Eco-sheet

15 kW induction motor – impact of efficiency increase varies according to electricity mixes

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This eco-sheet has been produced by Leonardo ENERGY in the context of its project 'Efficiency and ecodesign'. It aims to demonstrate and quantify the environmental benefits of high efficiency electrical equipment.

The objective of this case study is to analyse the effects of improving the efficiency of a 15kW induction motor in various countries with different energy mixes. The results show that an improvement of efficiency has higher environmental implications in countries with an electricity generation based on fossil fuels rather than renewable energy sources or nuclear.

The case study was produced using the Eco-design Toolbox models, owned by the European Copper Institute.

1 Product description and typical application

The following is an environmental product declaration for two types of 15 kW low-voltage induction motors, operating a motor driven system. Typical applications are water pumping, compressed air, or ventilation. The two designs that are analysed correspond to the efficiency classes Eff1 and Eff2.

2 Scope of the LCA

The declared units for the LCA are the production phase, the utilization phase and the recycling phase. All LCA data were taken from the GaBi4 database. The modelling and the inventory data (specifically regarding data quality aspects) were performed in accordance with ISO 14040 series as far as applicable.

2.1 Manufacturing

The manufacturing phase covers the most significant materials, cf table 1:

Material	Eff 2 motor	Eff 1 motor
Aluminium	3.1	3.3
Copper	8.3	10.3
Electrical steel	72.4	104

Table 1 – Bill of materials for the motor types (in kg) [SAVE, 1999]

2.2 Utilization

For the utilization phase, the electricity grid mixes from the average EU25, France (predominantly Nuclear), Germany (mixed nuclear, gas and coal) and Poland (predominantly coal) were used. The grid mixes are expressed in table 2:

	EU25	France	Germany	Poland	Austria
Hard coal	21.14	4.57	23.13	56.63	11.40
Lignite	9.43	0	26.99	37.10	1.65
Nuclear	32.19	79.44	28.56	0	0
Oil	4.66	1.04	1.73	1.66	3.00
Natural gas	19.66	3.25	10.51	2.08	18.10
Hydro	11.01	11.59	4.76	2.44	64.32
Wind	1.91	0.10	4.32	0.09	1.53

Table 2 – electricity grid mixes for selected countries (% of energy source)

The losses were calculated as the environmental impact, using the following parameters:

Parameter	Eff 2	Eff 1
Rating (kW)	15	15
η (%)	89.4	91.8
Lifetime (years)	20	20
Load (%)	50	50
Operating hours (per year)	6000	6000

Table 3 – use profile for the 2 motor types

The mechanical output of the motor at the axis is considered useful work, delivering input to the driven system (compressor, fan, pump,…).

2.3 End of life

The end of life is defined by the amount of dismantled material for recycling (kg)/amount of shred material for recycling (kg). The masses of recyclable materials are calculated as environmental credits.

3 Results

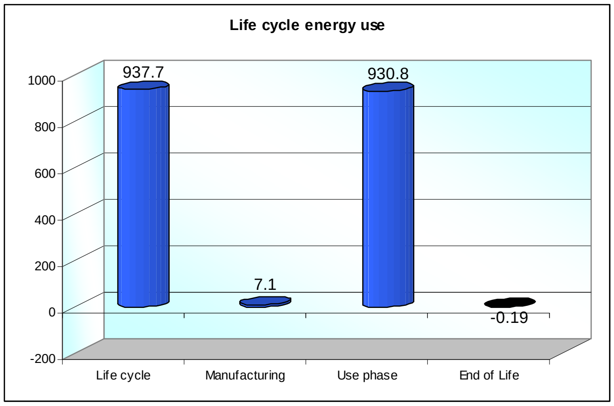
3.1 Inventory

The table bellow compiles the results obtained from the LCA modelling of the 2 types of motors using the electricity grid mixes of 4 different countries.

Parameters	Unit	EU 25		France		Germany		Poland		Austria	
		Eff 2	Eff 1	Eff 2	Eff 1	Eff 2	Eff 1	Eff 2	Eff 1	Eff 2	Eff 1
Primary energy consumption (non-RES)	GJ	1267.8	937.7	1525.5	1127	1289.8	953.3	1259.7	931.1	433.4	322.7
Primary energy consumption (RES)	GJ	76.7	57.3	67.9	50.7	60.1	44.9	16.5	12.7	366.7	270.9
Carbon dioxide	kg	59041	43717	12395	9302	75210	55598	122160	90198	33993	25256
Nitrogen Oxides	kg	105.9	78.4	23	17.2	134.2	99.2	243.3	179.6	55.6	41.3
Sulphur dioxide	kg	246.7	182.3	41.6	30.9	429.3	316.8	694.9	512.5	98.6	73.1
Acidification potential	kg SO_2-eq	321.8	237.9	58.1	43.3	524.5	387.1	867.1	639.6	138	102.4
Eutrophication potential	kg Phosphate-eq	16.9	12.6	4.05	3.02	20.3	15	35.7	26.4	9.4	6.97
Global warming pot. (100 yrs)	kg CO_2-eq	63519	47066	13371	10327	79437	58753	129960	95993	36794	27369
Ozone layer depletion pot.	kg R11-eq	0.015	0.011	0.037	0.027	0.014	0.009	0.00024	0.00019	0.00009	0.00009
Photochemical Ozone creation pot.	kg Ethene-eq	19.4	14.4	3.8	2.9	29.1	21.5	48	35.5	9.14	6.83

Table 4 – Inventory results (including environmental impact categories CML 2001) per life cycle for the 2 motor types, as produced by the Eco-design Toolbox

The Toolbox subdivides impact per life cycle phase (manufacturing, utilization and end of life). In this case, over 90% of the life cycle environmental impact is in the utilization phase. As a result, the use phase, and more specifically electricity use, dominates the life-cycle impact (see figure 1). (recycling of materials at the end of life is accounted as a credit). Hence the importance of an accurate estimate of lifetime, load and efficiency.



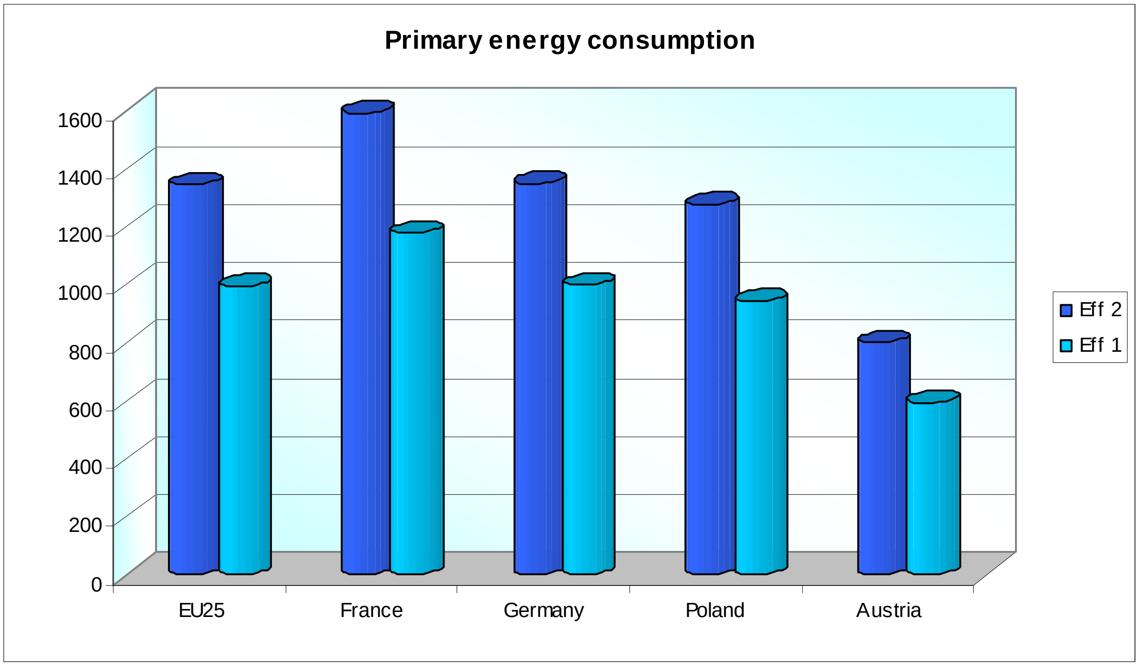


Figure 2 –Primary energy consumption (GJ) for the life cycle of the two types of motors

The environmental impact is also highly dependent on the electricity generation mix. Figure 2 shows the electricity consumption over the motor life time for a regular motor (Eff 2) compared to a highly efficient motor (Eff 1). Note the influence of the power plant efficiency; Austria (60% hydro power) using less primary energy than France (70% nuclear). Germany and Poland (based on coal and gas) show similar figures. Figure 3 shows that CO_2 emissions reduce with reduced electricity consumption (Eff1 compared to Eff2). However, the order of magnitude of CO_2 emissions substantially differs from country to country. This is due to the different sources of primary energy used to generate electricity.

France (Nuclear power) and Austria (Hydro power) have lower CO_2 emissions. Power generation using coal has higher CO_2 emissions, being the cases for Germany (23% coal and 27% lignite) and Poland (56% coal and 37% lignite)

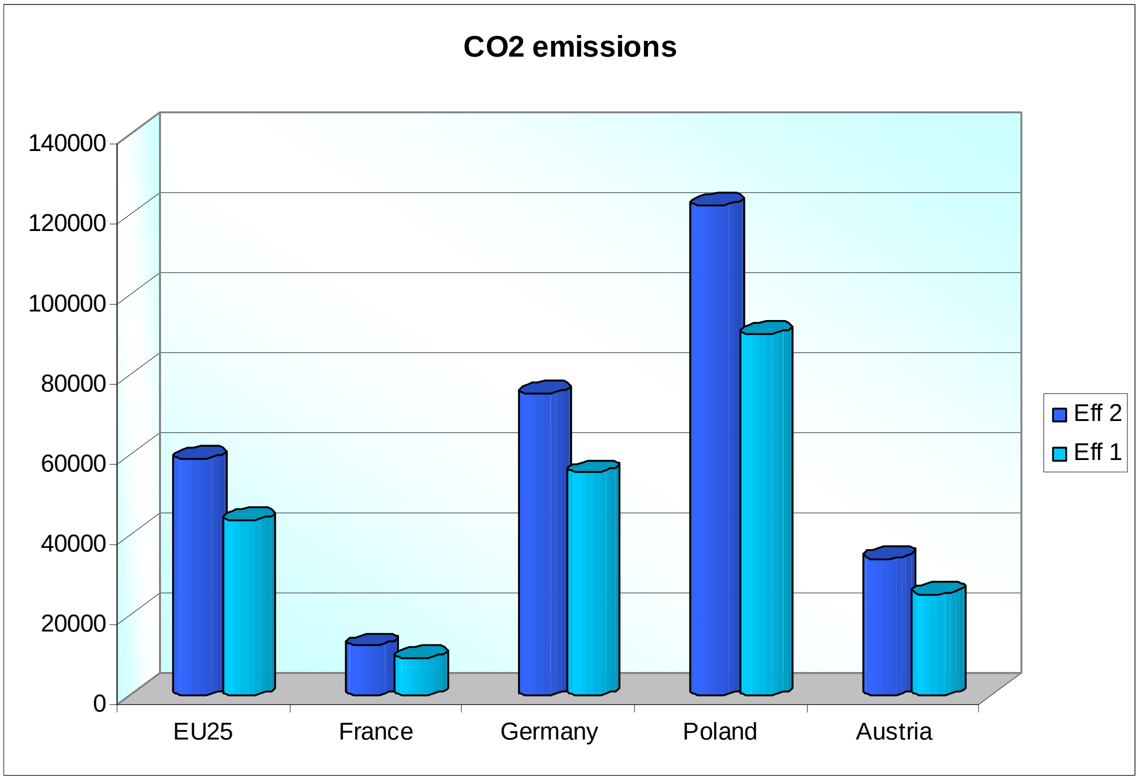


Figure 3 – CO_2 emissions (kg) for the life cycle of the two types of motors

Using the method '1' described in [PE Europe, 2005], one can calculate the environmental performance of using additional copper (Cu) to increase motor efficiency.

The following table indicates the CO_2 savings (net and per kg of copper), taking into account that increasing the efficiency of a 15kW motor from Eff 2 to Eff 1 implies additional 2 kg of copper.

	EU25	France	Germany	Poland	Austria
Reduced CO_2 emissions	15324	3093	19612	31962	8737
Reduced CO_2 emissions per kg Cu	7662	1546.5	9806	15981	4368.5

Table 5 – Reduced CO_2 emissions in kg per motor by increasing the efficiency

Each additional kg of copper used will save a different amount of CO_2 emissions according to the country and its electricity generation mix. Given that one kg of copper is responsible for 3kg of CO_{2e} emissions in production phase (for electrical applications), [Copper, 2006], the environmental payback is substantial. In Poland, one kg of copper could save more than 15 tonnes of CO_{2e} emissions when used to improve the efficiency of a motor. These environmental benefits are yet consolidated because at the end of life the kg of copper can be 100% recycled for the next application maintaining its properties.

4 References

[Copper, 2006] ECI, information site providing up to date life cycle data on its key products, www.copper-life-cycle.org

[GABI] The respective tools and models have been provided by PE Europe, Hauptstrasse 111-113, D-70771 Leinfelden-Echterdingen (Stuttgart), Germany, www.gabi-software.com

[PE Europe, 2005] PE Europe, Recommendation Paper, Options for Calculating the Long term sustainability of copper use, November 2005, available from www.leonardo-energy.org

[PSR, 2000] EPD, Product specific requirements for rotating electrical machines, May 2000, available form www.envirodec.com

[Save, 1999] European Commission – DG TREN, Study on technical – economic and cost – benefit analysis of the energy efficiency improvements in industrial three phase induction motor, 1999

[Toolbox, 2005] The original information of this environmental declaration sheet is taken from the results of the GaBi 4 i-Report referring to the ecodesign toolbox 2005 (for information, contact Sergio Ferreira, email saf@eurocopper.org)