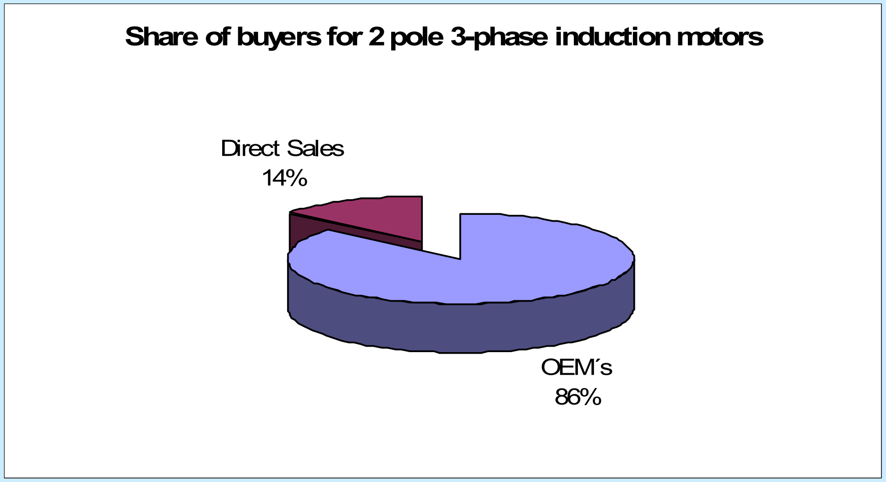


Total motor-sales in the scope of the Voluntary Agreement of CEMEP.

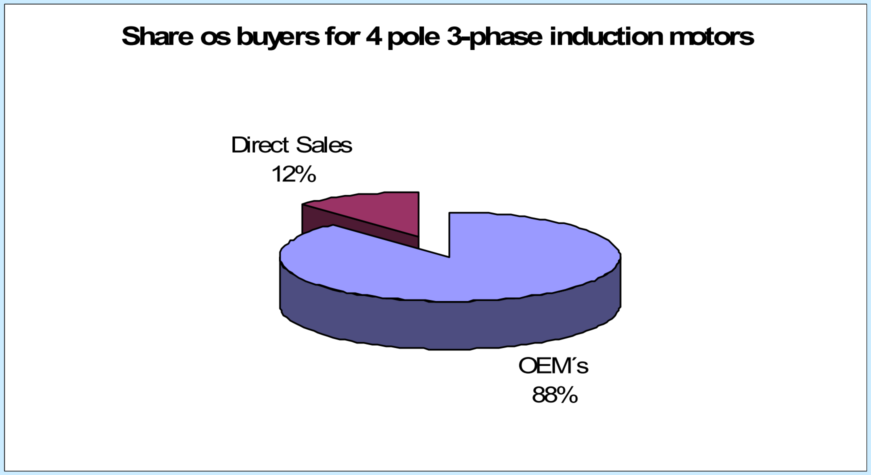
Economics and Markets

Market and stock data

- Direct sales and Original Equipment Manufactures - OEM’s:

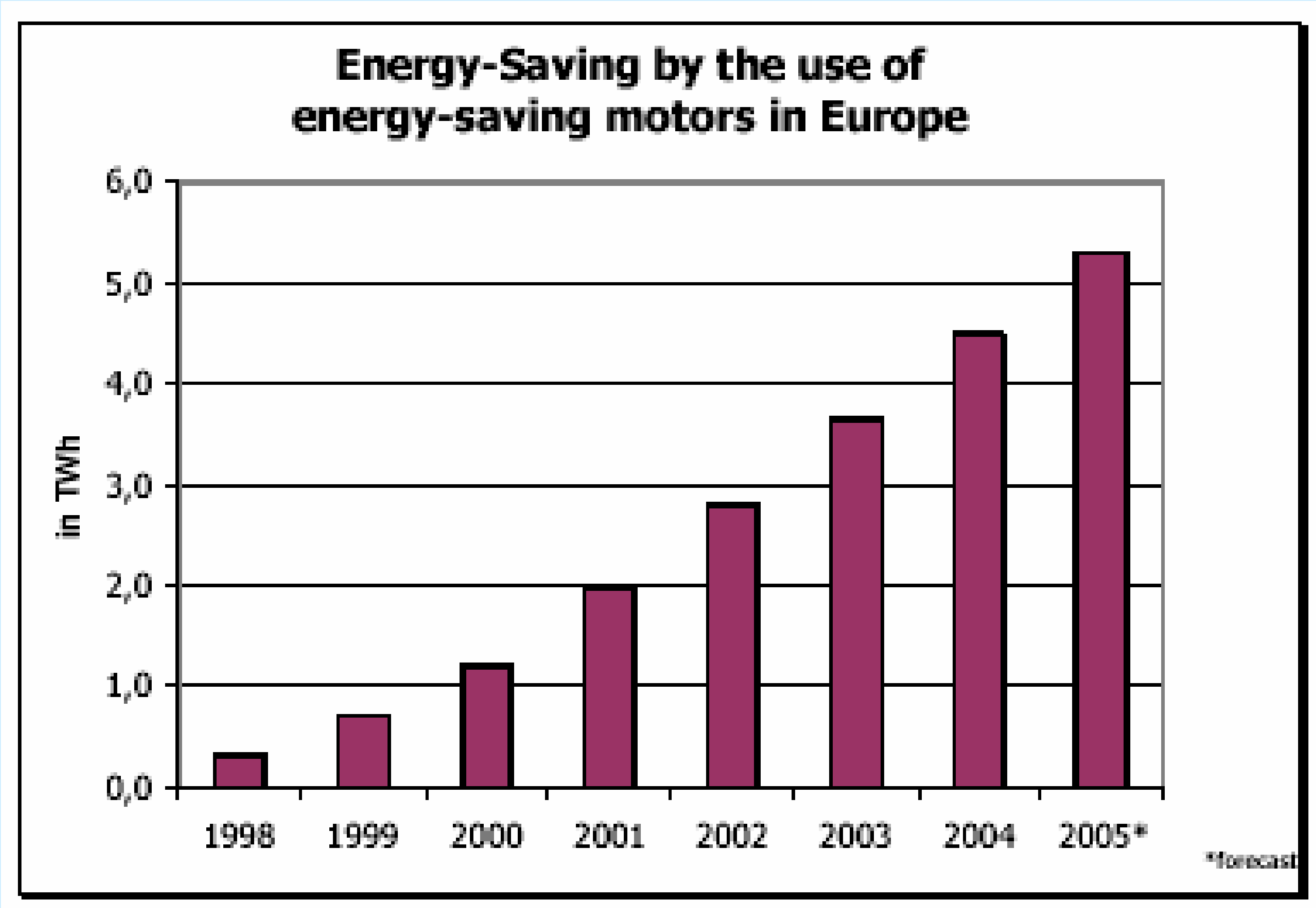


Share of buyers for 2 pole 3-phase motors in EU



Share of buyers for 4 pole 3-phase motors in EU

OEM´s constitutes an important barrier to encourage the sales of Energy Efficiency Motors



Energy-Saving achieved by the EU/CEMEP agreements in Europe.

Energy savings associated with the adoption of minimum efficiency levels

SAVE Study On Cost-Effectiveness of Motor Efficiency (1999)

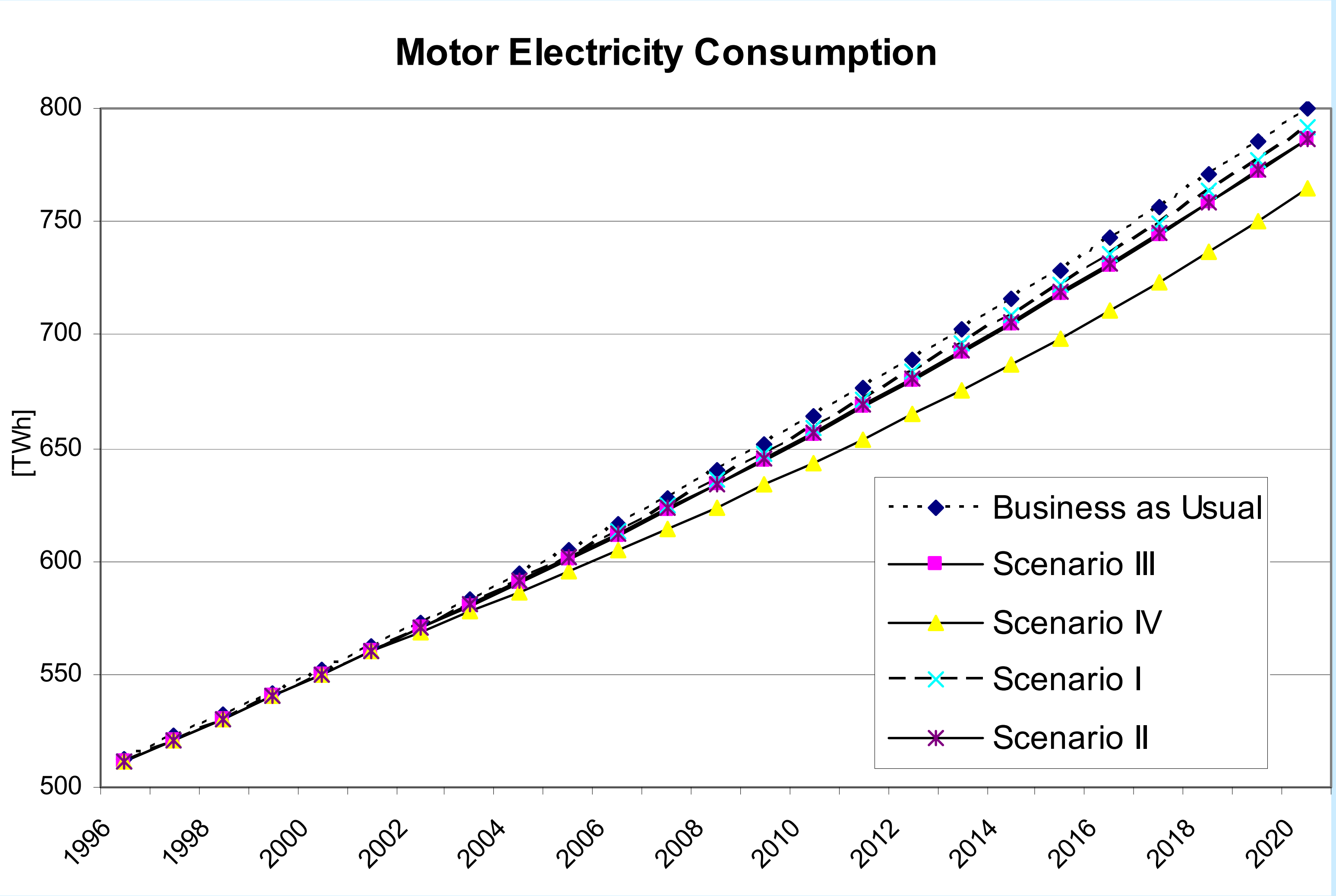
- **Scenario I**: This is the CEMEP agreement. During year 2003 sales of motors in Class 3 will be reduced by 50% (the first step will be during 2001 to reduce the sales of this class by 30%). No further regulation until 2015. This scenario leads to a lower replacement of standard motors by higher efficiency motors.

- **Scenario II:** Scenario I plus weak regulation (ban on Class 3) from January 1, 2006. This scenario is similar to Scenario I, but it will produce a delayed impact. This is very similar to what has happened in the last 6 years.

- **Scenario III:** From January 1, 2003 onwards, no Class 3 motors can be sold. No further regulation until 2015. In this scenario, all Class 3 motors will be replaced by Class 2 and to a less extent by Class 1 motors.

- **Scenario IV:** From January 1, 2003 onwards, no Class 3 motors can be sold. **<u>From January 1 2006 onwards no Class 2 motors can be sold</u>**. In this scenario all stock will progressively be replaced by Class 1 motors.

Scenario IV, with mandatory Class 1 minimum efficiency standards, leads to the highest savings (about 35 TWh by 2020).



Motor electricity consumption in the industrial and tertiary sectors, for 2 and 4 pole motors, in the range 1.1 - 75 kW for each considered scenario.

Electricity prices

For Industry in EU25 (excise taxes included; current prices in Euro per 100 kWh).

Electricity have significantly increased in 2005 and 2006

	1990	1995	2000	2001	2002	2003	2004
EU25	6.21	6.20	5.33	5.47	5.50	6.15	5.69
EU15	6.21	6.24	5.44	5.58	5.55	6.27	5.79
BE	5.75	6.03	5.53	5.72	5.84	5.87	5.96
CZ			4.11	3.93	4.30	4.16	4.00
DK	4.37	4.71					
DE	7.52	8.10	5.42	5.72	5.63	7.02	7.40
EE					3.49	4.14	4.14
EL	5.52	4.82	4.80	4.80	5.00	5.15	5.28
ES	7.08	6.16	5.63	5.14	4.90	5.00	5.10
FR	4.96	5.61	4.91	4.82	4.87	4.87	5.00
IE	5.24	5.06	5.30	5.31	6.48	6.48	6.85
IT	6.00	6.24	7.21	8.48	8.32	9.02	8.36
CY			8.22	9.90	8.37	9.08	7.79
LV							3.59
LT						4.81	4.81
LU	4.83	4.83	4.46	3.94	4.01	4.21	4.31
HU		2.72	3.93	4.01	4.57	4.63	4.76
MT		5.14	5.86	5.93	6.06	5.79	5.65
NL	4.53	4.78					
AT		6.88				5.65	6.17
PL			3.95	4.15	5.16	4.95	4.37
PT	6.41	6.55	5.25	5.30	5.56	5.64	6.11
SI		4.64	5.09	5.09			5.24
SK							6.58
FI		4.42	3.80	3.77	4.08	5.65	5.54
SE			2.83	2.43	2.62	6.20	4.45
UK	5.64	4.84	5.76	5.32	5.24	4.60	4.01

Real vs. nominal efficiency

The nominal efficiency represents the average value of a representative sample of manufactured motors for each product category.

The motor real full load efficiency can deviate from the nominal efficiency, due to several effects, namely the following:
-Testing errors. Round-robin tests with that same motors performed in different laboratories, using direct test methods (e.g. IEEE 112-B), lead to maximum errors of near 10%.
-Different characteristics of raw materials (particularly magnetic steel) and manufacturing tolerances can lead to a variation of up to 10 % in the motor losses.

In USA, NEMA allows a maximum 20% tolerance in the losses, which applied to the nominal efficiency, leads to the minimum guaranteed efficiency.

Dosage of auxiliary inputs during use

-The main input of electric motors is electricity.

-Larger motors are periodically lubricated.

-Most motors are subjected to repair several times during their lifetime when fail (or show signs of imminent failure).

-In this operation new copper windings and bearings are installed. Old bearings and copper wire can be recycled.

Motor lifetime is influenced by many factors:

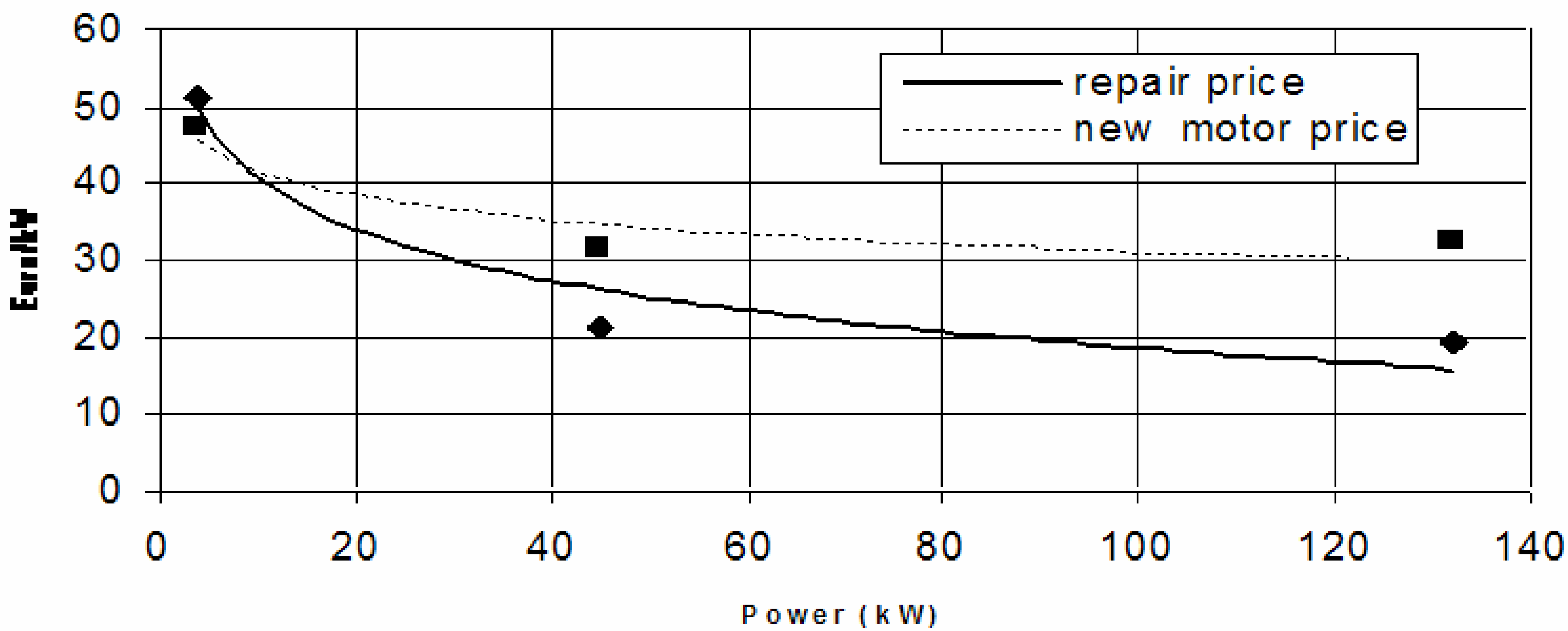
-number of operating hours
-load factor including possible overloading,
-frequency of start/stop cycles
-power quality
-environmental conditions (temperature, vibrations, humidity, chemical pollutions).

Average motor life (including repairs)

Power range	Average life (years)
1.0 – 7.5 kW	12
7.5 – 75 kW	15
75 – 250 kW	20

End-of-Life actual behaviour

Motor larger than 5 kW are normally repaired when they fail. For small motors it is not in general economical to repair them.



Comparison between repair prices and new motor prices in €/kW.

Numbers of the motors repaired each year in the EU-15.

Motor size	**Nº units**
1.0 – 7.5 kW	308 000
>7.5 – 75 kW	166 000
>75 kW	208 000

Motor repairs by power category.

Motor size [hp]	**Percentage repaired**
1-5	20%
6-20	61%
21-50	81%
51-100	90%

Best practice in sustainable product use

-High efficiency motors, such as EFF1, seem a good option for most industrial applications with a medium to large number of operating hours.

-High efficiency motors, because of lower rotor slip, normally have a higher rotating speed than standard efficiency motors. In retrofit applications, when driving loads such as centrifugal pumps or fans, the power consumption of the high efficiency motor may be higher.

-In applications in which the number of operating hours is small (e.g. emergency pumps and ventilators) high efficiency motors may lead to higher lifecycle costs.

Best practice in sustainable product use

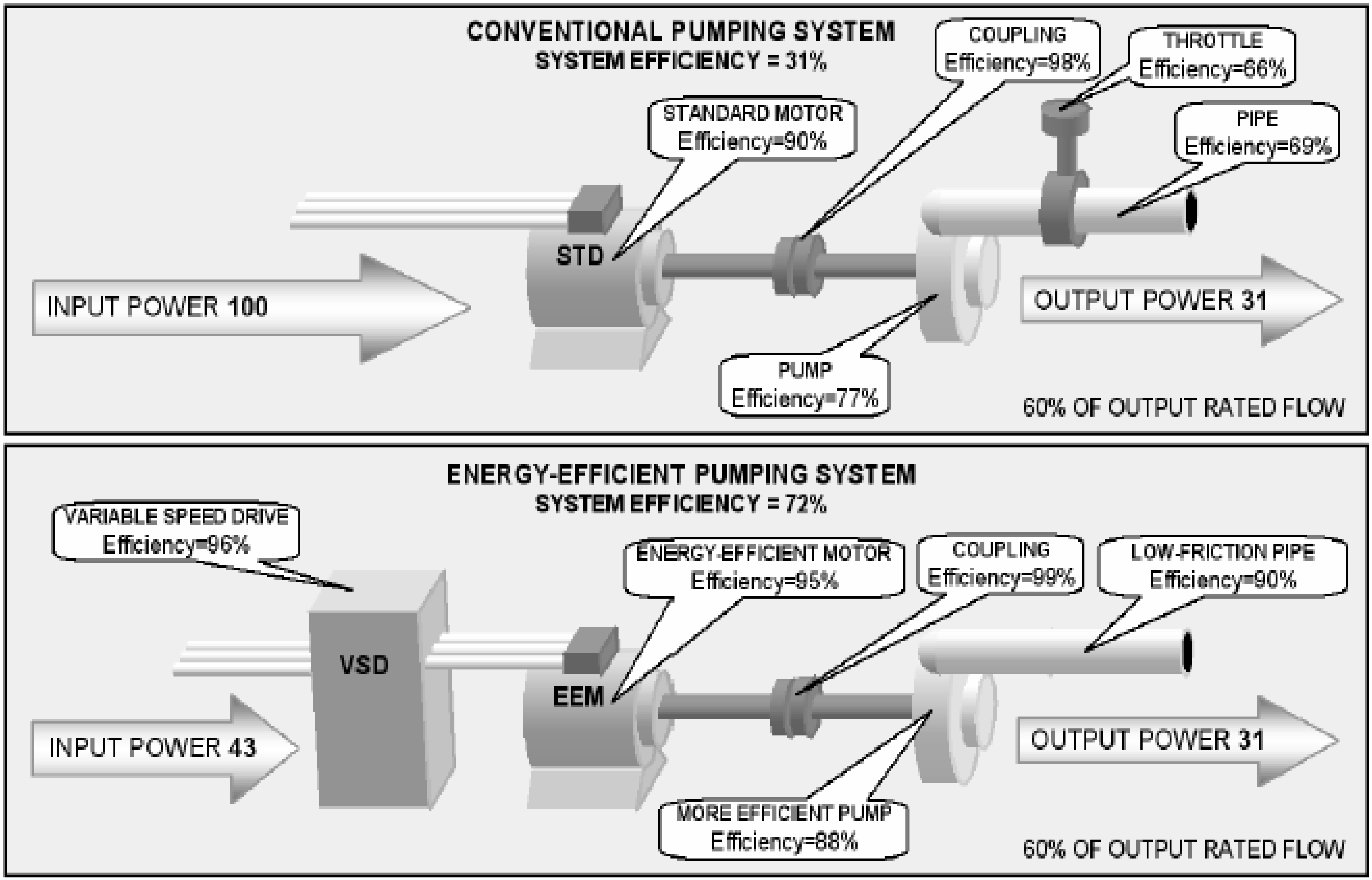
-Premium efficient motors may be considered for applications with a very large number of operating hours.

- However in a typical motor system, electric motors can only tap about 10% of the available savings potential. Even so, energy efficient motors are a first step which can start focusing attention in the motor systems.

- There is a need to consider the efficiency of the whole motor systems, in which a much higher savings potential is normally available (typically 25-30%).

Electric Motor System – Key Factors:

-Power quality;
-Motor controller (VSDs);
-Motor selection;
-Transmission ;
-End-use device (e.g. Pump, fan, etc)
-System and design
-Type of process
-Maintenance practices


CONVENTIONAL PUMPING SYSTEM
SYSTEM EFFICIENCY = 31%
COUPLING
Efficiency=98%
THROTTLE
Efficiency=66%
STANDARD MOTOR
Efficiency=90%
PIPE
Efficiency=69%
STD
INPUT POWER 100
OUTPUT POWER 31
PUMP
Efficiency=77%
60% OF OUTPUT RATED FLOW
ENERGY-EFFICIENT PUMPING SYSTEM
SYSTEM EFFICIENCY = 72%
VARIABLE SPEED DRIVE
Efficiency=96%
ENERGY-EFFICIENT MOTOR
Efficiency=95%
COUPLING
Efficiency=99%
LOW-FRICTION PIPE
Efficiency=90%
VSD
EEM
INPUT POWER 43
OUTPUT POWER 31
MORE EFFICIENT PUMP
Efficiency=88%
60% OF OUTPUT RATED FLOW

Local infrastructure impacts (energy, water, telecom, physical distribution, etc.)

-High efficiency motors not only lead to electricity savings, but also to similar demand savings.

-Therefore, this demand reduction translates into additional economic benefits since there is less need to invest in the expansion to the power system infrastructure (generation, transmission and distribution).

-Additionally there will be a small reduction in the transmission and distribution losses both in the network and inside the industrial plants.

Product definition : Electric motors (1-150 kW)

▪Number of Phases - AC Motors

- 3 PHASE AC motors largely dominate integral hp market;
  - –Single phase motors represent a small part of the electricity consumption in that power range;

▪General purpose Induction motors and special motors

- –General purpose Induction motors have by far the large sales and energy consumption;
- –The integration of special motors (flameproof, explosion proof E.g. IEEE 841, high humidity applications) should be questioned to the stakeholders) ;

▪Number of poles: 2;4 and 6 (Note Aus/NZ also consider 8 poles)

▪Voltage 400 V +-XX% Tolerance

▪Single-speed

▪Continuous duty

Product Definition

-Power range

1–150 kW is quoted in the terms of reference, but a lower bound of 0.75 kW and an upper bound such as 200 kW is suggested for discusssion to take into account standard power sizes and market sales in both power boundaries.

Definition of Basecase for the Products under consideration

–Selection of average EU representative model(s) or construction of average EU model(s) characteristics from several important product-subcategories in the product group.

-Number of Models
-Power/Frame Size
-Number of Poles

Environmental Analysis

The the following additional data is required to perform the environmental analysis:

1- Production Phase

- Bill of Materials (BOMs), including packaging;
- Manufacturing processes, including emissions;
- Proportion of scrap raw materials produced;
- Volume and weight of the packaged product.

2 - Distribution Phase

Volume and weight of the packaged product.

3 - In Use Phase

- Product lifetime;
- Lifetime energy consumption according to both test standards and the real-life situation;
- Repairs (parts, cost and eco-impact of personnel involved, eco-impact of affected production processes);
- Any product specific direct emissions.

4 - End of life phase

- Proportions close-loop recycled, re-used, sent to landfill.

5 - Technical Analysis of Best Available Technology (BAT)

- State of the art in applied research of the product (prototype level);
- State of the art at component level (prototype, test and field trial level);
- State of the art of best existing production technology globally (extra-EU).

Improvement potential - design options:

•Their monetary costs (extra production cost*multiplier = end-use price increase) and – if any – benefits (lower operating expense)

•Their environmental benefits and – if any – adverse environmental trade-offs.

•Ranking of options according to Life Cycle Costs/Payback Period and identification of point of LLCC, with its environmental improvement potential.

•Assessment of (cluster of) options with the highest absolute environmental saving potential: the so-called Best Available Technology BAT, with its environmental improvement potential.

With reference to the basecase model(s), the MEEUP methodology to calculate the eco-impact and lifecycle cost difference of the improved design options.

Policy, impact and sensitivity analysis

•Policy and scenario analyses

•Impact analysis industry and consumers

•Sensitivity analysis; test of the robustness of the “significant environmental aspects”, varying base assumptions.

While this project is explicitly not about defining policies, it will look at the impact of any changes in behaviour that might result from any EC legislation or voluntary actions.