Fraunhofer Institute Systems and Innovation Research

Dr. Peter Radgen[1], Julia Oberschmidt
Fraunhofer Institute Systems and Innovation Research,
Karlsruhe, Germany

W.T.W. Cory
Independent Consultant, Colchester, UK

EuP Lot 11:

Fans for ventilation in non residential buildings

Final Report

[1] Corresponding author: peter.radgen@isi.fraunhofer.de; phone +49/721/6809-295

Karlsruhe, April 2008

Introduction

The EuP Directive and the Preparatory Studies

The Energy Using Products (EuP) Directive (2005/32/EC) [European Commission, 2005] allows the European Commission to develop measures to reduce the eco-impact of energy using products within the EC. Products that do comply with these measures may have the CE mark attached, those which do not could ultimately be prohibited from being traded within the EC.

According to Article 1 the purpose of the EuP Directive is to establish „*a framework for the setting of Community ecodesign requirements for energy-using products with the aim of ensuring the free movement of those products within the internal market*“ and to provide „*for the setting of requirements which the energy-using products covered by implementing measures must fulfil in order for them to be placed on the market and/or put into service. It contributes to sustainable development by increasing energy efficiency and the level of protection of the environment, while at the same time increasing the security of the energy supply*“ [European Commission, 2005]. The Directive goes beyond just energy efficiency considerations, as it also considers whole life cycle costs, including production and disposal costs. It can therefore be thought of as „energy efficiency, but not at any price.”

A previous study for the Commission [VHK, 2005] designed a methodology that gives a framework for environmental impact assessment of Energy-using products with key environmental factors (energy, waste, water, emissions to air, and emissions to water). In addition to this methodology the EuP EcoReport spreadsheet model was developed, which is provided by the European Commission, linking the materials consumption in the production phase, the energy consumption in the use phase and the recycling of the product at the end of its life to the ecological impact. The preparatory studies are essential about collecting the input data to this model and analysing the outputs. This comprises economic, material and energy use data. The model requires the input of the information collected in a structured way and uses an internal database to convert material quantities from product Bill of Materials (such as grams of types of plastic, metal and other materials) into standard ecofactors.

It is not the aim of this study to question or change the methods and weighting schemes used within this model to calculate environmental impact categories. Furthermore, different environmental impact categories such as global warming or acidification potential can not be summed up to quantify the „overall“ environmental impact. The products need to be compared in each category regarding their absolute value or their value in relation to their „distance to target“. The weighting of the different ecological impact categories should be made in a more qualitative way. It should be noted however, that this weighting of different environmental factors is a policy issue which will be decided beyond the study.

The Inception Reports and the final report

The inception reports as well as the final report all follow the prescribed sequence of headings in the MEEUP methodology report[1]. To analyse the eco-impact of the products additionally the EuP EcoReport spreadsheet-model was developed, which is also used in this study[2].

In the first stage of this project the focus was on collecting the data for steps 1-3 of the MEEUP methodology. In particular we focussed on collecting and analysing market sales statistics for the different varieties of product. Due to the poor data available from official statistics we made considerable effort to obtain market data in collaboration with manufacturers and manufacturers associations. Based on this work we got better insight into the market and filled the gaps in statistical data with „best estimates".

The methodology starts by considering all types of sub-products within each of the four categories within this Lot. For fans the first level of split is into axial, centrifugal and other fans, which are then broken down even further into sub categories.

According to Article 15 of the EuP Directive [European Commission, 2005] only those EuPs shall be covered by an implementing measure or by a self-regulation measure which

- represent a significant volume of sales and trade, indicatively more than 200,000 units a year within the Community according to most recently available figures;
- have a significant environmental impact within the Community;
- present significant potential for improvement in terms of its environmental impact without entailing excessive costs, taking into account in particular:
  - the absence of other relevant Community legislation or failure of market forces to address the issue properly;
  - A wide disparity in the environmental performance of EuPs available on the market with equivalent functionality.

As for the 200,000 threshold, no data is officially available on the number of units produced for specific fan types that are in particular used in non residential buildings. Therefore we had to base our decision regarding the fan types to be analysed on key information from market research and manufacturers quoting. The number of specific fan types in use for ventilation of non residential buildings was then estimated with a model based on the statistical data available together with best guesses of required data. Therefore some iteration was needed to finally decide on the list of products to be analysed in our study.

We tried to work together with fan manufacturers to collect the eco inputs (Bill of Materials) for the products but we encountered a strong reluctance from most manufacturers to provide us with the necessary data. So to complete the BOMs for the different product categories under consideration and to derive generalised BOMs independent of in-

1 [VHK, 2005, pp. 145-153] The MEEUP methodology report can be downloaded from http://ec.europa.eu/energy/demand/legislation/doc/2005_11_28_finalreport1_en.pdf

2 The EuP EcoReport spreadsheet-model can be downloaded from http://www.ecomotors.org/files/EuP_EcoReport_v5.xls

dividual manufacturers we used the information available on materials, total weight and motor power to generate the required BOMs. Based on all the information available the specifications for each product category were derived to create the „base case reference model". This is one that can be considered representative of a whole class of products, and should represent the „typical" case that we expect will be sold in three years time. This projection is necessary so that any implementing measures relate to products available at the anticipated time of introduction.

We have re-run the eco-analysis with the best available technology (BAT) that we expect will be available at the same time, from which the European Commission can understand the eco gains that can be made from measures to improve their share of the market. Furthermore the best next (not yet available) technology (BNAT) has been analysed, which represents the long-term technical potential for improvement.

To get a deeper insight into the most important impact factors for improvements we used the EuP EcoReport spreadsheet model to undertake a sensitivity analysis of any key inputs and Framework conditions such as electricity prices that might change during the lifetime of the products.

As this is the draft final report to the Commission, in which we have taken into account stakeholder comments and/or suggestions, the results presented will be helpful regarding the EuP implementation process for the product categories under consideration.

Data accuracy

We are aware that in many cases the available data (market data, technical data, recycling data, economic data, etc.) is not highly precise but it has been cheeked against best data available. During the stakeholder process we have made suggestions or presented „best estimates", backed up with what evidence is available and invited external experts to comment on these. However, the spirit of the preparatory reports is that we should not spend excessive time debating the detail of all numbers or statistics; rather we should focus on the factors that are significant.

More about the studies

The study is about technical and market issues of products only. The study group and the European Commission are aware of the larger energy savings achievable through improving the design and control of the system to which the products in this Lot belong. However, the scope of this particular programme of work is clearly restricted to the energy using product (the fan) only. It is typically easier to handle product efficiencies rather than system efficiencies, as the latter have to be defined for each system individually. Problems may arise from the fact, that a product with a high efficiency might perform worse in a specific system environment than a standard product, if for example the selection of the required size was not made correctly. Many studies partly supported under the SAVE program have pointed to the importance of the systems [Radgen, 2002; Radgen 2001, Falkner, 2001, de Keulenaer, 2004]. However this aspect might be better covered by measures other than legislation, for example the volun-

tary MotorChallenge[3] or GreenBuilding[4] Programs launched by the European Commission

Stakeholders are also encouraged to read key background documents to this study. Of particular interest are the MEEUP background methodology [VHK, 2005] and the EuP Directive [European Commission, 2005] itself. They can be downloaded from the project web-site www.ecomotors.org.

3 www.motor-challenge.eu or http://re.jrc.ec.europa.eu/energyefficiency/motorchallenge/

4 http://re.jrc.ec.europa.eu/energyefficiency/greenbuilding/

Table of Contents

Index of Tables

Index of Figures

List of Abbreviations

BEP	Best Efficiency point
EC-Motor	Electronically commutated direct current motor (equivalent to brushless DC motor)
NACE	Nomenclature of economic activities
Prodcom	PRODuction COMmunautaire (statistical data on production in Europe)
WEEE	Waste electrical and Electronic Directive
RoHS	Directive on the Restriction of the use of certain hazardous substances in electrical and electronic equipment
LVD	Low voltage directive
SFP	Specific fan power
AMCA	Air movement and control association international, US
η	Efficiency
Q	Air flow rate
p	pressure

1 Product Definition, Standards, Legislation

Fans can be defined as „rotary bladed machines that are used to maintain a continuous flow of a gas, typically air", or more generally as appliances used to „move gases from one place to another" [Radgen, 2002]. In terms of their field of application fans can be categorized as in Figure 1. By definition, in this EuP preparatory study only fans for ventilation in non residential buildings are considered (also including industrial buildings, but not ventilation for industrial processes).

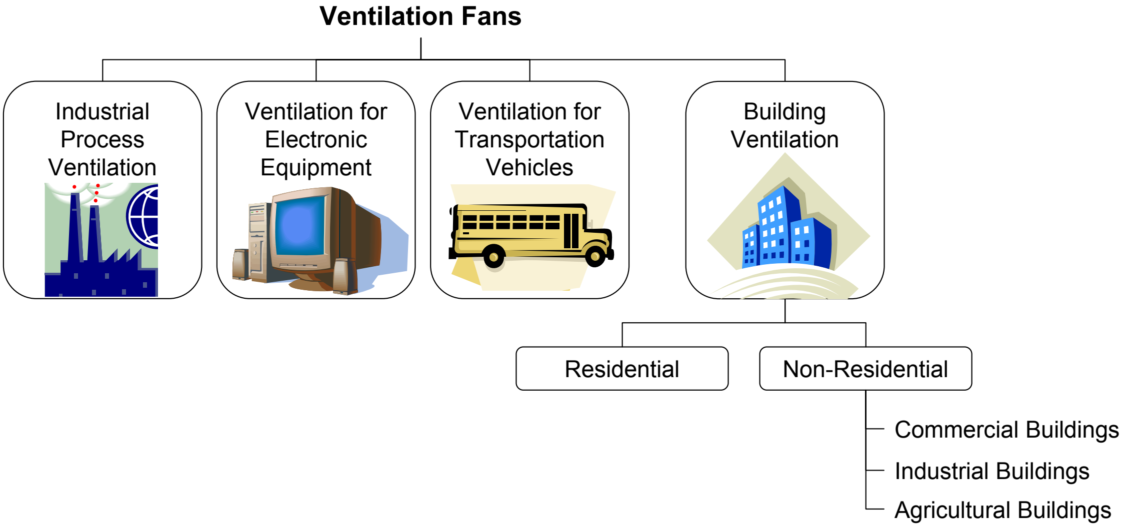


Figure 1: Categorization of fans by field of application

Non residential buildings include commercial and industrial buildings. According to [Frost & Sullivan Ltd., 2000] commercial buildings include offices, retail buildings, leisure areas (hotels, bars, fitness clubs, theatres, and the like) and institutions. Related product categories concerning fans in this context (serving different purposes) are packaged air-conditioning systems, split systems, multi-split systems, central-based air-conditioning systems, fan coils, air handling units and chillers. Some of these products are not within the scope of lot 11, but are dealt with in lot 10 (air-conditioning and ventilation in residential buildings)[5]. The product definition of lot 10 includes roof fans, extraction fans, window fans, wall fans and hood fans as products to be considered [Riviere, 2007].

Whereas lot 10 is looking on residential units, lot 11 only considers non residential applications. For a detailed list of the fan products analysed in this study (lot 11) see Table 11, page 21. It is thought likely that because the same products might be used in applications within the scope of lots 10 and 11, there may be some overlap between the two studies, i.e. some products might be used in non residential as well as in residential buildings. However, the overlap will be small; especially as in lot 11 only products with a power above 125 W are considered.

5 http://www.ecoaircon.eu/

1.1 Product category and performance assessment

Eurostat's Prodcom[6] product classification contains the following references to fans and ventilators [Eurostat, 2006b]. They fall in to two main categories non domestic and domestic products.

Table 1: Prodcom categories for non domestic products

29.23 Manufacture of non-domestic cooling and ventilation equipment	
Prodcom code	Description
29.23.20.30	Axial fans (excluding table, floor, wall, window, ceiling or roof fans with a self-contained electric motor of an output <= 125 W)
29.23.20.50	Centrifugal fans (excluding table, floor, wall, window, ceiling or roof fans with a self-contained electric motor of an output <= 125 W)
29.23.20.70	Fans (excluding table, floor, wall, ceiling or roof fans with a self-contained electric motor of an output <= 125 W, axial fans, centrifugal fans)

Table 2: Prodcom categories for domestic products

29.71 Manufacture of electric domestic appliances	
Prodcom code	Description
29.71.15.30	Table, floor, wall, window, ceiling or roof fans, with a self-contained electric motor of an output <= 125 W
29.71.15.33	Roof ventilators
29.71.15.35	Other ventilators
29.71.15.50	Ventilating or recycling hoods incorporating a fan, with a maximum horizontal side <= 120 cm

NACE/CPA category 29.71 refers to „Manufacture of electric domestic appliances„ therefore the related product categories (29.71.15.30, 29.71.15.33, 29.71.15.35 and 29.71.15.50) are not within the scope of this EuP preparatory study, which only deals with fans for non residential buildings and excludes the domestic appliances. It should however be noted, that the product categories under 29.23 also include products with a power requirement below 125 W, if they are not to be used in domestic appliances. The numbers under 29.23 therefore includes also small fans for electronic cooling applications such as Laptops, PCs and printers as well as fans which are used in the transport sector which are driven by electricity generated on board with fuels as the primary energy source.

Due to varying customer needs there are many different types of fans [Cory, 2005], also within the three relevant Prodcom categories. The range of operating pressure and mass flow required by the different applications is very wide if compared to the op-

6 „Prodcom [PRODuction COMmunautaire] is a system for the collection and dissemination of statistics on the production of manufactured goods. […] It is based on a product classification called the Prodcom List which consists of about 4500 headings relating to manufactured products. Products are detailed on an 8-digit level; 1 to 4 digits refer to the NACE classification in which producing enterprise is normally classified“ [http://epp.eurostat.ec.europa.eu/portal/page?_pageid=2594,58778937&_dad=portal&_schema=PORTAL#PROD]

erating map of a given fan. This has compelled designers to find different design solutions [Radgen, 2002].

As an example in Figure 2 the main types of fans are characterised according to the main flow path in the fan. Centrifugal fans in this picture should be among Prodcom category 29.23.20.50, axial fans among 29.23.20.30; mixed and tangential should be part of category 29.23.20.70 (at least those with a self-contained electric motor of an output > 125 W). Performances of the different fans in terms of delivery pressure, volume flow, power and efficiency vary from one design to another. It is possible, in general, to obtain the same pressure and volume flow with different fan types as long as the dimensions and rotational speed for each of them are correctly selected [Radgen, 2002]. This means that while in our eco-analysis we consider different product categories separately, any EuP implementing measures must consider the functional commonality of the different types.

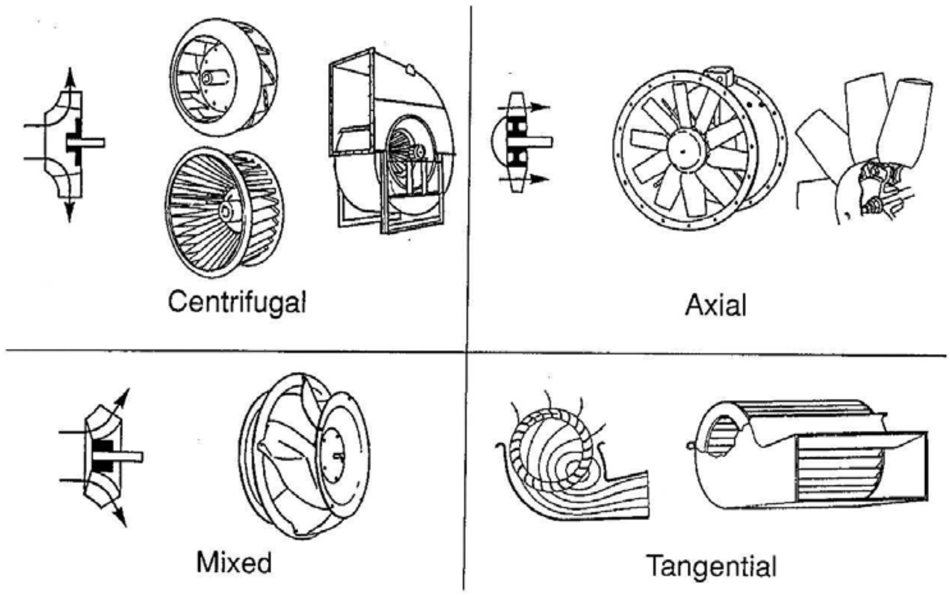


Figure 2: Classification of different types of fans [Cory, 1992]

Table 3 gives an overview about the most common variants of the above fan types and their efficiencies. The fan market is a global market, meaning that the same products are used within and outside EU-25. Differences result from the different frequencies used in different parts of the world (50 Hz vs. 60 Hz). In Appendix 1 different fan types that are used in ventilation for buildings and for other applications are described in more detail.

Table 3: Types of fans in use and typical peak efficiencies of fan wheels (Base year: 2005)

Fan type		**Fan total efficiency % (peak)**
Centrifugal	Aerofoil	88
	Backward-curved	84
	Backward-inclined	80
	Forward-inclined	70
Axial	Vane-axial	85
	Tube-axial	75
	Propeller	55
Mixed-flow		75
Tangential		25

Note: The overall efficiency of a fan product will be considerably less due to losses in transmissions, motors and control. The fan may also be selected at a duty point other than that for its peak efficiency, in the interest of cost, size, outlet velocity, noise etc.

1.1.1 Fan components

A fan consists of a bladed rotor whose shape may vary according to fan type, housed in a casing. The rotor is connected e.g. through a shaft to a motor (nearly all types of fans for air conditioning and ventilation are driven by electric motors) and it can be preceded or followed by a stationary blade row. The shape of inlet and outlet ducts is also very important and their shapes will depend on the application and on fan type.

1.1.1.1 Axial fans

The main components of an axial fan are the impeller, the blade, the hub, the motor and the housing (Figure 3). There are different options for direction of rotation and motor position for axial fans, as shown in Table 4. The labels shown in Table 4 are commonly used when labelling fans.

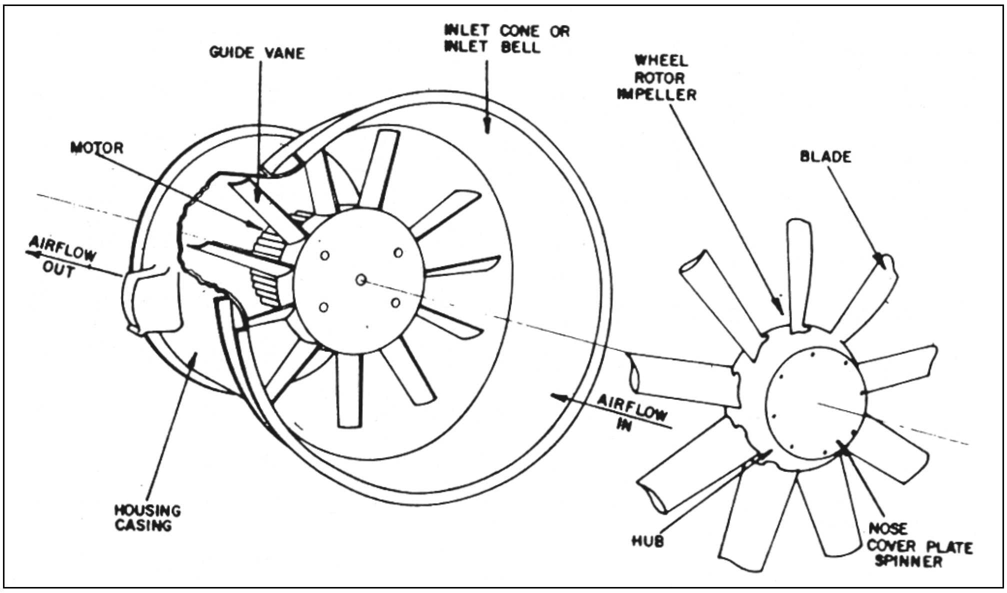
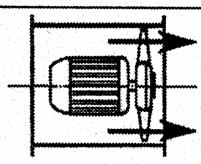
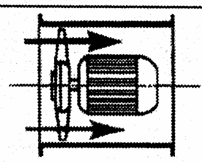
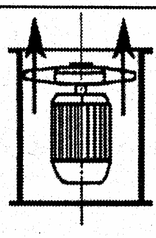
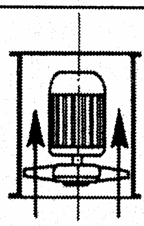
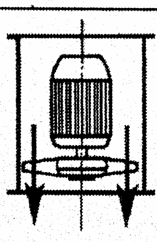
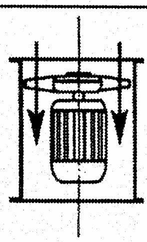


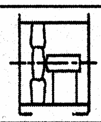
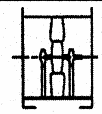
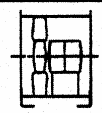
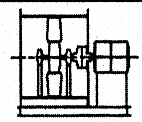
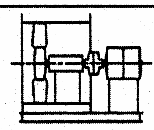
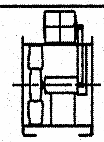
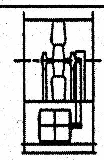
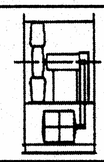
Figure 3: Components of an axial fan [ASHRAE, 1988]

Table 4: Motor Position for axial fans [Cory, 2005]

		A Motor upstream	B Motor downstream
Horizontal axis		 A	 B
Vertical axis	U Upward discharge	 AU	 BU
	D Downward discharge	 AD	 BD

There are also different possibilities that can be used to couple the motor with the fan. Table 5 shows the different options for connecting the motor to the fan.

Table 5: Axial fans – different options for coupling the drive and the fan [Cory, 2005]

Arrangement No.	Description	Motor position (see Figure 9.4)	Outline drawing
1	For belt drive. Impeller overhung on shaft running in 2 bearings, suitably supported.	—	
3	For belt drive. Impeller overhung on shaft running between bearings and supported by fan housing.	—	
4	For direct drive. Impeller overhung on driving motor shaft. No bearings on fan. Driving motor base-mounted or integrally direct-connected.	—	
7	For coupling drive. Generally as arrangement 3 but with a base for the driving motor.	—	
8	For coupling drive. Generally as arrangement 1 plus an extended base for the driving motor.	—	
9	For belt drive. Generally as arrangement 1 but with a driving motor outside and supported by the fan casing.	—	
11	For belt drive. Generally as arrangement 3 but with fan and driving motor outside and supported by a common base frame	W or Z (very rarely X or Y)	
12	For belt drive. Generally as arrangement 1 plus an extended base for the driving motor.	W or Z (very rarely X or Y)	

1.1.1.2 Centrifugal fans

The main components of a centrifugal fan are the inlet cone, the blades, the impeller, and the scroll (Figure 4) [Radgen, 2002]. As for axial fans also for centrifugal fans there are different options to couple the drive with the fan as can be seen in Table 6.

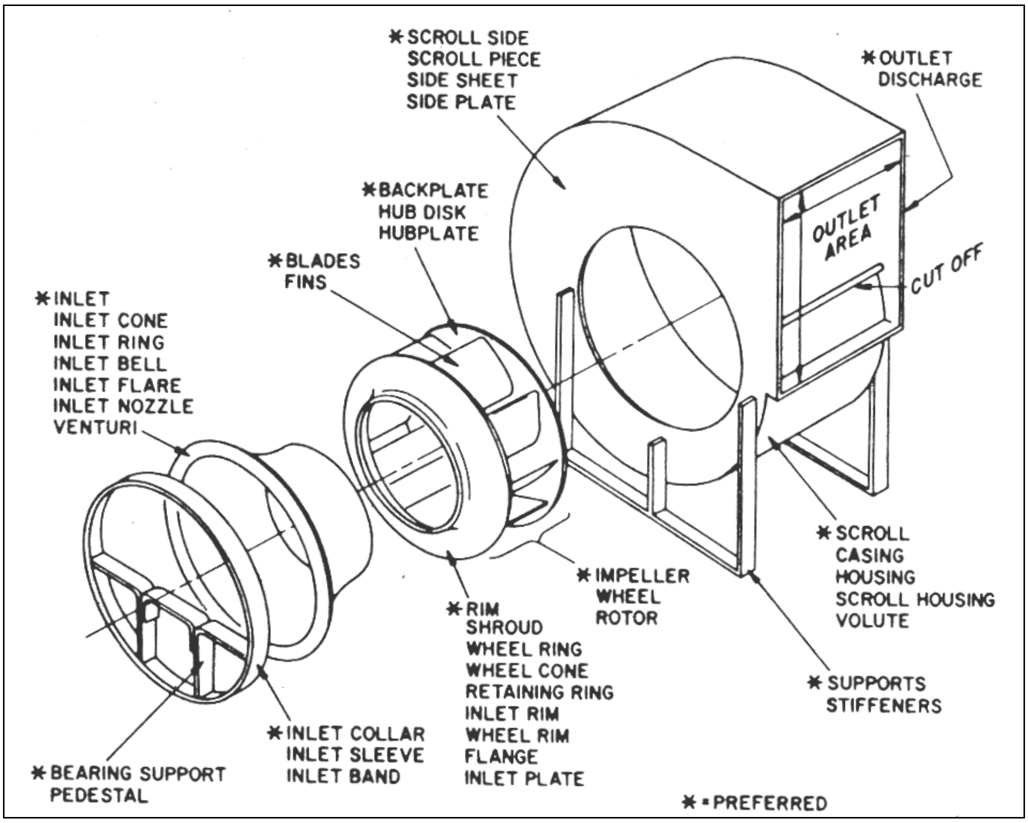


Figure 4: Components of a centrifugal fan [ASHRAE, 1988]

Table 6: Centrifugal fans – different options for coupling the drive and the fan [Cory, 2005]

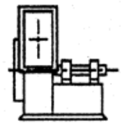
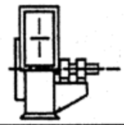
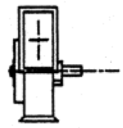
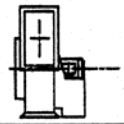
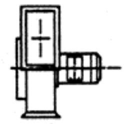
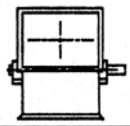
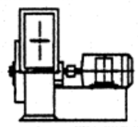
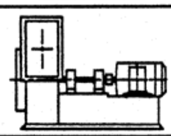
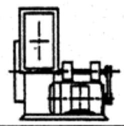
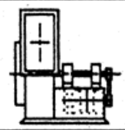
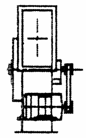
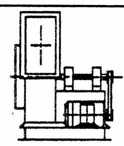
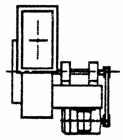
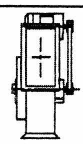
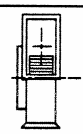
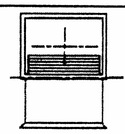
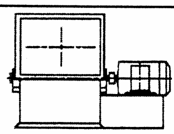
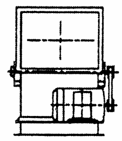
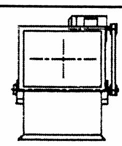
Arrangement No.	Description	Motor position (see Figure 9.4)	Outline drawing
1	Single-inlet fan for belt drive. Impeller overhung on shaft running in 2 plummer block bearings supported by a pedestal.	–	
2	Single-inlet fan for belt drive. Impeller overhung on shaft running in bearings supported by a bracket attached to the fan casing.	–	
3	Single-inlet fan for belt drive. Impeller mounted on shaft running in bearings on each side of casing and supported by the fan casing.	–	
4	Single-inlet fan for direct drive. Impeller overhung on motor shaft. No bearings on fan. Motor supported by base.	–	
5	Single-inlet fan for direct drive. Impeller overhung on motor shaft. No bearings on fan. Motor attached to casing side by its flanged end-shield.	–	
6	Double-inlet fan for belt drive. Impeller mounted on shaft running in bearings on each side of casing and supported by the fan casing.	–	
7	Single-inlet fan for coupling drive. Generally as arrangement 3 but with a base for the driving motor.	–	
8	Single-inlet fan for coupling drive. Generally as arrangement 1 plus an extended base for the driving motor.	–	
9	Single-inlet fan for coupling drive. Generally as arrangement 1 but with the motor mounted on the outside of the bearing pedestal.	W or Z	
10	Single-inlet fan for belt drive. Generally as arrangement 1 but with the drive motor inside the bearing pedestal.	–	

Table 6 (continuation)

Arrangement No.	Description	Motor position (see Figure 9.4)	Outline drawing
11	Single-inlet fan for belt drive. Generally as arrangement 3 but with the fan and motor supported by a common base frame.	W or Z (very rarely X or Y)	
12	Single-inlet fan for belt drive. Generally as arrangement 1 but with the fan and motor supported by a common base frame.	W or Z (very rarely X or Y)	
13	Single-inlet fan for belt drive. Generally as arrangement 1 but with the motor fixed underneath the bearing pedestal.	—	
14	Single-inlet fan for belt drive. Generally as arrangement 3 but with the motor supported by the fan scroll.	—	
15	Single-inlet fan for direct drive. Driving motor in-set within impeller and fan casing.	—	
16	Double-inlet fan for direct drive. Driving motor in-set within impeller and fan casing.	—	
17	Double-inlet fan for coupling drive. Generally as arrangement 6 but with a base for the driving motor.	—	
18	Double-inlet fan for belt drive. Generally as arrangement 6 but with a fan and motor supported by common base frame.	W or Z (very rarely X or Y)	
19	Double-inlet fan for belt drive. Generally as arrangement 6 but with the motor supported by the fan scroll.	—	

NOTE Arrangements 1, 3, 6, 7, 8 and 17 may also be provided with the bearings mounted on pedestals for base set independent of the fan housing.

1.1.2 Integrated fan/motor

Article 2 of the EuP Directive defines an „Energy-using product“ and „components and sub-assemblies“ as follows [European Commission, 2005]:

> *„1. ‘**Energy-using product**’ or ‘**EuP**’ means a product which, once placed on the market and/or put into service, is **dependent on energy input** (electricity, fossil fuels and renewable energy sources) to work as intended, or a product for the generation, transfer and measurement of such energy, **including parts dependent on energy input and intended to be incorporated into an EuP** covered by this Directive which are **placed on the market and/or put into service as individual parts for end-users** and of which the environmental performance can be assessed independently;“*
>
> *„2. ‘**Components and sub-assemblies**’ means parts intended to be **incorporated** into EuPs, and which are **not placed on the market and/or put into service as individual parts for end-users** or the environmental performance of **which cannot be assessed independently**;“*

For centrifugal fans, especially with higher power requirements, the motor is often coupled to the fan wheel by a transmission system (e.g. a belt drive) in such a way, that it might be in principle possible to separate the fan from the motor. In this case it could make sense to analyse the fan wheel alone. However for axial fans the fan wheel is typically directly mounted on the motor shaft, or the fan and motor are fully integrated (e.g. Figure 5 and Figure 6). In these cases it is impractical to analyse the motor and the fan separately and the EuP to be considered is the fan including the incorporated motor.

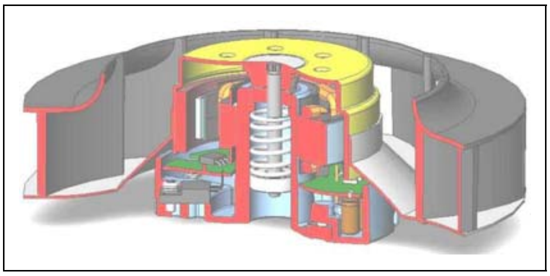


Figure 5: Backward curved centrifugal fan with integrated EC motor [Lelkes, 2005]

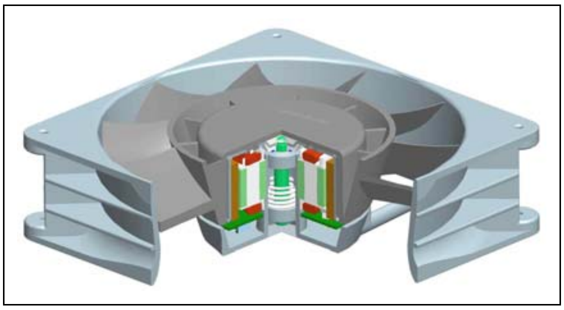


Figure 6: Compact mixed-flow fan with integrated external rotor motor [Lelkes, 2005]

Highly integrated products are getting more and more important in the market for non residential building ventilation. It is therefore necessary to include them in the analysis. The typical integrated AC motor is the so called „inside out” motor and may also have an integrated speed control. However the same functionality can be achieved by a non integrated fan product with a drive made up of transmission (e.g. flange, V-belt, flat belt, gear box), motor (mainly AC) and sometimes speed controller. Both types of product, integrated and non-integrated, have the same function: to move a specified volume of air with a specified pressure increase.

Furthermore, most of the motors used to drive the fans typically do not fall into the category of standard AC motors as analysed in the motor study in Lot 11. Inside out motors, Brushless DC motors (EC-motors), or individually designed AC motors for fans which make up the largest share of the fan drives are therefore not covered by the motors part of the study. Furthermore those special fan motors are not covered by any of the commonly known motor standards on efficiency or other issues.

In any case the **product „placed on the market“ is typically the fan including the motor**. The market for those products can be either the OEM market or the final consumer market, where the EuP Directive covers products for both of these markets. Regardless of which market they serve, integrated and non-integrated products need to be compared with each other in view of the EuP Directive as they compete on the market to be used in the same application. In the case of non-integrated products fan and motor might sometimes be sold separately. However, in most cases fans are sold by the fan manufacturer together with the motor or fan manufacturers do even produce the motor themselves and therefore the product placed on the market is still the complete fan plus motor unit.[7] Furthermore the EuP spreadsheet model for analysis of the use phase of the product requires the electricity used by the product as an input. Therefore the boundaries for the energy-using product fan have been defined as in Figure 7.

As in most cases fan manufacturers are selling combined products or are selling the motor together with the fan, for the EuP analysis real data can be retrieved for the fan wheel as well as motor and transmission efficiencies or for the efficiency of the fan product as a whole. If in some cases the motor and transmission to be used might not be sold together with the fan assumptions have to be made for analysis of the complete product as defined in Figure 7. Based on our own analysis of the products and the market we recommend using the methodology summarized in Figure 8 in those cases, where the motor/drive is **not** sold together with the fan (in any other case data of the „real“ product is used).

Compared to earlier versions of this approach we now exclude assumptions for flat belt and multiple V-belt drives. Even if flat belt drives are achieving much higher efficiencies (about 7 to 10 %-points higher than V-belt drives), end users will tend to use the cheaper and less efficient V-belt drives. In addition the number of belts will decrease efficiency; however this effect will be typically compensated by the increasing efficiency of the transmission with increasing power. As differences are rather small compared to other factors, the simplification of the calculation is preferred against the only minor improved preciseness. To guarantee that high efficiency belt drives are used to drive the

7 Although there is no statistical data to back-up this assertion this has been confirmed by fan manufacturers at several meetings.

fan the parts for the belt drive should be supplied at the same time as the fan. In this case the real values can be used for the calculation. Low default values are therefore leading to advantages for manufacturers who are supplying also the transmission and/or motor. The default values used for motor, transmission and controls were agreed with the stakeholders during the stakeholder meetings:

- Motor efficiency η_M to be assumed:
  - If **P_{el} > 1.1 kW** use motor efficiency η_M as required to achieve EFF2 rating.
  - If **P_{el} < 1.1 kW** calculate motor efficiency η_M by the following formula: $\eta_M = 0{,}0629*\ln(P_W) + 0{,}653$ (P_W = shaft power). This equation is based on the typical efficiencies of single phase motors with capacitor[8].
- If the fan has **direct drive**, assume transmission efficiency η_T of 100 %.
- If the fan is to be driven by a **belt drive**,
  - for **P_{el} < 1 kW** assume transmission efficiency η_T of 75 %
  - for **1 kW < P_{el} < 5 kW** assume transmission efficiency η_T of 83 %[9]
  - For **P_{el} > 5 kW** assume transmission efficiency η_T of 90 %.
- It is assumed that the decrease in belt-efficiency over life-time-of the fan is negligible.

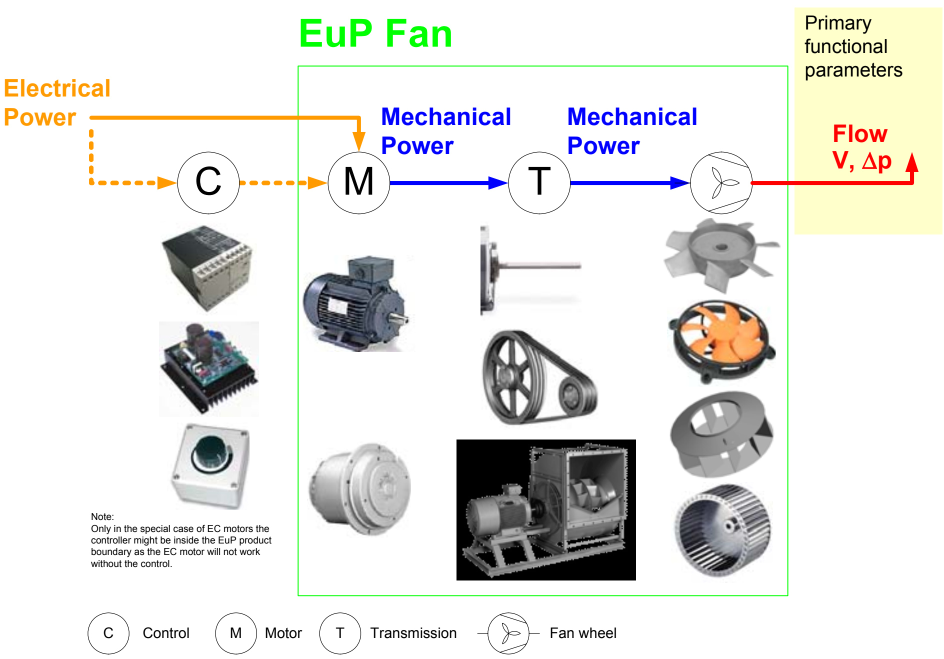


Figure 7: Product boundaries for the energy-using product fan

8 An overview of typical efficiencies of small power motors can be found in chapter 0.

9 Some values for achievable transmission efficiencies are given in [VDI 6014, Draft, 2006]

One remaining issue is then how to deal with the fan control. Control systems typically add additional losses to the system but are increasing part load efficiency. When only peak efficiencies are compared, a speed control with a frequency converter[10] or a transformer control will be of disadvantage for the product, i.e. a fan without control would have higher peak efficiency. Therefore, for those fan products including speed control an efficiency bonus is granted by multiplying the overall efficiency (fan incl. drive) by a compensation factor C_C. The proposed compensation factors are based on typical efficiencies of frequency converters and vary depending on the electrical power input of the product:

- for **P_{el} < 1 kW** assume control compensation factor C_c of 1.15
- for **1 kW < P_{el} < 5 kW** assume control compensation factor C_c of 1.11
- for **P_{el} > 5 kW** assume control compensation factor C_c of 1.04

Apart from the efficiency of the product components furthermore it is necessary to take account of the fact that in reality the components will not be matched optimally. This means that the efficiency of the fan product in use will be lower than the theoretical product efficiency (η_P) calculated by multiplying the efficiencies of the components. Therefore an additional compensation factor (C_m = 0.9) is introduced to account for losses due to suboptimal matching of components.

Based on the discussion above the flow chart in Figure 8 shows, how to calculate the overall efficiency of the fan product in the context of the EuP Directive.

10 The term frequency converter is equivalent to the terms variable frequency drive (VFD) and VSD. However the abbreviation VFD is not well known and VSD is a protected trademark for some motor driven systems. We therefore use in this study the term frequency converter.

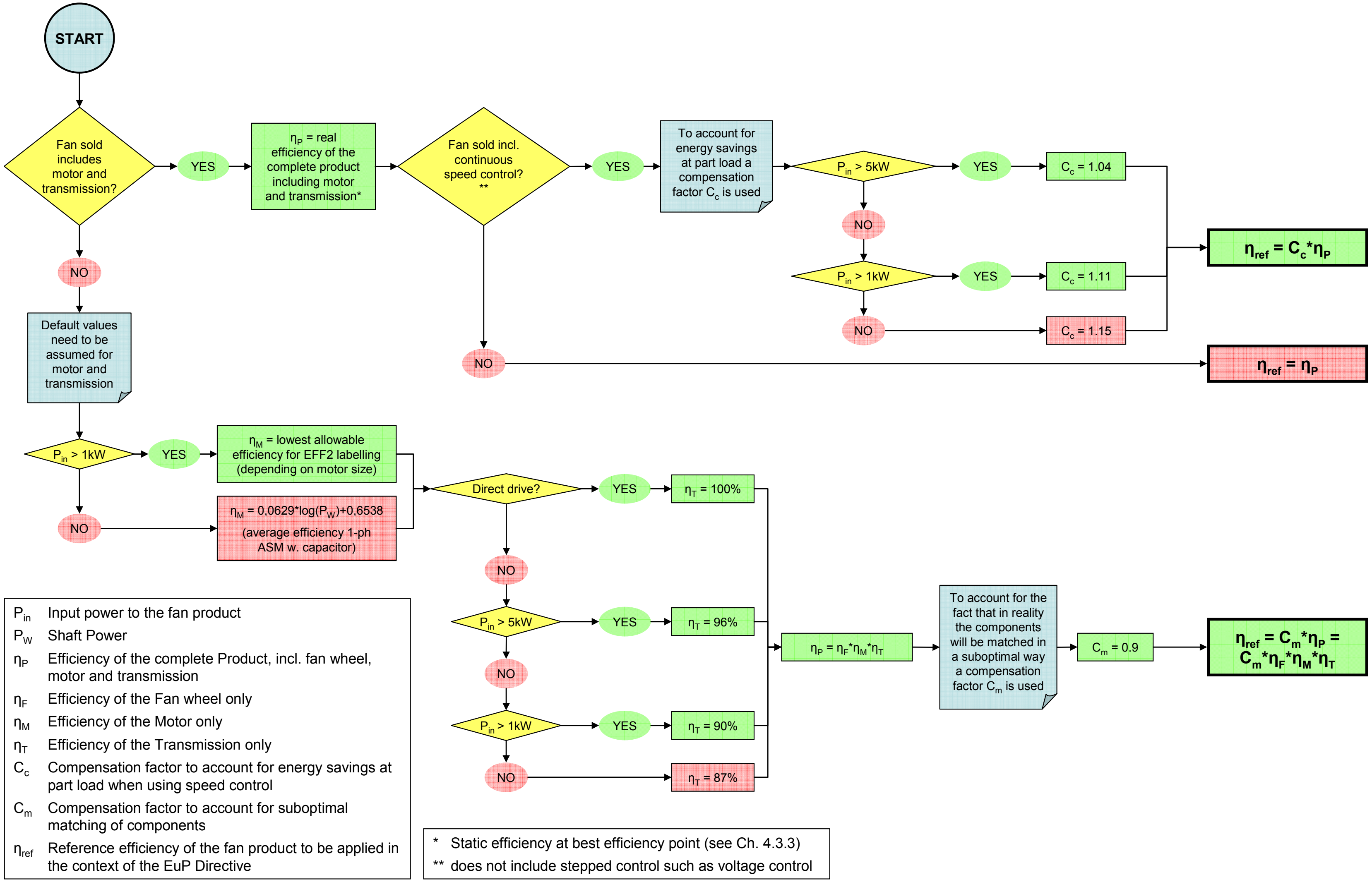


Figure 8: Flow chart for overall efficiency calculation of fan products

By using the above mentioned assumptions in any case complete fan and drive systems can be compared. The scheme defines the necessary common basis for analysis of different products sold on the market, serving to supply ventilation in non residential buildings. It should be noted, that besides the application of this rule in energy efficiency calculations the additional product components have also to be considered in the bill of materials (BOM) for these products. Therefore data from the BOM for motors as also collected within lot 11 will be used for completion of the system. However, the study on motors will only consider motors above 0.75 kW power input whereas within the fans study smaller motor sizes will also be considered. Moreover, the motor section does not include analysis of motors used specifically for fans but only considers motors of the commodity type. All of our analysis (base case, improved product, and best next available technology) will be based on a product boundary as shown in Figure 7.

Figure 9 shows a comparison of the materials used in an EFF1 average motor (3-phase induction motor) for different motor sizes. The figure shows an approximately linear decease for most of the materials. Only for electrical steel a significant decrease in specific material use can be observed. Based on this data the materials consumption for smaller motors for the analysis of the fan product can be estimated. The data collected for the AC motors for EFF1 and EFF2 motors has been fitted with a polynomial of second degree to calculate motor BOMs for sizes which are used for fans but which are handled not explicitly by the motor study. Additional information on motor BOMs can be found in Chapter 0 (Annex).

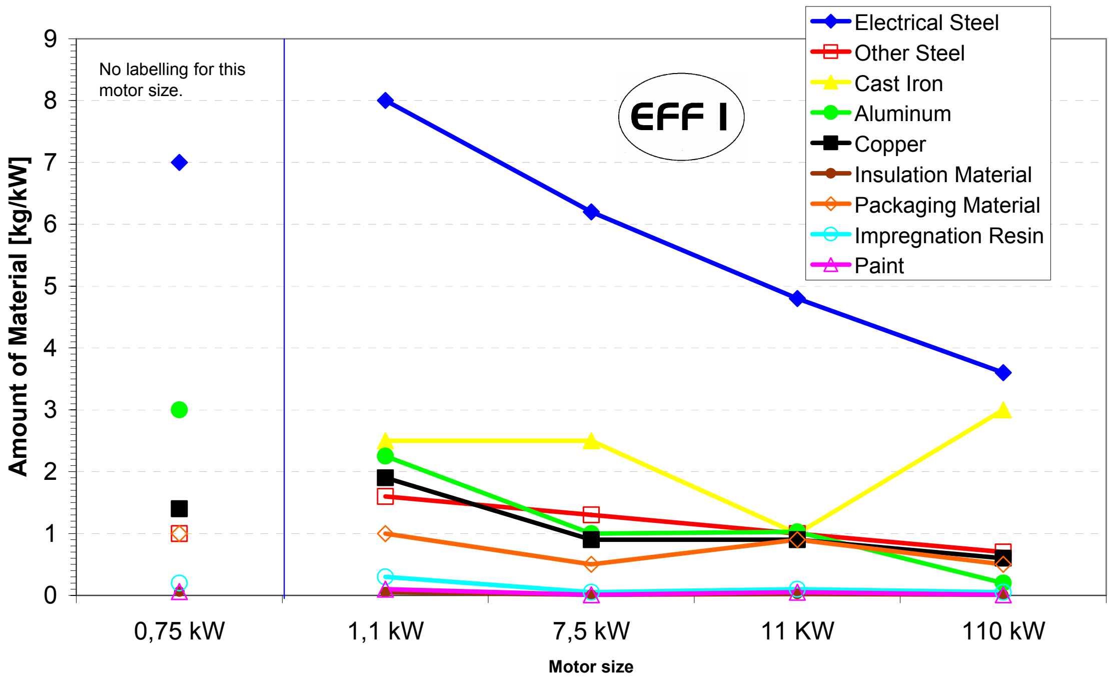


Figure 9: Material consumption for average EFF1 motors of different sizes [motor study, CEMEP, own calculations]

It has to be pointed out that the data in Figure 9 does only apply to 3-phase induction motors. Concerning the smaller 1-phase motors, these are also used very often for fans. These smaller 1-phase motors are not included in the motors part of the study.

1.1.3 Fan types for building ventilation

For building ventilation, different fan types are in use. For a better understanding of the fan use for building ventilation Figure 10 shows the different applications. The most well known products are the roof fans. These are located on the roof of the building and are connected to a ducting system to extract air from the building. In the case of factory buildings it is also possible that they are not attached to a ducting system. Roof fans are typically centrifugal but axial flow fans and sometimes also mixed flow fans are used.

The function of the air extraction fans is about the same as for roof fans but they eject the air through the walls. Their location is inside the building whereas the roof fans are located outside the building, which has implications on the materials used and the weather protection required.

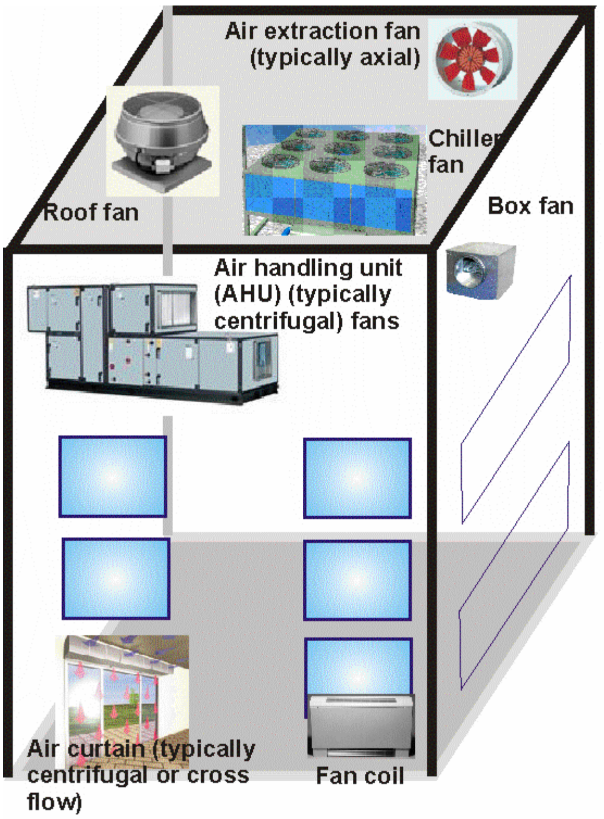


Figure 10: Fans for non residential buildings (agriculture applications are not shown)

If not only ventilation but in addition heating and air conditioning of a building are required, air handling units are applied (AHUs). AHUs are composed of different parts in one casing, including heat exchangers, filters, water evaporator, air intake and air ex-

traction fan. AHUs are connected to the air distribution system of the building. As the scope of this study is restricted to ventilation only, AHUs, which are also used for heating an air conditioning, will not be further analysed within this study. Care should be taken, however, that fan products for the OEM market which are incorporated in AHUs will be analysed and could consequently be subject to implementing measures. This means, a European manufacturer of AHUs would only be allowed to incorporate those fan products in his AHU which do comply with the EuP Directive. As long as there are no implementing measures for AHUs regarding the EuP Directive, manufacturers of AHUs outside the EU could therefore have a competitive advantage, as in their country they could also incorporate fan products that don't need the CE mark and therefore would not need to comply with the EuP Directive for being traded outside the EU (for further discussion see chapter 8.3, pp. 174 ff.).

The same applies to fans incorporated in fan coils. These are another option for central based air conditioning in combination with the central pre-treatment of air. In this case each room to be conditioned needs to be equipped with a fan coil. Fans used in fan coils are much smaller in size but are larger in numbers.

Looking at central ventilation systems, chillers and their cooling fans also need to be considered. Even if the cooling fans for the chiller are not part of the building ventilation system, their energy consumption can not be neglected.

Besides the centralised systems, decentralised air conditioning systems are used. These packaged split or multi-split air conditioning systems are common especially for the retrofitting of existing buildings with air conditioning. Split systems are typically equipped with two fans, one on the condenser and one on the evaporator side of the refrigeration cycle. In these systems the fan is generally working with free inlet and outlet.

In public buildings or shopping centres air curtains are widely used. Due to the high frequency of people entering or leaving the building the entry doors remain open during the day. Therefore air curtains are used to reduce heating and cooling losses by separating the air inside and outside the building.

Small window fans, typically with a power below 125 W are sometimes used to extract air from single rooms. However in commercial buildings the application of such smaller types of fans is limited. They are more common e.g. in private buildings and will therefore not be considered within this study.

Smoke extract fans, which are only in used in emergency cases, have in general non energy consumption as they do not run under normal conditions. Therefore purely smoke extract fans are not further considered as energy using product. On the other hands, there is some trend to combine the general ventilation duty and the smoke extract duty in one single fan product. However due to larger clearances between the different parts of the fan to achieve higher temperature resistant, the efficiency of such fans is typically much lower. As they will be used as other ventilation fans they will be not excluded from the analysis.

1.1.4 Fans for agriculture applications

The scope of the study is to analyse fans for ventilation in non residential buildings. This also includes agricultural buildings, where fans are mainly used in three different applications [Franke, 2005; Wilcke/Morey, 1999; Mekikdjan/Sévila, 1990]:

- for temperature and humidity control in livestock buildings such as barns, poultry houses, pig and cow farms, by providing fresh clean air or mixing the air in the building (To some extend also used for removal of dust, chemicals and other gases to protect livestock from illnesses and disease).
- circulation of air in greenhouses
- drying of various crops that are hold in storage buildings and silos (e.g. potatoes)

Agriculture fans are typically designed for a lifetime of 30.000 – 40.000 hours. The drive type is usually direct drive but it can also be belt driven. The blades and the impeller are often die-cast in aluminium alloy, the nozzles are typically manufactured in hot-dip galvanized thin sheet steel, and the frame, if the fan is of box type, can also be galvanised or manufactured from aluminium.

Agriculture fans are usually axial flow fans with the number of blades ranging from 3 to 9, if the fan has only one column. The number of blades mainly depends on the rotational speed of the motor. The higher the speed the smaller is the number of blades. A similar relationship can be observed between size and speed, as the speed increases typically when the diameter decreases. Figure 11 shows typical examples of fan use in agriculture. In some cases fans are used for re-circulating air, e.g. in barns (left of Figure 11); in other cases fans are used for air extraction/supply. The system to be used depends on the needs of the user and building layout.

Figure 11: Fan use for agriculture applications [Heidenreich, n.d.]

Table 7 shows the relationship between speed, fan diameter and the specific fan power. Specific fan power (SFP) is the common indicator for energy efficiency of fans in agricultural applications.

Table 7: Typical data for agriculture fans [DLG, n.d.]

Speed	**number of revolutions**	**fan diameter**	**specific fan power (SFP)**
	[rpm]	**[mm]**	**[W/(1000m^3/h)]**
low-speed	300 – 700	800 – 1250	25 – 35
middle-speed	800 – 1000	600 – 900	30 – 40
high – speed	> 1200	500 – 700	40 – 45

For many agriculture applications, the required air flow rate is determined by the flow rate required per agricultural product / animal, which is stored / held in the building to be ventilated. In livestock buildings it is therefore expressed as m^3/(h*animal), in storage buildings as m^3/(h*t) and in silos as m^3/(h*m^2) in greenhouses. The required airflow is mainly determined by the temperature, therefore the air flow requirements vary significantly between seasons.

Table 8 shows the additional volume flow per cow required to compensate for the heat intake by a non insulated roof of a shed with a roof size of 10 m^2. The higher the roof temperature is the higher the heat intake and therefore the ventilation requirement.

As the heat and humidity is mainly coming from the life stock, the ventilation requirements are typically derived from the number of feedstock. Table 9 as an example shows the suggested number of livestock per fan type depending on the fan diameter, the air volume and the weight of the animals in a pig farm.

As already mentioned, in agriculture applications in Europe energy efficiency is typically expressed as the electrical power consumed per unit of air flow achieved (SFP – Specific Fan Power). As a general rule the efficiency of a fan increases (i.e. SFP decreases) with the fan diameter.

Table 10 give values for typical efficiencies for agriculture fans. High values for standard and high efficiency of agriculture fans related to fan diameter are shown.

Table 8: Increased ventilation rate required based on heat intake from non insulated roof for a cow stable [Heidenreich, n.d.]

Temperature on the roof (non insulated roof) [°C]	35	40	45	50	55	60
Heat intake for a roof area of 10m² required per cow [W/cow]	165	330	495	660	825	990
Additional air flow required [(m³/h)/cow]	174	348	521	695	869	1043

Table 9: Air flow rate for stable ventilation for different live stock for static pressure of 50 kPa [Hydor, 2006]

Fan diameter (mm)	450	500	630
Supply (number of phases)	Single / three	Single / three	Single / three
Air flow (m³/h)	5,120	8,140	10,600
Suggested number of livestock per fan			
Early Weaners (23 kg/Weaner)	118	188	245
Porky pigs (68 kg/porky pig)	40	63	83
Heavy hogs (91 kg/heavy hogs)	30	48	62
Ventilation rate required is 1.88 $(m^3/h)/kg_{Livestock}$			

Table 10: Relation between fan diameter and efficiency [Sanford, 2004; own calculation]

Fan diameter	**Efficiency range** [W/(1000 m³/h)]	**High efficiency** [W/(1000 m³/h)]
24 " (609,6 mm)	30.34 to 67.65	< 36.79
36" (914.4 mm)	24.84 to 46.35	< 29.43
48" (1219.2 mm)	21.80 to 43.60	< 29.43
50" to 54' (1270 to 1371.6 mm)	17.84 to 36.56	< 25.59

It has also to be stressed, that fans used in agriculture applications are exposed to vast amounts of dust, moisture and other gases such as ammonia. They accumulate dirt on blades, louvers, and shrouds. Even if dirt on fan blades has typically only a small effect on fan performance, dirt on louvers and guards can reduce airflow by as much as 30 to 40 %. Fan louvers and guards should therefore be cleaned regularly and lubricated (using graphite to prevent dirt accumulation) to prevent significant efficiency losses. Louvers should be removed where fans are running continuously to avoid the pressure drop over the louver, but guards need typically to remain in place to prevent personal or animal injury.

1.1.5 Product categorization for this study

Based on our own analysis and previous consultations with stakeholders eight product categories were defined [Report Cycle 2]: four different types of axial flow fans, five different types of centrifugal flow fans and one other type of fan (roof fans). However, based on experiences with data collection and standardization of the data to be used in such a way as needed for the EuP analysis methodology, a new categorization of fan products was elaborated. The final categorization (Table 11) is supposed to reflect the different applications in the market and to suit the needs of the EuP methodology. Following the Prodcom product categorisation (Table 1, page 2) for each category shown in Table 11 only those products will be analysed with a power output >125W, as any smaller building ventilation fans are assumed to be applied only in the residential sector. Figure 12 shows examples for the categories selected.

Table 11: Definition of product categories for ventilation fans (non-residential buildings)

Product Category	Direction of flow	Type	Typical Sizes [mm]	Example
1	Axial	<= 300 Pa (static pressure)	200 - 1,400	 Source: Helios
2		> 300 Pa (static pressure)	200 - 1,400	
3	Centrifugal	forward curved blades (with casing)	120 - 1,600	 Source: Nicotra
4		backward curved blades (no casing)	120 - 1,600	 Source: ebmpapst
5		backward curved blades (with scroll housing)	120 - 1,600	 Source: Ziehl-Abegg
6	Other	Box fans	100 - 1,000	 Source: Fläktwoods
7		Roof fans	250 - 1,000	 Source: Gebhardt
8		Cross-flow fans	60 - 120	 Source: ebmpapst

Note: Size refers to impeller diameter except for box fans where it refers to spigot size.

The different fan categories can be found in all applications, even if there might be some preference. For example, most agricultural fans are of axial type (categories 1 and 2). Centrifugal free wheels (category 4) are mainly used for air handling units. Boxed fans (category 6) are mainly used in commercial buildings. The main application of cross-flow fans (category 8) are air curtains. However, the main aim of all ventilation products is to move air, independent from the type of building; therefore the different products can not be allocated to particular building types (agricultural, commercial, industrial). Fans solely designed for smoke extraction in emergency cases or fans produced to comply with the ATEX directive (Directive 94/9/EC) are excluded from the analysis.

Some discussion has occurred as to whether the forward curved and the backward curved centrifugal fans should be separated into two distinct categories. Both are centrifugal and can in principle substitute each other, whereas the efficiency of backward curved centrifugal fans is much higher compared to the forward curved type. The main reason to keep them in separate categories is the fact, that air delivery of forward curved fans of similar impeller diameter is in general higher than for backward curved ones.

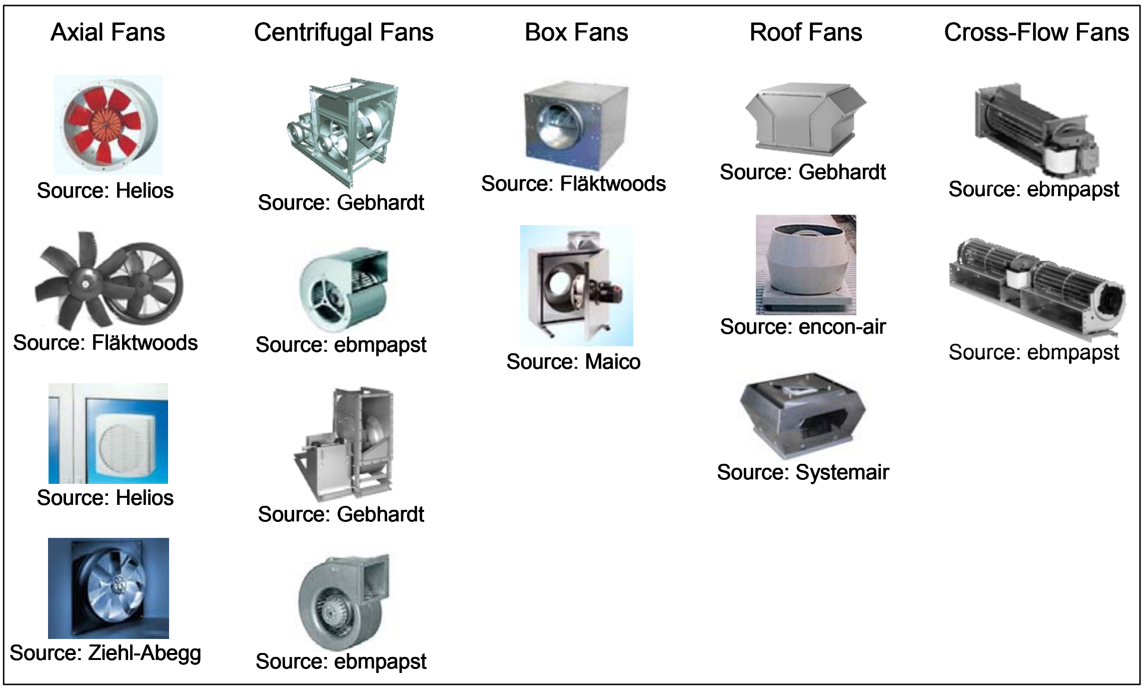


Figure 12: Examples for the fan categories to be considered.

As an example, Figure 13 shows efficiency data for one series of centrifugal fans for belt drive that includes impellers with backward as well as forward curved blades. The data shown is derived from technical data (fan performance charts) on FläktWoods' Centrimaster GX [FläktWoods, 2003]. The figure clearly shows that the efficiency of the backward curved fans is around 20 %-points (or about 40 %) higher than for forward curved fans. At the same time air delivery of the smaller forward curved impellers is about 30 to 50 % higher than for backward curved impellers of the same size. With increasing size of the impeller, the difference in airflow decreases below 10 %, i.e. the advantage of the forward curved impeller with regard to higher air flow is becoming less significant. At the same time, however, the efficiency advantage of the backward curved impeller remains fairly constant.

As the advantage of higher air delivery for forward curved fans decreases with increasing impeller size, this leads to the conclusion, that forward and backward curved centrifugal fans could be treated in the same product category with the same minimum efficiencies for larger fan sizes. Only for the small fans they might be treated in two different groups in the beginning but could be merged in the long run to one category. However, apart from air delivery, forward curved fans are also advantageous in terms of noise. Therefore, in some applications especially in the building ventilation sector

where the fans are installed within the building (e.g. fan coil units) a substitution of forward curved with backward curved fans will not be feasible.

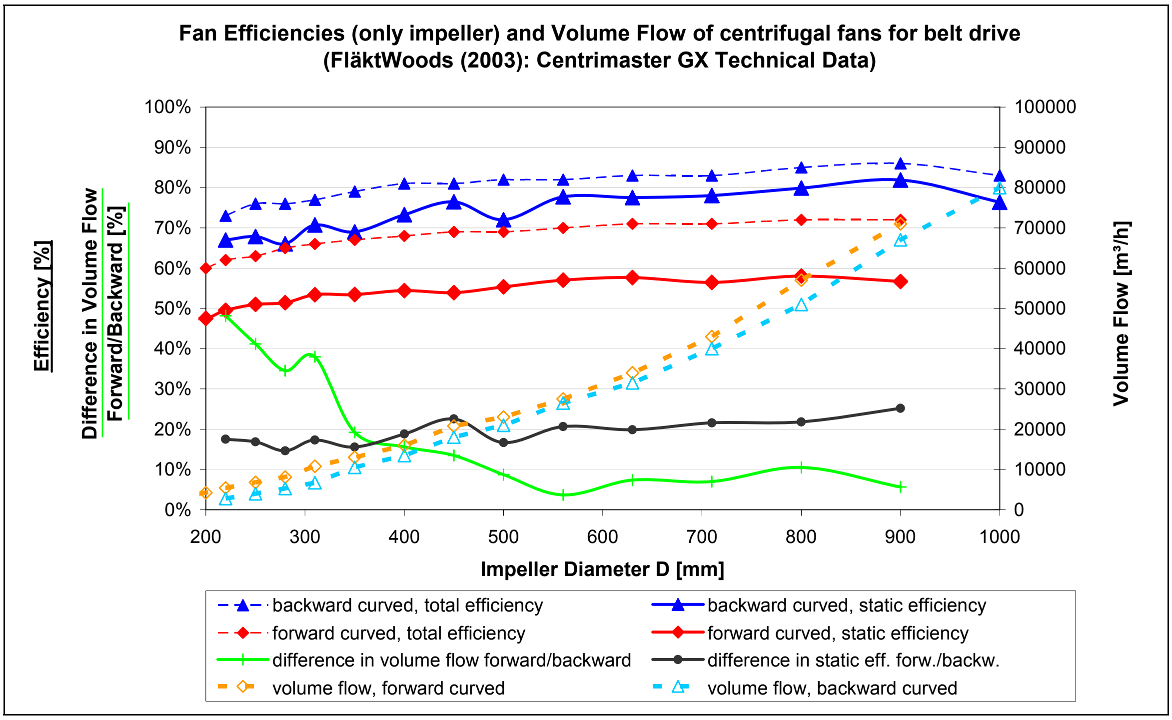


Figure 13: Efficiency and air delivery of forward and backward curved centrifugal fans [based on data from FläktWoods, 2003]

1.1.6 Definition of primary functional parameters

There are two characteristics that are considered to be the primary functional parameters of a fan:[11]

- the increase in pressure of the gaseous flow (Δp)
- The velocity of the flow i.e. air delivery (m^3/h).

The functional unit is the reference value for any fan considered, and is independent of type. It also helps to set the boundaries for comparison of different products. For the fans in this study, this may be assessed by considering the rate of air moved at a specified pressure increase (m^3/h).

1.1.7 Secondary functional parameters

Apart from the characteristics mentioned above there are a lot of other technical issues that have to be considered when selecting an appropriate fan (see also chapter 0, Annex). The most important ones are assumed to be:

11 In Appendix 2 more variables and parameters to be considered are listed.

- Diameter of the fan (m)
  The same flow and pressure increase can be achieved with fans of different sizes. The size of a fan has an impact on the flow parameters in the fan and therefore influences efficiency. Typically larger fans are more efficient.
- Volume and weight of the fan
  The weight of the fan gives an indication about the amount and type of materials used. Reduced weight will lower the amount of materials used and therefore reduce the environmental impact during production.
- Type of the fan (axial/centrifugal, backward/forward-inclined etc.)
  The efficiency of a fan depends on the shape of the blades. Forward curved centrifugal blades are much less efficient than backward curved blades, however, as already mentioned above there are differences in other secondary parameters such as size and noise.
- Type of drive and electrical supply
  To operate the fan, single phase or three phase motors can be used, either standard ones or special purpose ones. Besides AC motors, EC motor[12] are becoming increasingly important, especially at sizes below 3 kW.
- Noise level and vibration
  Noise and vibrations produced by fans can cause acceptability problems, especially in the commercial applications. If fans are installed outside there might be regulations which limit acceptable noise levels.
- Control systems
  To vary the volume flow through the fan different control systems (e.g. voltage switch, frequency control, electronic commutation, dampers, and phase controlled modulation) can be used.
- Mounting arrangements and inlet/outlet sizes.
  For possible mounting arrangement see Table 4 to Table 6.

1.2 Test Standards

There are a large number of standards that are of importance to ventilation and air conditioning in non residential buildings. The most important standards are the international ISO standards, but also European or national standards. However, most standards don't deal with efficiency but with other issues such as for example noise or vibration.

1.2.1 General ISO Standards related to fans

Some of the ISO-standards listed in the following relate to „industrial fans“. However, within ISO the term industrial fan is not only used in the context of industrial process ventilation but for all kind of fans **except those for residential ventilation**. This means that those ISO-standards referring to industrial fans do also apply to fans for ventilation in non residential buildings. Table 12 shows ISO-standards addressing general issues concerning fans.

12 An EC motor is an electronically commutated DC motor

Table 12: General ISO-Standards relevant for fans

ISO 3258:1976	Air distribution and air diffusion -- Vocabulary
ISO 3649:1980	Cleaning equipment for air or other gases -- Vocabulary
ISO 6580:2005	General-purpose industrial fans -- Circular flanges -- Dimensions
ISO 7807:1983	Air distribution -- Straight circular sheet metal ducts with a lock type spiral seam and straight rectangular sheet metal ducts -- Dimensions
ISO 13349:1999	Industrial fans -- Vocabulary and definitions of categories
ISO 13351:1996	Industrial fans -- Dimensions
ISO 14617-9:2002	Graphical symbols for diagrams -- Part 9: Pumps, compressors and fans

A number of the international standards (Table 12 to Table 15) have been adopted by members of the European Union as national standards. It is also hoped that many will be adopted as European standards under the Vienna agreement [ISO/CEN, 2001] Currently, a CEN Technical Committee (CEN/TC 156 Ventilation for buildings) is looking at the applicability of the ISO standards concerning fans, if they are useful to be adopted as European standards and if otherwise other CEN standards should be implemented.

1.2.2 Performance testing

Some ISO-standards are addressing issues such as test and rating methods for fans or systems incorporating a fan (Table 13). Many of these refer to air distribution and air diffusion as well as issues such as aerodynamic properties.

Table 13: ISO-standards addressing performance testing of fans

ISO 5151:1994	Non-ducted air conditioners and heat pumps -- Testing and rating for performance
ISO 5219:1984	Air distribution and air diffusion -- Laboratory aerodynamic testing and rating of air terminal devices
ISO 5220:1981	Air distribution and air diffusion -- Aerodynamic testing and rating of constant and variable dual or single duct boxes and single duct units
ISO 5220:1981/ Add 1:1984	Variable primary flow rate control devices with induced flow facility
ISO 5221:1984	Air distribution and air diffusion -- Rules to methods of measuring air flow rate in an air handling duct
ISO 5801:1997	Industrial fans -- Performance testing using standardized airways
ISO/DIS 5801:2006	Industrial fans -- Performance testing using standardized airways
ISO 5802:2001	Industrial fans -- Performance testing in situ
ISO 7244:1984	Air distribution and air diffusion -- Aerodynamic testing of dampers and valves
ISO 13253:1995	Ducted air-conditioners and air-to-air heat pumps -- Testing and rating for performance
ISO 13348:2006	Industrial fans -- Tolerances, methods of conversion and technical data presentation
ISO 13350:1999	Industrial fans -- Performance testing of jet fans

Of special importance might be ISO/DIS 5801:2006, describing the different standardized airways for performance testing. However no studies are known, analysing the effect of the different test equipments on the results of performance measurements. The new standard recommends some types of equipment to be used but for some more time there will still be are larger numbers of different types of test equipment on the market, which will hamper the comparison of test results on a common basis.

1.2.3 Energy use

In December 2002 the Energy Performance of Buildings Directive (EPBD)[13] was approved [EU, 2002]. As a result, the 25 EU member states had to implement a series of legal measures before January 4 2006. New buildings (residential, commercial, etc.) and a substantial number of existing buildings shall have an energy performance certificate based on the calculated energy performance of the building, and heating and air-conditioning systems above a certain capacity shall be inspected regularly. Figure 14 summarizes requirements that arise from the EPBD.

To support the implementation of the EPBD with a harmonised framework CEN is preparing draft standards under a mandate from the Commission (Mandate 343). This framework will cover the requirements for the energy performance calculations for buildings and building services systems, ways of expressing energy performance, crite-

13 EU Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings, published in the Official Journal of the European Communities on January 4 2003.

ria for the indoor environment, inspection of heating and air-conditioning systems and conversion to primary energy [Hogeling, 2006]. Table 14 shows those European standards related to the EPBD that might also have implications for energy usage of fans. Most of these address systems and not the fan product itself.

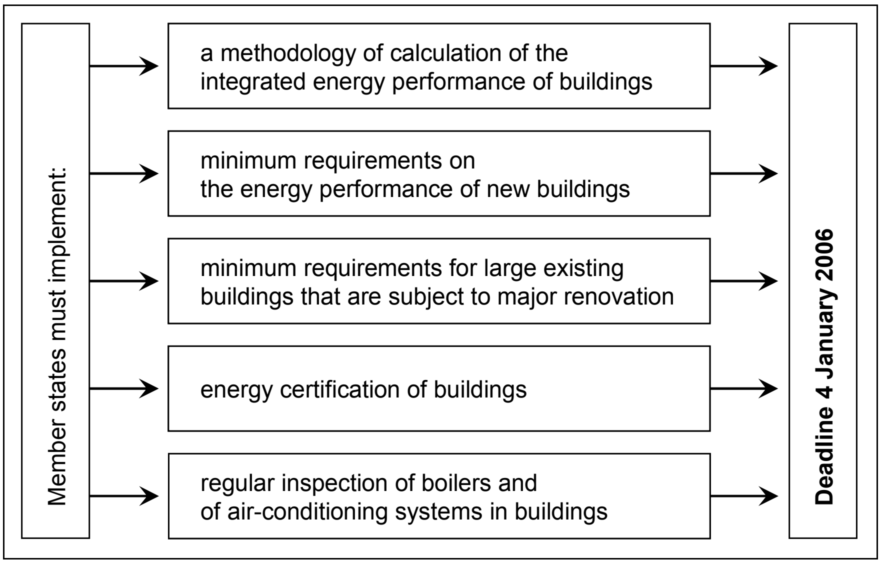


Figure 14: The requirements of the Energy Performance of Buildings Directive [Wouters et al., 2006]

Table 14: Standards related to the EPBD

prEN15240	Ventilation for Buildings – Energy performance of buildings -Guidelines for the inspection of air-conditioning systems.
prEN15315	Energy performance of buildings – Overall energy use, primary energy and CO_2 emissions.
prEN15242	Ventilation for buildings – Calculation methods for the determination of air flow rates in buildings including infiltration.
prEN15241	Ventilation for buildings – Calculation methods for energy requirements due to ventilation systems in dwellings.
prEN13779	Ventilation for non residential buildings – Performance requirements for ventilation and room conditioning systems (revision of EN 13779).
prEN15239	Guidelines for inspection of ventilation systems
prEN15251	Criteria for the indoor environment, including thermal, indoor air quality, light and noise.
EN12101	Smoke and heat control systems – Part 1: Specification for smoke barriers.
EN12103	Smoke and heat control systems – Part 3: Specification for powered smoke and heat exhaust ventilators.
EN 13141-8	Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 8: Performance testing of un-ducted mechanical supply and exhaust ventilation units (including heat recovery) for mechanical ventilation systems intended for a single room.

1.2.4 Health and safety

In Table 15 international standards are summarized that address health and safety issues in conjunction with ventilation. Most of these are concerned with air quality or fire resistance of ventilation systems or their components.

Table 15: ISO-standards addressing Health and Safety Issues

ISO 12499:1999	Industrial fans -- Mechanical safety of fans -- Guarding
ISO 6242-2:1992	Building construction -- Expression of users' requirements -- Part 2: Air purity requirements
ISO 6584:1981	Cleaning equipment for air and other gases -- Classification of dust separators
ISO 6944:1985	Fire resistance tests – Ventilation ducts
ISO 10294-1:1996	Fire resistance tests -- Fire dampers for air distribution systems -- Part 1: Test method
ISO 10294-2:1999	Fire resistance tests -- Fire dampers for air distribution systems -- Part 2: Classification, criteria and field of application of test results
ISO 10294-3:1999	Fire resistance tests -- Fire dampers for air distribution systems -- Part 3: Guidance on the test method
ISO 10294-4:2001	Fire resistance tests -- Fire dampers for air distribution systems -- Part 4: Test of thermal release mechanism
ISO 10294-5:2005	Fire resistance tests -- Fire dampers for air distribution systems -- Part 5: Intumescing fire dampers

1.2.5 Noise and vibrations

Most of the ISO-standards concerned with noise and vibration describe different methods for determining sound power levels, see Table 16. Others are about defining vibration levels.

Table 16: ISO-standards addressing Noise and Vibration

ISO 5136:2003	Acoustics -- Determination of sound power radiated into a duct by fans and other air-moving devices -- In-duct method
ISO 10302:1996	Acoustics -- Method for the measurement of airborne noise emitted by small air-moving devices
ISO 13261-1:1998	Sound power rating of air-conditioning and air-source heat pump equipment -- Part 1: Non-ducted outdoor equipment
ISO 13261-2:1998	Sound power rating of air-conditioning and air-source heat pump equipment -- Part 2: Non-ducted indoor equipment
ISO 13347-1:2004	Industrial fans -- Determination of fan sound power levels under standardized laboratory conditions -- Part 1: General overview
ISO 13347-2:2004	Industrial fans -- Determination of fan sound power levels under standardized laboratory conditions -- Part 2: Reverberant room method
ISO 13347-3:2004	Industrial fans -- Determination of fan sound power levels under standardized laboratory conditions -- Part 3: Enveloping surface methods
ISO 13347-4:2004	Industrial fans -- Determination of fan sound power levels under standardized laboratory conditions -- Part 4: Sound intensity method
ISO 14695:2003	Industrial fans -- Method of measurement of fan vibration
ISO 14694:2003	Industrial fans -- Specifications for balance quality and vibration levels

1.3 Existing legislation

1.3.1 Legislation and agreements at European community level

There are several general EU Directives that could have an impact on fans of the types considered in this study, see Table 17. The WEEE and RoHS directive do not apply to fans covered in this study. However based on the statements of the manufacturers during the consultation process, their products are anyway compliant with both of these directives.

Table 17: General EU environmental / safety legislation

EU Legislation	Scope
Waste Electrical and Electronic Directive (WEEE)	The aim of the WEEE Directive is to establish producer responsibility to prevent the generation of electrical and electronic waste and to promote reuse, recycling and other forms of recovery. It applies to electrical and electronic equipment (EEE) ▪ which is dependent on electric currents or electromagnetic fields in order to work properly ▪ designed for a voltage rating not exceeding 1,000V for AC and 1,500V for DC ▪ generation, transfer and measurement of such currents and fields Furthermore only those products are covered which are falling under on of the following categories: ▪ large household appliances ▪ large household appliances ▪ IT and telecommunications equipment ▪ Consumer equipment ▪ Lighting equipment ▪ Electrical and electronic tools (exc. large-scale stationary industrial tools) ▪ Toys, leisure and sports equipment ▪ Medical devices (exc. all implanted and infected products) ▪ Monitoring and control instruments ▪ Automatic dispenser As fans for ventilation in non-residential buildings are not falling under any of these categories they are considered not to be covered by the WEEE [EU, 2003a; European Commission, 2002]
Restriction on the Use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS)	Restrictions on the use of hazardous substances in the manufacture of electronic equipment are imposed since 1 July 2006, through the RoHS Directive. The type of electronic equipment is defined as in the WEEE Directive, therefore fans for ventilation in non-residential buildings are considered not to be covered. However, the substances restricted through the RoHS Directive (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE)) are normally not used in the manufacture of fans. [EU, 2003a; EU, 2003b]
Low Voltage Directive (LVD)	For the purposes of this Directive „electrical equipment“ means any equipment designed for use with a voltage rating of between 50 and 1,000 V for AC and between 75 and 1,500 V for DC. [EU, 2006]
General Product Safety Directive (GPSD)	The Directive applies to products intended for or likely to be used by consumers. It obliges producers to place only „safe“ products on the market. [EU, 2001]
Machinery Directive	This directive provides the regulatory basis for the harmonisation of the essential health and safety requirements for machinery at a European Union level. It not only promotes the free movement of machinery within the Single Market, but also guarantees a high level of protection to EU workers and citizens. Machinery is described in the Directive as "an assembly of linked parts or components, at least one of which moves, with the appropriate actuators, control and power circuits, etc., joined together for a specific application, in particular for the processing, treatment, moving or packaging of a material". The manufacturer is responsible for verifying whether a particular product falls within the scope of the Machinery Directive. [EU, 1998]

1.3.2 Legislation at member state level

Concerning legislation this is usually based on total system efficiency but not on the fan itself. Some countries like **Sweden** have adopted the approach to specify the energy consumption of the ventilation system by the measurement of the specific fan power (SFP). The specific fan power gives the specific energy consumption of the fan per volume of air delivered. As pressure losses in the system and losses related to the motor or the control system are accounted for in the specific value, the SFP is a good energy indicator for the whole system but does not necessarily give an indication of the efficiency of the fan used.

The SFP can be expressed as $SFP = \frac{P_{Fan}}{\dot{V}_{total}} = \left[\frac{W}{(l/s)}\right]$.

Table 18 shows typical values of the SFP for systems with different performance. The system hereby includes all parts of the ventilation system such as filters, heat exchangers, dampers, and ducting.

Table 18: Specific fan power and the efficiency of the fan system

Performance	SFP [W/(l/s)]	SFP [W/(1000 m^3/h)]
good	1	277.8
average	5	1388.9
poor	10	2777.78

SFP has also been adopted by the **UK** in its new building regulations [Department for Communities and Local Government, 2006]. Thereby maximum acceptable values of SFP are specified according to the type of system (see Table 19). Other nations within EU, e.g. **Germany**, are considering doing the same. The German EnEv [EnEv, 2006] will also use the SFP related to a single fan or the weighted average for all fans of a building. The minimum efficiency required will be selected from the efficiency classes as given in prEN 13779:2005(D).

Table 19: Maximum permissible specific fan power according to [Department for Communities and Local Government, 2006]

	new buildings [W/(l/s)]	**existing buildings** [W/(l/s)]	**new buildings** [W/(1000m³/h)]	**existing buildings** [W/(1000m³/h)]
central mechanical ventilation incl. heating, cooling and heat recovery	2.5	3	694.44	833.33
central mechanical ventilation with heating and cooling	2	2.5	555.56	694.44
all other central systems	1.8	2	500.00	555.56
local ventilation only units within the local area, such as window/wall/roof units, serving one room or area	0.5	0.5	138.89	138.89
local ventilation only units remote from the area, such as ceiling void or roof mounted units, serving one room or area*	1.2	1.5	333.33	416.67
other local units, e.g. fan coil units (rating weighted average**)	0.8	0.8	222.22	222.22

* this also includes fan assisted terminal VAV units where the primary air and cooling is provided by central plant

** calculated by: $(P_{mains,1},SFP_1+P_{mains,2},SFP_2+P_{mains,3},SFP_3+\ldots)/(P_{mains,1}+P_{mains,2}+P_{mains,3}+\ldots)$

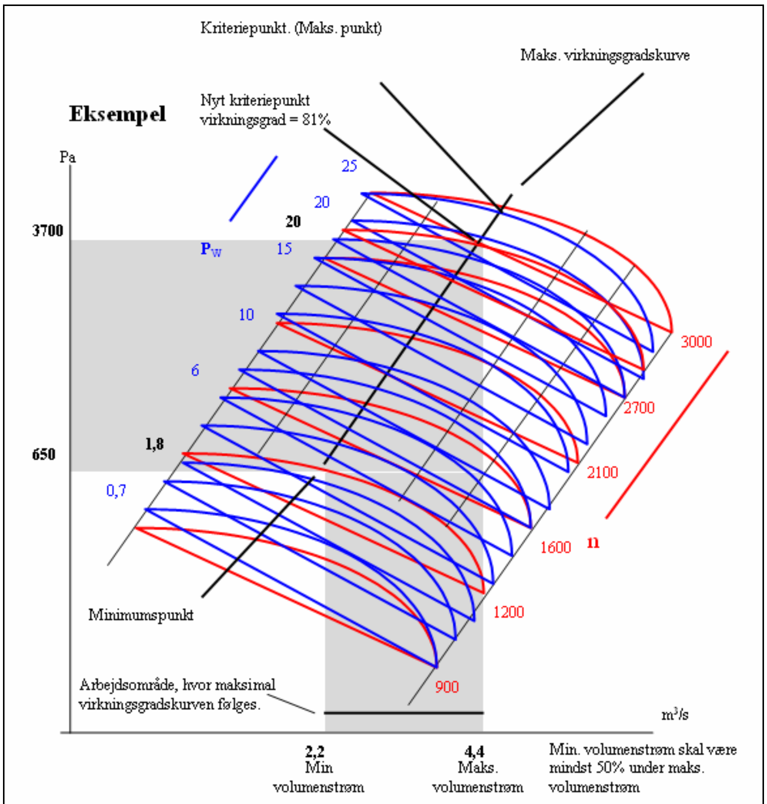
Other countries such as **Denmark** have started a voluntary labelling scheme for fans called „Spareventilator“[14]. In Denmark a fan can be called a „Spareventilator“ if it complies with a demand for high energy-efficiency as defined by the Danish power companies. Only those fans that have been approved by the power companies may be labelled with the Spareventilator-logo, Figure 15.

Figure 15: Spareventilator-logo

The campaign is focussing in particular on the fan itself. All data must be described in the measuring report for the individual fan and must be verifiable. The documentation

14 http://www.spareventilator.dk

of the fan's efficiency concerning pressure and air volume must be in accordance with **ISO 5801**. The stated efficiency rate must be as a minimum in accordance with the **Tolerance Class 2**, as stated in **ISO 24166**. The requirements and definitions for "Spareventilator" are illustrated in Figure 16. The efficiency data has to be recorded for each fan as in Table 20 and refers to total pressure rise (Pt), i.e. total efficiency of the fan. All fans can only be registered once as energy-efficient fans.



Skema til indberetning af data

Fabrikat	Type	Maksimal virkningsgrad for ventilator	Akseleffekt i kW		Volumenstrøm m³/s		Trykstigning Pa (Pt)	
			fra	til	fra	til	fra	til
xxx	yyy	81	1,8	20	2,2	4,4	680	3700

Bemærkning: Dette er en spareventilator, som i "Tabel med virkningsgradskrav" går ind under intervallet 10 - 20 kW.

Figure 16: Requirements and definitions for Spareventilator (example) [http://www.spareventilator.dk/ukversion/]

Table 20: Performance data record for Spareventilator

Type	Maximum efficiency rate for fan	Shaft power in kW		Volume flow (m³/s)		Pressure rise Pa (Pt)	
		From	To	From	To	From	To

Table 21 shows the data for the minimum efficiency at the best efficiency point for centrifugal and axial fans. So the Danish scheme assumes the same minimum efficiencies for our product categories 1 to 5, and it is a voluntary scheme.

In addition to centrifugal and axial fans two additional categories of fans are covered: Fans used for transporting air dust, particles and material (which are out of the scope of this study) and chamber fans.

Table 22 shows the minimum requirements for the relevant power sizes of box fans. A unique value of 65 % (fan excluding motor) has been fixed.

Table 21: Minimum efficiency for centrifugal and axial fans to fulfil „Spareventilator“ requirements

Shaft power	From 0 to and with 0,5 kW	From 0,5 to and with 1 kW	From 1 to and with 3 kW	From 3 to and with 10 kW	From 10 to and with 20 kW	From 20 to and with 50 kW	From 50 to and with 100 kW	Larger than 100 kW
Minimum parameters for maximum efficiency rates	76 %	78 %	79 %	80 %	81 %	82 %	83 %	84 %

Table 22: Minimum efficiency for chamber fans (box fans) to fulfil „Spareventilator“ requirements

Shaft power	From 0 to 3 kW
Minimum parameters for maximum efficiency rates	65 %

Table 23 shows the companies that have registered products within the categories radial, axial and chamber fans. Figure 17 shoes the total efficiency of the registered radial, axial and chamber fans. As can be seen the spread of efficiencies is widest for chamber fans. Most of the registered fans are of the radial type, which are generally more efficient than axial fans.

Table 23: Companies that have registered radial, axial and/or chamber fans for Spareventilator (in brackets: number of products registered)

AIRCON DANMARK A/S (26)	NB VENTILATION A/S (173)
BONI aps (plastventilator) (140)	Nicotra (11)
Dantherm A/S (11)	Nilan A/S (16)
Dantherm Filtration A/S (25)	NK INDUSTRI A/S (72)
EJNAR A. WILSON A/S (plastvent.) (41)	Novenco (153)
EXHAUSTO (76)	Øland A/S (148)
Fläkt Woods A/S (106)	Parlock A-S (1)
GEA KLIMATEKNIK (32)	REGUVENT (24)
GENVEX (2)	Servex Ventilation A/S (28)
GEOVENT A/S (17)	SWEGON A/S (27)
Jenk's eftf. a/s (166)	SYSTEMAIR A/S (53)
JHM - Jørgen Hansen Maskinfabrik A/S (83)	Tecvent ApS (1)
LF Ventilation A/S (2)	WOLF - DK (19)
Nautiluft (222)	Ziehl-abegg AG (3)

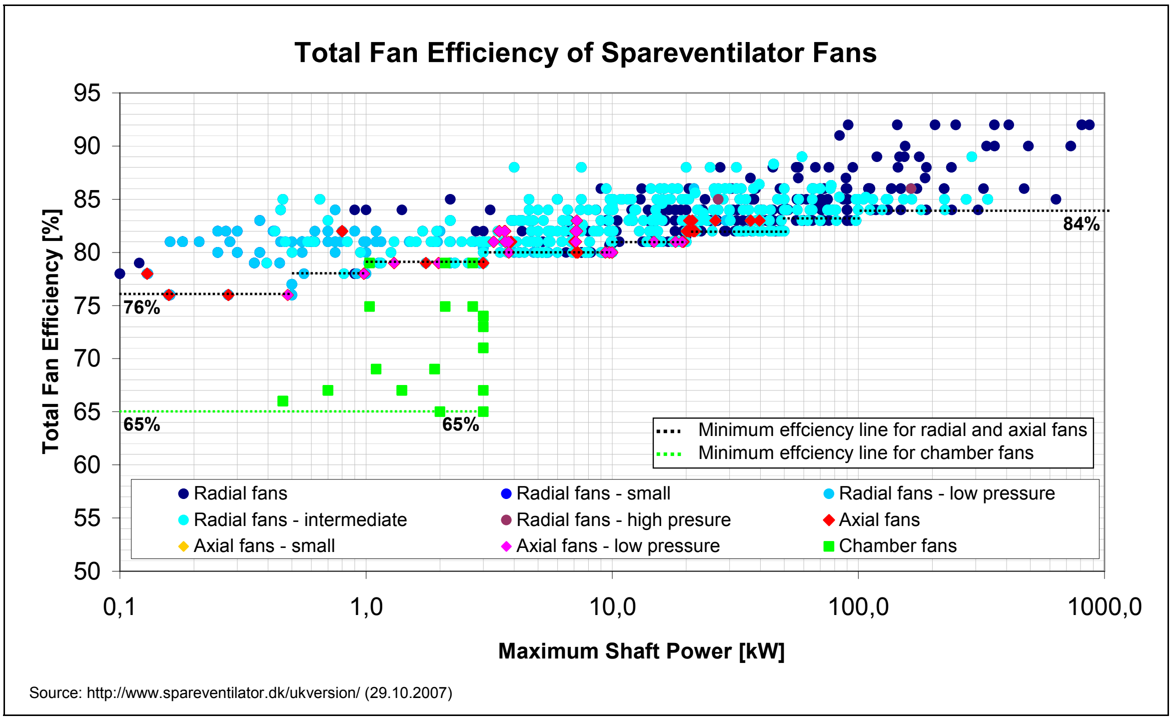


Figure 17: Total Fan Efficiency of Spareventilator Fans (not including motor) [http://www.spareventilator.dk/ukversion/, 29.10.2007]

In addition to national and international legislation and standards, a significant number of national guidelines related to fans and HVAC systems exist (Table 24). There might exist other national guidelines in the EU, however the authors have not been able to identify them although they deal mainly with air conditioning and not fans. Stakeholders had been requested to provide the known information with relevance to this study. The information delivered by the manufacturers together with the results of our own research is included in this report.

Table 24: Matrix of existing national guidelines [REHVA, 2004]

	Germany (www.vdi.de/tag/)	UK (www.cibse.org)	Netherlands (www.isso.nl)	France (www.aicvf.com)
Air Conditioning	VDI 3803-2002 Air Conditioning Systems	GSB02: CIBSE Guide B2: ventilation and air conditioning	ISSO-P31: Measuring points and measuring methods for HVAC installations	Guide 4: Principles of airflow calculation applied to HVAC engineering Guide 10: Design and calculation of air-conditioning installations
Shopping areas ventilation	VDI 2082-2000: Ventilation for sales outlets			
Ventilation Systems		AM10 natural ventilation in non domestic buildings AM13 Mixed mode ventilation	ISSO-P28: Balanced ventilation – Recommendations for design and construction ISSOI/SBR-P805: Handbook moisture and ventilation	Guide 5: Design and Calculation of ventilation systems in buildings
Economic efficiency	VDI 2067-2000: Economic efficiency of building installations	GVF Guide F: Energy efficiency in buildings	ISSO-P37: Energy indicator office building ISSO-P45: Methods to calculate energy savings. ISSO/SBR-P300: Energy efficient office buildings; indoor climate and energy consumption ISSO/SBR-804: Energy efficient ventilation	

1.3.3 Third country legislation

1.3.3.1 US energy Star program

The Energy star program by the US Environmental Protection Agency (EPA) deals only with fans for residential ventilation, which are outside the scope of our study. However

one should consider the approaches to define minimum efficiency standards for residential fans as they could also be useful for the non-residential sector. The energy star program of the United States defines eligibility criteria for residential fans to use the energy star logo. Two different product categories are covered by the energy star program, the ceiling fans and the ventilation fans for bathrooms and kitchens.

For ceiling fans, qualifying products shall meet or exceed the minimum requirements for total airflow and airflow efficiency given in Table 25, when operating in a downward-blowing direction. Since October 1, 2004, the tested representative model (i.e., unit shipped to test facility) must meet the minimum requirements. Once a representative model has qualified as ENERGY STAR, all additional units manufactured under the same model name/number, and found in the distribution channel (i.e., retail), must perform within 5 percent of the tested performance levels submitted to the US Environmental Protection Agency EPA and listed on the ENERGY STAR Web site.

Table 25: Air Flow Efficiency Requirements [Energy Star, 2006a]

Fan Speed	Minimum Air-flow [cfm]	Efficiency Requirement [cfm/W]	Minimum Air-flow [m^3/min]	Efficiency Requirement [W/(1000 m^3/h)]
Low	1,250	155	35	3.84
Medium	3,000	100	84	5.95
High	5,000	75	140	7.94

This specification defines residential ceiling fan airflow efficiency on a performance basis: Cubic feet per minute (cfm) of airflow per watt of power consumed by the motor and controls. This treats the motor, blades, and controls as one product, allowing multiple approaches to reach a given efficiency level.

Efficiency is to be measured on each of the three fan speeds (low, medium, high). For those ceiling fan models that offer more than three speeds, manufacturers may choose the three individual speed settings that should be used to comply with the performance levels in Table 25. However, at the time of testing measurements should be taken and reported for all discrete operating speeds.

In addition to the ENERGY STAR mark, packaging of ENERGY STAR qualified residential ceiling fan models shall also state airflow, fan power consumption, and airflow efficiency at each of their three operating speeds, as determined by the test procedures. If the ceiling fan model offers more than three speeds, performance results should be indicated for all speeds on the packaging, pointing out which three speeds were used to qualify the fan as ENERGY STAR. This information shall appear as in Table 26 on the outside of the package.

Table 26: Necessary information on packaging for energy star fans

Fan Speed	Airflow	Fan Power Consumption (without lights)	Airflow Efficiency (higher is better)
Low	__ CFM	__ watts	__ CFM/watt
Medium	__ CFM	__ watts	__ CFM/watt
High	__ CFM	__ watts	__ CFM/watt

Besides the eligible criteria for ceiling fans, similar criteria have been set for other residential ventilation products. ENERGY STAR qualified kitchen range hoods, bathroom and utility fans, and inline fans provide energy savings compared to standard products and are significantly quieter than standard models. Products that meet the energy-efficiency criteria outlined in Table 27, below, may qualify for the ENERGY STAR. In addition to these requirements, all qualified residential ventilating fans must also meet requirements regarding noise.

Table 27: Criteria for ENERGY STAR Qualified Residential Ventilating Fans – Minimum Efficacy Levels [Energy Star, 2006b]

Type of Residential Fan	Airflow		Minimum Efficacy Level [W/(1000 m^3/h)]	Minimum Efficacy Level [cfm/W]
	cfm	m^3/min		
Range Hoods	up to 500	up to 14	212.6	2.8
Bathroom and Utility Room Fans	10 -80	0.28-2.24	425.2	1.4
Bathroom and Utility Room Fans	90-130	2.52-3.64	212.6	2.8
Bathroom and Utility Room Fans	140-500	3.92-14	212.6	2.8
In-Line (single-port & multi-port) Ventilating Fans			212.6	2.8

1.3.3.2 AMCA certified rating for fan air performance

AMCA[15] (Air Movement & Control Association International Inc.) has set up a manual to describe the technical procedures to be used in connection with the AMCA Certified Ratings Programme for Fans – Air Performance. The rating program is used to confirm that fans certified achieve at least minimum performance values as laid out by AMCA [AMCA, 2005]. The document allows various methods to drive the test unit and to measure the power input to the fan. Transmission losses may or may not be included in the power measurement. For fans that are supplied with shaft and bearings the fan power input measurement should include the bearing losses.

15 http://www.amca.org/

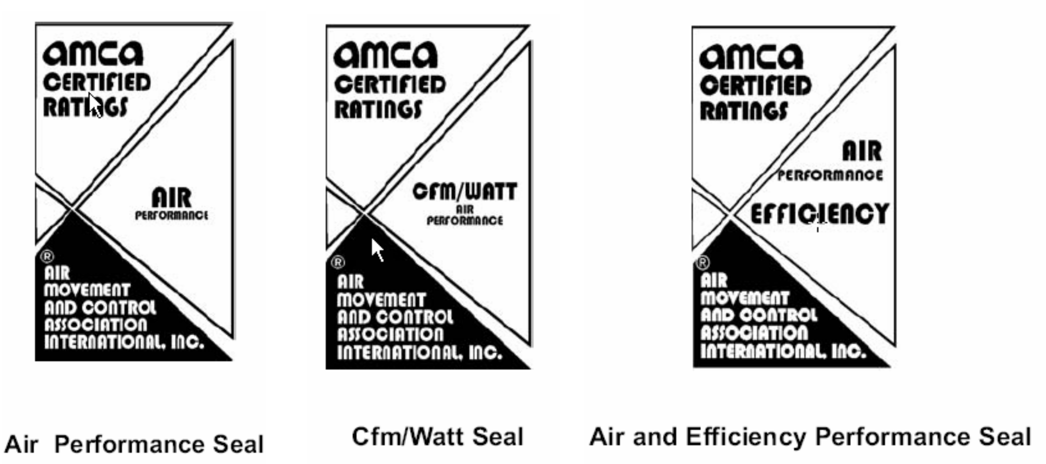


Figure 18: Air Performance, CFM/Watt and Air and Efficiency Performance Seal used to mark certified products [AMCA, 2005]

This AMCA certified rating programme applies to fans within the scope of AMCA International for which performance rating catalogues are published and made available to the public. If a manufacturer wants to have performance ratings for both licensed and non-licensed products in the same catalogue, there must be a clear distinction made. Products which fulfil the requirements of the AMCA certified rating program can use the related seals to mark that the products comply with the requirements.

Four different rating methods can be applied but it should be clearly stated for which test configuration the values have been obtained. The four allowed configurations are:

A: Free inlet, free outlet

B: Free inlet, ducted outlet

C: Ducted inlet, free outlet

D: Ducted inlet, ducted outlet

The efficiency in the catalogues may be static or total and the stated absorbed power may be impeller, shaft, electrical input, or mechanical output power. It shall be appropriate to the particular fan arrangement and rating method. The manufacturer shall clearly state over what range of airflows the efficiencies are certified. E.g. the following statement has to be used adjacent to the efficiency ratings: „Efficiency ratings are fan static (or fan total) and include (or exclude) bearing and/or power transmission losses."

The performance ratings of each model number shall include:

- Airflow rate
- Static pressure and/or total pressure
- Fan input power
- Impeller speed
- Inlet air density (if other than standard air)
- Fan static and/or fan total efficiency (optional).

1.3.3.3 AMCA certified rating for agricultural fans

The importance of fans for agriculture applications is underlined by the special AMCA rating for agriculture fans [AMCA, 2003]. As energy consumption is important for these fans, the cfm/W Air performance is of major importance in this rating scheme. However care should be taken when comparing values from the AMCA scheme with values used in Europe to compare the efficiency of agriculture fans. Whereas AMCA is using cfm/W in Europe the unit W/(1000m^3/h) is more common. Comparing these values could be misleading due to the fact, that at cfm/W the higher values and for W/(1000m^3/h) the lower values indicate higher fan performance, but numbers could be very close by, Figure 19.

10 cfm/W = 10 ft^3/(min W) = 58,858 W/(1000 m^3/h)

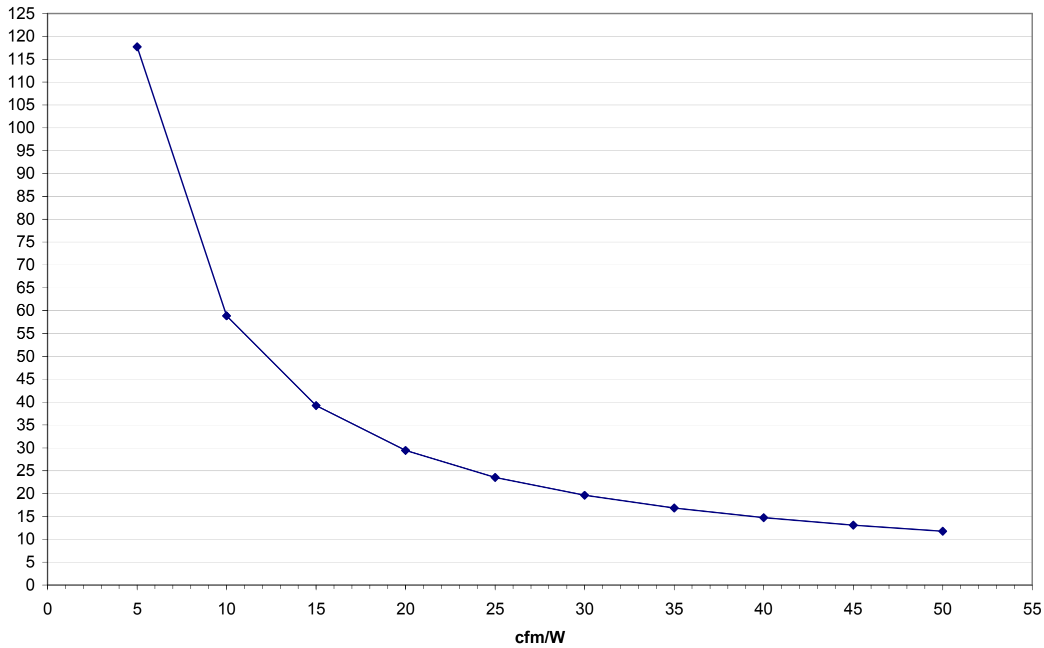


Figure 19: Relationship between the performance parameters used in the US and in Europe for agriculture fans

1.3.3.4 Chinese minimum efficiency performance standard

In other countries outside of Europe, China is the only one that has published minimum efficiency standards for fans [China, 2005]. This standard is actually only available in Chinese. A translation has been produced to include the information about this standard. Talking to Chinese manufacturers at IKK[16] trade faire (Nürnberg 2006) however pinpointed, that even Chinese manufacturers are not aware of this standard. The un-

16 27. Internationale Fachmesse Kälte, Klima, Lüftung, 18 to 20 October 2006, www.ikk-online.com.

derlying testing standard for the Chinese MEPS is a Chinese standard and reference is made to ISO 5801:1979. Three categories of products are taken into consideration: Centrifugal fans, axial fans, centrifugal fans with external rotor motor for air conditioning equipment. The standard does not explicitly define if total or static efficiencies are used. The MEPS values are defined for the fan wheel alone, not including motor and transmission. For centrifugal fans the MEPS are dependent on specific speed and the pressure coefficient, ranging from 61 % as low and 86 % as the highest value. For axial fans the equivalent values are 66 to 78 % and for centrifugal with external rotor motor for air conditioning 43 to 59 %.

Summary Chapter 1:

- ❖ Prodcom Classification is not precise enough to allocated production numbers down to required product categories
- ❖ There are large number of product variations depending on coupling of fan and motor
- ❖ For some products motor and fan can not be analysed independently
- ❖ The product boundary for this analysis includes motor, transmission and fan wheel and to some extend the control
- ❖ Calculation procedure presented to make products with and without motor comparable
- ❖ Definition of 8 different product categories to be considered for non residential building ventilation
- ❖ ISO 5801:2006 „Performance testing using standardized airways“ identified as important standard for comparing fan efficiencies
- ❖ Energy Performance of Buildings directive using specific fan power for comparison (system approach)
- ❖ Voluntary fan labelling scheme in Denmark and the US, mandatory minimum efficiencies for fans in China.

2 Economic and Market Analysis

Market data available for fans is usually much aggregated with little data available on specific fan types. Data on three different categories of fans was analysed from Eurostat's Prodcom system. Less aggregated data for the product categories as defined in Table 11 are not available. The Prodcom categories of interest in the context of non-residential building ventilation are [Eurostat, 2006b]:

- 29.23.20.30 Axial fans (excluding table, floor, wall, window, ceiling or roof fans with a self-contained electric motor of an output ≤ 125 W)
- 29.23.20.50 Centrifugal fans (excluding table, floor, wall, window, ceiling or roof fans with a self-contained electric motor of an output ≤ 125 W)
- 29.23.20.70 Fans (excluding table, floor, wall, ceiling or roof fans with a self-contained electric motor of an output ≤ 125 W, axial fans, centrifugal fans)

Interpretation of the data for these categories in the context of the non residential building ventilation market is difficult, in particular for the following reasons:

1. The product categories available for fans (Table 11) are highly aggregated in terms of technology (e.g. only differentiation between axial, centrifugal and other fans).

2. The definition of product categories is not always clear, for example, even though the definition of axial (29.23.20.30), centrifugal (29.23.20.50) and other fans (29.23.20.70) does exclude „table, floor, wall, ceiling or roof fans with a self-contained electric motor of an output ≤ 125 W“ these categories can still include other fan types below 125 W, e.g. those fans used in transportation vehicles or within electronic equipment (e.g. laptops).

3. There can be significant double counting of some products, for example if a product is exported to one country, then modified or incorporated into another product, which is then exported again to another country.
4. The categories do not differentiate applications, i.e. fan products for means of transportation, industrial processes, ventilation of buildings, etc. are all reported to the same categories. This makes it in particular difficult to identify the share of fans used in ventilation for non residential buildings.

2.1 Generic economic data

2.1.1 EU Production

Table 28 and Table 29 show the most recent Eurostat figures on production available for the relevant fan categories.

Table 28: Eurostat Figures on Production, Jan-Dec 2005 (number of units)

No.	Country	29.23.20.30 - Axial fans	29.23.20.50 - Centrifugal fans	29.23.20.70 - (Other) fans
		[Number of Units]		
1	France	190,572	584,657	1,052,800
2	Netherlands	185,412	: (2)	: (2)
3	Germany	: (1)	: (1)	1,733,204
4	Italy	641,895	652,843	124,555
5	United Kingdom	271,629	117,446	148,310
6	Ireland	13,296	: (1)	: (1)
7	Denmark	: (2)	35,409	161,106
8	Greece	: (1)	286	0
9	Portugal	1,886	1,436	402
10	Spain	75,855	475,952	341,278
11	Belgium	: (1)	: (1)	: (1)
12	Luxemburg	0	0	0
13	Sweden	0	: (1)	722,223
14	Finland	310	10	20,700
15	Austria	: (1)	: (1)	: (1)
16	Malta	0	0	0
17	Estonia	0	0	: (1)
18	Latvia	0	0	: (1)
19	Lithuania	0	6	0
20	Poland	76,318	107,345	6,978
21	Czech Republic	: (1)	: (1)	: (1)
22	Slovakia	0	0	: (1)
23	Hungary	8,446,892	977	1,250
24	Slovenia	: (1)	: (1)	: (1)
25	Cyprus	0	0	0
26	Romania	478	600	: (1)
27	Bulgaria	46,522	2,405	: (1)
	EU15TOTALS	: (1)	: (1)	4,359,673
	EU25TOTALS	: (1)	: (1)	4,516,152
	Totals of No. 1 to 27	9,951,065	1,979,372	4,312,806

: no data available
(1) Data for this item is confidential and has been suppressed
(2) Data for this item is estimated and has been suppressed

As can be seen in a lot of cases data is incomplete for confidentiality reasons. For example for Germany no number of units is available for the categories 29.23.20.30 (axial fans) and 29.23.20.50 (centrifugal fans) (Table 28). The numbers in Euro (Table 29) however suggest that Germany is the largest manufacturer of these types of products. In terms of units the data suggests that in general the main manufacturers of fans are in France, the Netherlands, Germany, Italy, United Kingdom and Spain. For axial fans the number of units for Hungary is surprisingly the highest among the data available. For category 29.23.20.70 (other fans) also Sweden shows a high number of units. The data in Euro furthermore shows that Denmark, Belgium and Poland are important.

Table 29: Eurostat Figures on Production, Jan-Dec 2005 (Euros)

No.	Country	29.23.20.30 - Axial fans	29.23.20.50 - Centrifugal fans	29.23.20.70 - (Other) fans
		[Euro]		
1	France	30,890,408	151,257,000	92,121,000
2	Netherlands	35,964,076	49,868,000	18,322,000
3	Germany	267,240,367	278,144,855	335,465,393
4	Italy	: (2)	233,272,000	45,818,000
5	United Kingdom	82,411,921	89,801,111	38,669,202
6	Ireland	: (1)	: (1)	: (1)
7	Denmark	18,983,897	40,247,054	14,939,209
8	Greece	209,740	382,358	0
9	Portugal	: (1)	4,583,398	2,850,206
10	Spain	9,987,528	72,338,909	37,598,105
11	Belgium	: (1)	67,701,007	: (1)
12	Luxemburg	0	0	0
13	Sweden	0	: (1)	68,773,351
14	Finland	: (2)	10,000	24,744,229
15	Austria	: (1)	: (1)	: (1)
16	Malta	:	0	0
17	Estonia	:	0	: (1)
18	Latvia	:	0	: (1)
19	Lithuania	:	4,924	0
20	Poland	:	11,703,927	3,657,022
21	Czech Republic	:	: (1)	8,412,027
22	Slovakia	:	0	: (1)
23	Hungary	:	1,699,847	443,644
24	Slovenia	:	: (1)	: (1)
25	Cyprus	:	0	0
26	Romania	:	1,043,198	: (1)
27	Bulgaria	:	870,743	: (1)
	EU15TOTALS	450,942,108	995,176,616	: (1)
	EU25TOTALS	:	1,013,615,477	712,496,211
	Totals of No. 1 to 27	445,687,937	1,002,928,331	691,813,388

: no data available
(1) Data for this item is confidential and has been suppressed
(2) Data for this item is estimated and has been suppressed

Based on the data available from 1995 to 2005 the Eurostat figures on production were amended with "best estimates" for each country of EU27 from 1995 to 2005. The results are shown in Figure 20 and Figure 21.

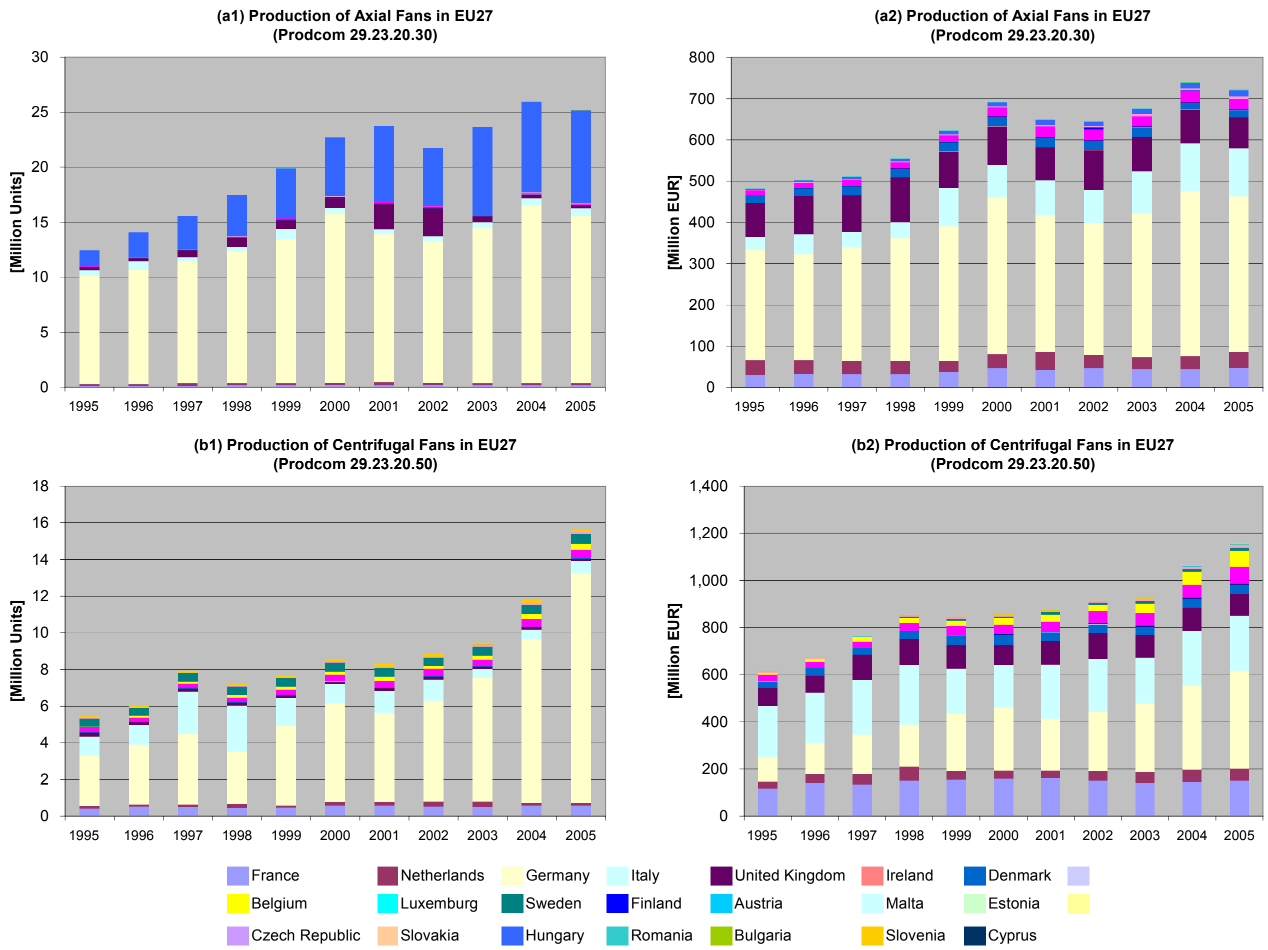


Figure 20: Eurostat figures on production for axial fans (29.23.20.30) and centrifugal fans (29.23.20.50), 1995-2005 [Eurostat, 2006b; own estimates]

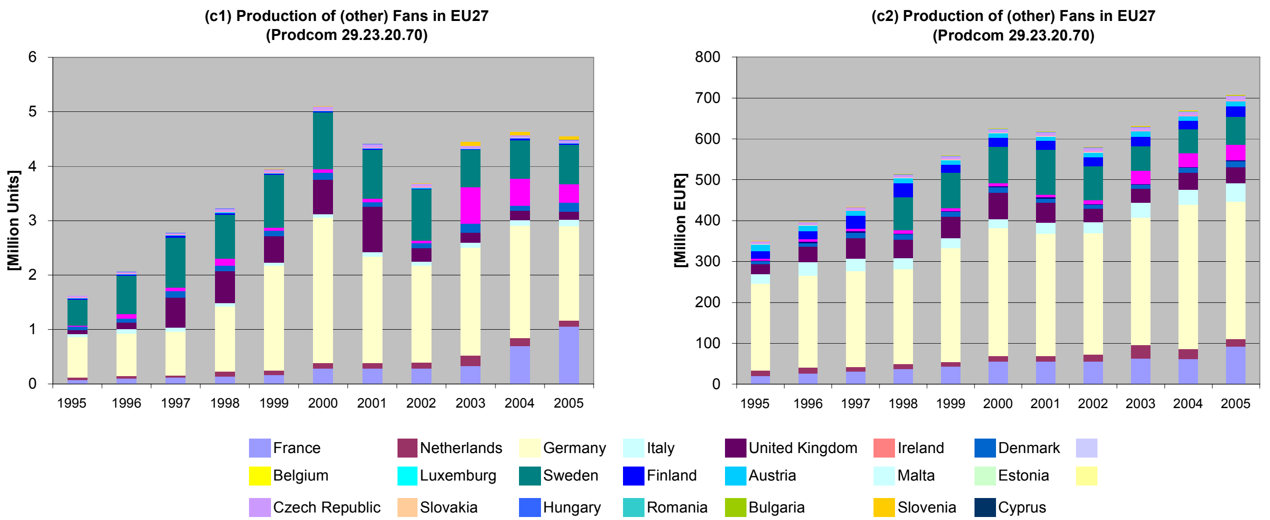


Figure 21: Eurostat figures on production for (other) fans (29.23.20.70), 1995-2005 [Eurostat, 2006b; own estimates]

Figure 20 (a1) shows that most of the axial fans in terms of units produced in Europe is in Germany and Hungary.[17] For Hungary the number of units produced is surprisingly high, especially compared to the share of European market volume in Euro (Figure 20 (a2)). An explanation for this could be if in Hungary was a manufacturing site for very small (and cheap) axial fans, e.g. for ventilation of computer equipment. For Germany as well, in particular compared to its share in Euro, the share in number of axial units produced seems very high. Other countries which have a significant share of market volume (in Euro) are France, Netherlands, Italy, United Kingdom, Denmark and Spain.

Regarding the production of centrifugal fans (Figure 3 (b1) and (b2)), except Hungary, the same countries as for axial fans are showing major shares of the market. For other fans (Figure 21), Sweden, United Kingdom and Germany show the highest shares. Overall, the graphs show an increasing trend in the production of fans and the most important market players in the three product categories seem to be in France, the Netherlands, Germany, Italy, the United Kingdom, Denmark and Spain, for axial fans furthermore in Hungary and for other fans also in Sweden.

VDMA (Verband Deutscher Maschinen- und Anlagenbau – German Engineering Federation) also collects data on ventilation and air conditioning products. Based on this data, Figure 22 gives an indication of how big the fan market is compared to the air conditioning market.

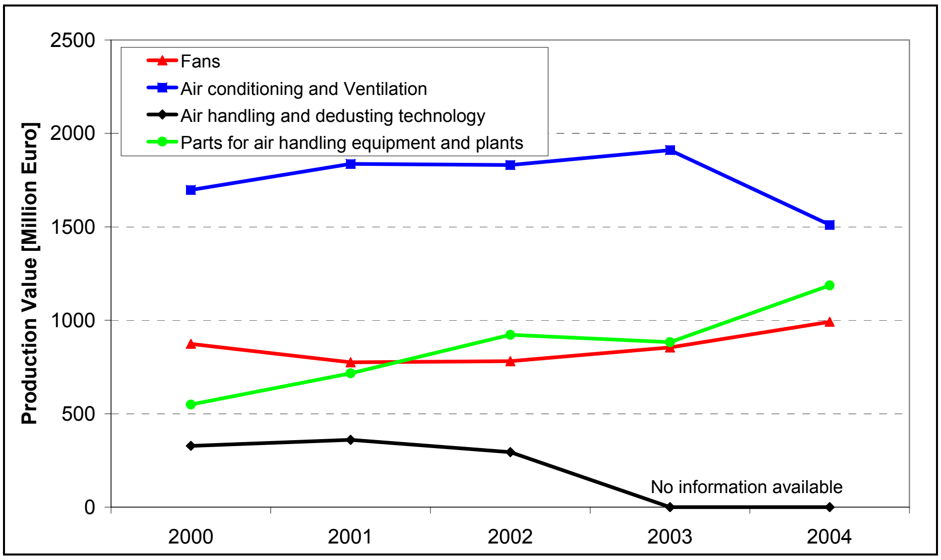


Figure 22: Production value air handling products in Germany [VDMA, 2003, 2004]

17 Note that for Hungary the numbers from 2001 to 2005 are not estimated. For production of axial fans in Germany there is only data available for 1995 and 1996, data for later years is estimated.

2.1.2 Extra and Intra EU Trade

Table 30 to Table 33 show import and export data for EU27 for 2005. The numbers shown for the member states refer to intra+extra European trade. The numbers displayed for "EU15TOTALS" and "EU25TOTALS" refer to extra EU15/EU25 trade only. It can be seen from these figures that considerable numbers of all types of products are traded within and outside EU25. The main trade occurs within the European Union.

Table 30: Eurostat Figures on Imports, Jan-Dec 2005 (number of units)

No.	Country	29.23.20.30 - Axial fans	29.23.20.50 - Centrifugal fans	29.23.20.70 - (Other) fans
		[Number of Units]		
1	France	5,119,236	1,471,190	3,483,665
2	Netherlands	7,639,098	364,903	3,682,961
3	Germany	25,763,988	3,505,112	8,412,178
4	Italy	8,141,690	1,512,572	7,054,198
5	United Kingdom	4,633,379	3,030,892	7,918,353
6	Ireland	553,139	321,536	489,918
7	Denmark	979,571	266,668	291,815
8	Greece	35,414	436,385	435,215
9	Portugal	151,589	840,425	377,903
10	Spain	2,050,439	443,583	4,507,969
11	Belgium	861,096	167,064	1,305,234
12	Luxemburg	34,985	1,680	21,966
13	Sweden	1,613,762	412,918	850,295
14	Finland	1,220,316	436,674	420,697
15	Austria	862,189	78,914	2,061,136
16	Malta	5,321	69,675	107,895
17	Estonia	51,182	31,297	52,551
18	Latvia	3,625	7,432	40,930
19	Lithuania	43,101	43,492	53,776
20	Poland	1,546,346	402,270	2,807,266
21	Czech Republic	4,939,755	84,729,860	2,231,383
22	Slovakia	329,116	2,692,444	1,092,380
23	Hungary	1,862,833	88,929	1,450,544
24	Slovenia	429,062	21,523	104,193
25	Cyprus	4,278	4,740	21,780
26	Romania	:	:	:
27	Bulgaria	:	:	:
	EU15TOTALS (Extra EU15 Imports)	43,281,542	3,400,309	28,850,497
	EU25TOTALS (Extra EU25 Imports)	38,103,072	1,066,866	29,948,044
	Totals of No. 1 to 27 (=Extra+Intra EU Imports)	68,874,510	101,382,178	49,276,201
	Intra EU25 Imports	30,771,438	100,315,312	19,328,157

: no data available

Table 31: Eurostat Figures on Imports, Jan-Dec 2005 (Euro)

No.	Country	29.23.20.30 - Axial fans	29.23.20.50 - Centrifugal fans	29.23.20.70 - (Other) fans
		[Euro]		
1	France	49,423,900	47,230,390	62,620,550
2	Netherlands	44,943,160	16,122,470	29,793,570
3	Germany	188,887,170	52,289,770	92,857,140
4	Italy	75,793,960	42,714,650	46,078,200
5	United Kingdom	56,368,450	39,881,170	55,089,290
6	Ireland	12,419,040	5,015,400	11,261,940
7	Denmark	9,640,860	15,928,200	4,559,130
8	Greece	2,407,100	5,407,360	2,939,550
9	Portugal	6,044,180	7,012,080	7,751,870
10	Spain	21,927,960	8,803,530	40,272,830
11	Belgium	20,686,720	12,826,740	35,039,920
12	Luxemburg	492,010	320,640	1,523,250
13	Sweden	40,167,940	22,087,060	17,573,540
14	Finland	20,805,000	24,917,130	9,504,700
15	Austria	22,666,950	6,686,500	33,675,730
16	Malta	298,640	1,978,910	557,990
17	Estonia	700,950	866,210	1,890,810
18	Latvia	379,350	1,286,730	1,148,910
19	Lithuania	1,288,080	3,517,490	2,900,390
20	Poland	17,413,300	8,162,070	34,730,840
21	Czech Republic	40,153,850	15,260,830	26,204,820
22	Slovakia	6,688,770	3,078,430	6,587,050
23	Hungary	29,857,610	3,750,060	11,144,680
24	Slovenia	6,159,860	1,350,280	3,710,740
25	Cyprus	184,730	225,610	523,450
26	Romania	:	:	:
27	Bulgaria	:	:	:
	EU15TOTALS (Extra EU15 Imports)	210,882,620	34,694,690	172,929,000
	EU25TOTALS (Extra EU25 Imports)	160,955,110	14,581,900	161,659,110
	Totals of No. 1 to 27 (=Extra+Intra EU Trade)	675,799,540	346,719,710	539,940,890
	Intra EU25 Imports	514,844,430	332,137,810	378,281,780

: no data available

Table 32: Eurostat Figures on Exports, Jan-Dec 2005 (number of units)

No.	Country	29.23.20.30 - Axial fans	29.23.20.50 - Centrifugal fans	29.23.20.70 - (Other) fans
		[Number of Units]		
1	France	659,427	126,891	1,731,009
2	Netherlands	6,835,077	152,776	2,604,146
3	Germany	21,025,446	13,583,481	6,093,290
4	Italy	3,623,145	1,636,260	15,854,360
5	United Kingdom	555,090	281,066	763,542
6	Ireland	15,818	3,894	8,706
7	Denmark	34,032	35,156	50,972
8	Greece	440	1,220	26,547
9	Portugal	507	13,756	33,842
10	Spain	526,247	416,756	1,006,376
11	Belgium	482,739	44,889	563,104
12	Luxemburg	13,605	26	7,251
13	Sweden	253,124	51,836	611,540
14	Finland	110,233	50,768	73,463
15	Austria	87,934	28,459	401,838
16	Malta	4	0	0
17	Estonia	3,635	2,662	2,894
18	Latvia	1,293	11,493	449
19	Lithuania	6,092	27,165	6,703
20	Poland	234,203	36,813	439,649
21	Czech Republic	881,261	33,110,178	348,170
22	Slovakia	8,117	420	6,294
23	Hungary	6,183,974	1,418,565	22,463
24	Slovenia	4,071	66,233	1,824,023
25	Cyprus	8	0	1,095
26	Romania	:	:	:
27	Bulgaria	:	:	:
	EU15TOTALS (Extra EU15 Exports)	13,653,724	6,562,931	12,664,130
	EU25TOTALS (Extra EU25 Exports)	9,988,299	4,634,681	9,128,765
	Totals of No. 1 to 27 (=Extra+Intra EU Exports)	41,545,522	51,100,763	32,481,726
	Intra EU25 Exports	31,557,223	46,466,082	23,352,961

: no data available

Table 33: Eurostat Figures on Exports, Jan-Dec 2005 (Euro)

No.	Country	29.23.20.30 - Axial fans	29.23.20.50 - Centrifugal fans	29.23.20.70 - (Other) fans
		[Euro]		
1	France	13,321,730	7,577,350	45,203,900
2	Netherlands	67,078,390	6,880,200	54,109,310
3	Germany	535,293,870	387,376,600	168,094,130
4	Italy	68,112,350	91,820,200	171,586,810
5	United Kingdom	62,901,590	20,326,090	34,196,250
6	Ireland	4,963,770	699,280	628,730
7	Denmark	11,073,070	16,560,230	5,654,320
8	Greece	32,740	149,440	239,920
9	Portugal	42,150	221,020	930,300
10	Spain	26,663,610	26,804,040	10,774,550
11	Belgium	7,664,830	9,265,000	14,483,460
12	Luxemburg	104,290	3,790	1,781,450
13	Sweden	13,055,460	9,695,780	52,115,870
14	Finland	2,874,630	4,669,490	15,948,850
15	Austria	3,864,550	4,313,360	11,166,940
16	Malta	490	0	0
17	Estonia	225,540	1,476,960	892,700
18	Latvia	123,870	174,880	13,440
19	Lithuania	924,810	3,355,160	1,229,560
20	Poland	2,257,560	4,005,020	4,870,910
21	Czech Republic	18,442,280	7,146,930	10,736,750
22	Slovakia	276,810	47,520	1,776,120
23	Hungary	124,326,310	24,483,330	704,570
24	Slovenia	466,060	2,357,670	14,609,290
25	Cyprus	2,430	0	6,450
26	Romania	:	:	:
27	Bulgaria	:	:	:
	EU15TOTALS (Extra EU15 Exports)	350,625,790	241,121,060	281,958,660
	EU25TOTALS (Extra EU25 Exports)	263,348,940	189,665,820	248,935,250
	Totals of No. 1 to 27 (=Extra+Intra EU Exports)	964,093,190	629,409,340	621,754,580
	Intra EU25 Exports	700,744,250	439,743,520	372,819,330

: no data available

2.1.3 Apparent EU consumption

Apparent consumption can be calculated based on production plus imports minus exports data from Eurostat. It reflects the number of new products entering the market per year. Table 34 and Table 35 show apparent consumption for the European Union by country for the year 2005 in number of units and in Euro. Some of the numbers are negative, i.e. the number of exports is higher than production plus imports. Therefore this data does not seem very reliable.

Table 34: Apparent Consumption, based on Eurostat Figures on production, Imports and Exports, Jan-Dec 2005 (number of units)

No.	Country	29.23.20.30 - Axial fans	29.23.20.50 - Centrifugal fans	29.23.20.70 - (Other) fans
		[Number of Units]		
1	France	4,650,381	1,928,956	2,805,456
2	Netherlands	989,433	:	:
3	Germany	:	:	4,052,092
4	Italy	5,160,440	529,155	-8,675,607
5	United Kingdom	4,349,918	2,867,272	7,303,121
6	Ireland	550,617	:	:
7	Denmark	:	266,921	401,949
8	Greece	:	435,451	408,668
9	Portugal	152,968	828,105	344,463
10	Spain	1,600,047	502,779	3,842,871
11	Belgium	:	:	:
12	Luxemburg	21,380	1,654	14,715
13	Sweden	1,360,638	:	960,978
14	Finland	1,110,393	385,916	367,934
15	Austria	:	:	:
16	Malta	5,317	69,675	107,895
17	Estonia	47,547	28,635	:
18	Latvia	2,332	-4,061	:
19	Lithuania	37,009	16,333	47,073
20	Poland	1,388,461	472,802	2,374,595
21	Czech Republic	:	:	:
22	Slovakia	320,999	2,692,024	:
23	Hungary	4,125,751	-1,328,659	1,429,331
24	Slovenia	:	:	:
25	Cyprus	4,270	4,740	20,685
26	Romania	:	:	:
27	Bulgaria	:	:	:
	EU15TOTALS	:	:	20,546,040
	EU25TOTALS	:	:	25,335,431
	Totals of No. 1 to 27	25,877,901	9,697,698	15,806,219

: no data available

Table 35: Apparent Consumption, based on Eurostat Figures on production, Imports and Exports, Jan-Dec 2005 (Euro)

No.	Country	29.23.20.30 - Axial fans	29.23.20.50 - Centrifugal fans	29.23.20.70 - (Other) fans
		[Euro]		
1	France	66,992,578	190,910,040	109,537,650
2	Netherlands	13,828,846	59,110,270	-5,993,740
3	Germany	-79,166,333	-56,941,975	260,228,403
4	Italy	:	184,166,450	-79,690,610
5	United Kingdom	75,878,781	109,356,191	59,562,242
6	Ireland	:	:	:
7	Denmark	17,551,687	39,615,024	13,844,019
8	Greece	2,584,100	5,640,278	2,699,630
9	Portugal	:	11,374,458	9,671,776
10	Spain	5,251,878	54,338,399	67,096,385
11	Belgium	:	71,262,747	:
12	Luxemburg	387,720	316,850	-258,200
13	Sweden	27,112,480	:	34,231,021
14	Finland	:	20,257,640	18,300,079
15	Austria	:	:	:
16	Malta	:	1,978,910	557,990
17	Estonia	:	-610,750	:
18	Latvia	:	1,111,850	:
19	Lithuania	:	167,254	1,670,830
20	Poland	:	15,860,977	33,516,952
21	Czech Republic	:	:	23,880,097
22	Slovakia	:	3,030,910	:
23	Hungary	:	-19,033,423	10,883,754
24	Slovenia	:	:	:
25	Cyprus	:	225,610	517,000
26	Romania	:	:	:
27	Bulgaria	:	:	:
	EU15TOTALS	311,198,938	788,750,246	:
	EU25TOTALS	:	838,531,557	625,220,071
	Totals of No. 1 to 27	130,421,737	692,137,710	560,255,278

: no data available

Due to the gaps in Eurostat data, the "Totals of No. 1 to 27" in Table 34 and Table 35 do not correctly reflect apparent consumption in EU27 of axial, centrifugal and other fans. Therefore, to estimate the number of fans placed on the market for non-residential building ventilation per product category, firstly, gaps in Eurostat data on production, imports and exports was amended with estimates to re-calculate apparent

consumption for the Prodcom categories 29.23.20.30 (axial), 29.23.20.50 (centrifugal) and 29.23.20.70 (others). As the Eurostat numbers for these categories do not only include fans for ventilation in non-residential buildings but also fans for industrial process ventilation, fans for transportation vehicles, fans for residential ventilation etc., secondly a model was developed to break down the number of units to the eight EuP product categories for non-residential building ventilation. This model is based on the available data and assumptions, for example regarding the share of applications per Prodcom category, the share of high and low pressure axial fans in the different applications etc. These assumptions are based on discussions with stakeholders, own market research and published data. The details of the model are shown in chapter 0 (Annex).

However, as the number of assumptions is very large, the obtained numbers should not be over-interpreted. Nevertheless the data seems to be consistent with the results of an earlier study [Radgen, 2001], where the total fans energy consumption in the tertiary sector was calculated. Table 36 shows results from the model for fan consumption in non-residential buildings by product category in 2005.

Table 36: Number of fans placed on the market in EU-27 in 2005

Product Category	Direction of flow	Type	Typical Sizes [mm]	Fan Consumption in non residential buildings by Category in 2005
1	Axial	<= 300 Pa (static pressure)	200 – 1,400	718,075
2	Axial	> 300 Pa (static pressure)	200 – 1,400	1,994,653
3	Centrifugal	forward curved blades (with casing)	120 – 1,600	1,091,680
4	Centrifugal	backward curved blades (no casing)	120 – 1,600	337,563
5	Centrifugal	backward curved blades (with scroll housing)	120 – 1,600	376,180
6	Other	Box fans	100 – 1,000	1,532,397
7	Other	Roof fans	250 – 1,000	2,694,325
8	Other	Cross-flow fans	60 – 120	182,428

2.2 Market and stock data

2.2.1 Installed base („stock“) and penetration rate

Based on Eurostat figures available from 1995 to 2005 on production, imports and exports the number of products entering the market in one year (= production + imports – exports, see chapter 2.1.3) was calculated. Where statistical data was missing, the Eurostat data was amended with estimates. Using the model described in chapter 0 (Annex) for each year the number of products per Prodcom category (29.23.20.30, 29.23.20.50, 29.23.20.70) was broken down to the 8 EuP product categories. Herewith the number of units going into the market for non-residential building-ventilation from 1995 to 2005 (for these years Eurostat data is available) was obtained. From there, apparent consumption for past and future years was estimated based on different growth rates.[18] Then, based on an average product lifetime of 15 years the number of products in use in past and future years was estimated.

Figure 23 and Figure 24 for each product category show the stock of products in use for non-residential building ventilation for four different growth scenarios:

- logarithmic growth based on a regression regarding apparent consumption from 1995 to 2005
- linear growth based on a regression regarding apparent consumption from 1995 to 2005
- constant growth rate of 2% for apparent consumption before 1995 and after 2005
- constant growth rate of 10% for apparent consumption before 1995 and after 2005

Based on these scenarios Table 37 shows the estimated minimum and maximum number of products in use in 2005 and 2025 for each product category. Due to the different assumptions about the growth rate of apparent consumption the numbers for 2025 varies widely. The largest number is not likely as it is based on a constant growth rate of 10%. However, even when assuming lowest growth rates the number of products in use is very high for all of the product categories, ranging from 3.6 Million for cross-flow fans to 52.5 Million for roof fans in 2025.

[18] From manufacturers we know that the growth rate in the last year was even around 20% but this is not typical value. This seems to be more a catch up of delayed investment during the previous years.

Table 37: Estimated Number of Products in use in 2005 and 2025

Product Cate-gory	Direction of flow	Type	Number of products in use for non-residential building ventilation	
			2005	**2025**
1	Axial	<= 300 Pa (static pressure)	6.1 – 7.3 Mio.	14.0 – 40.4 Mio.
2	Axial	> 300 Pa (static pressure)	16.8 – 20.2 Mio.	38.8 – 112.3 Mio.
3	Centrifugal	forward curved blades (with casing)	9.2 – 10.3 Mio.	16.8 – 61.4 Mio.
4	Centrifugal	backward curved blades (no casing)	2.8 – 3.2 Mio.	5.2 – 19.0 Mio.
5	Centrifugal	backward curved blades (with scroll housing)	3.2 – 3.5 Mio.	5.8 – 21.2 Mio.
6	Other	Box fans	20.6 – 23.0 Mio.	29.8 – 86.3 Mio.
7	Other	Roof fans	36.2 – 40.4 Mio.	52.5 – 151.7 Mio.
8	Other	Cross-flow fans	2.4 – 2.7 Mio.	3.6 – 10.3 Mio.

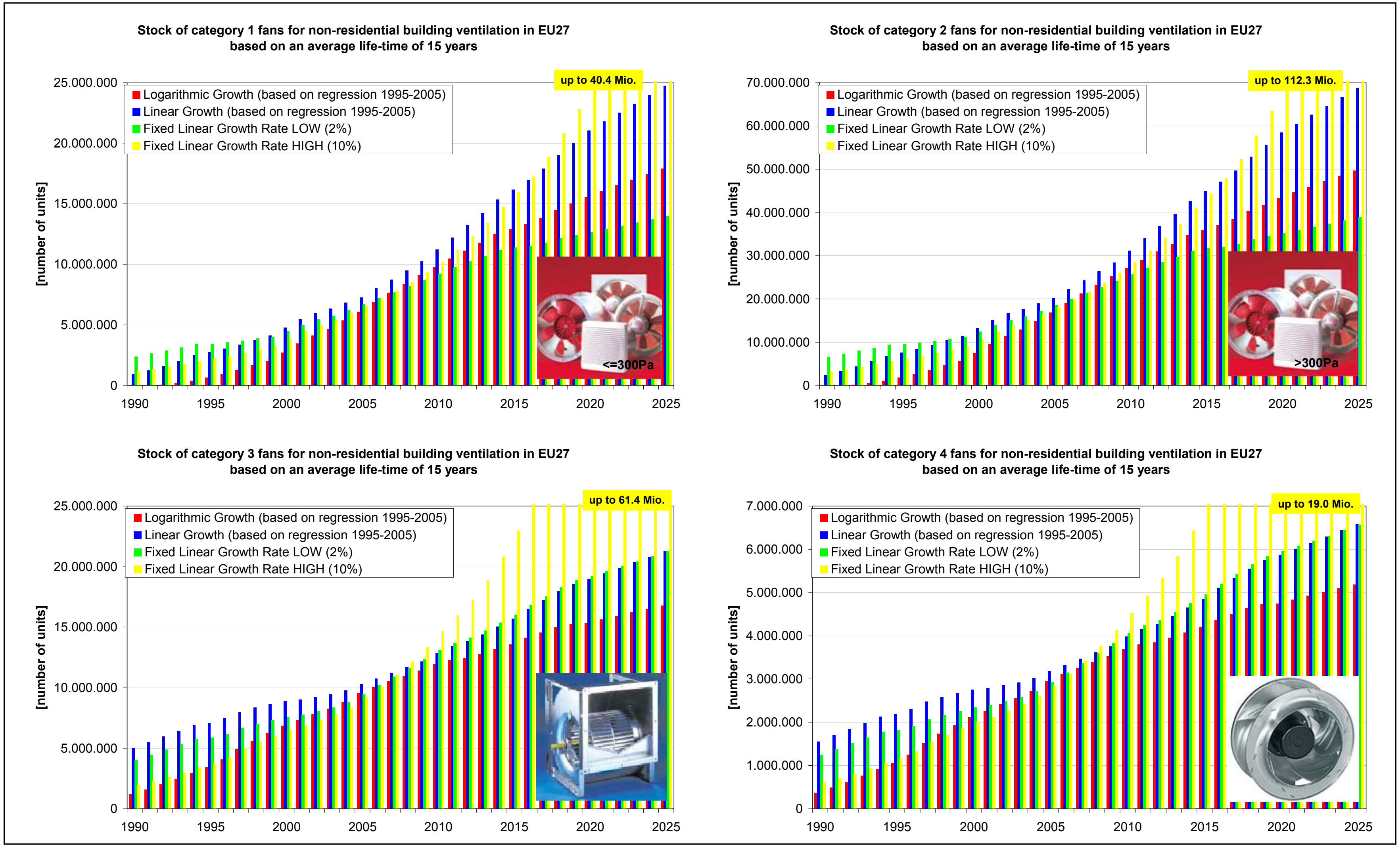


Figure 23: Number of products in use for non-residential building ventilation, product categories 1 to 4.

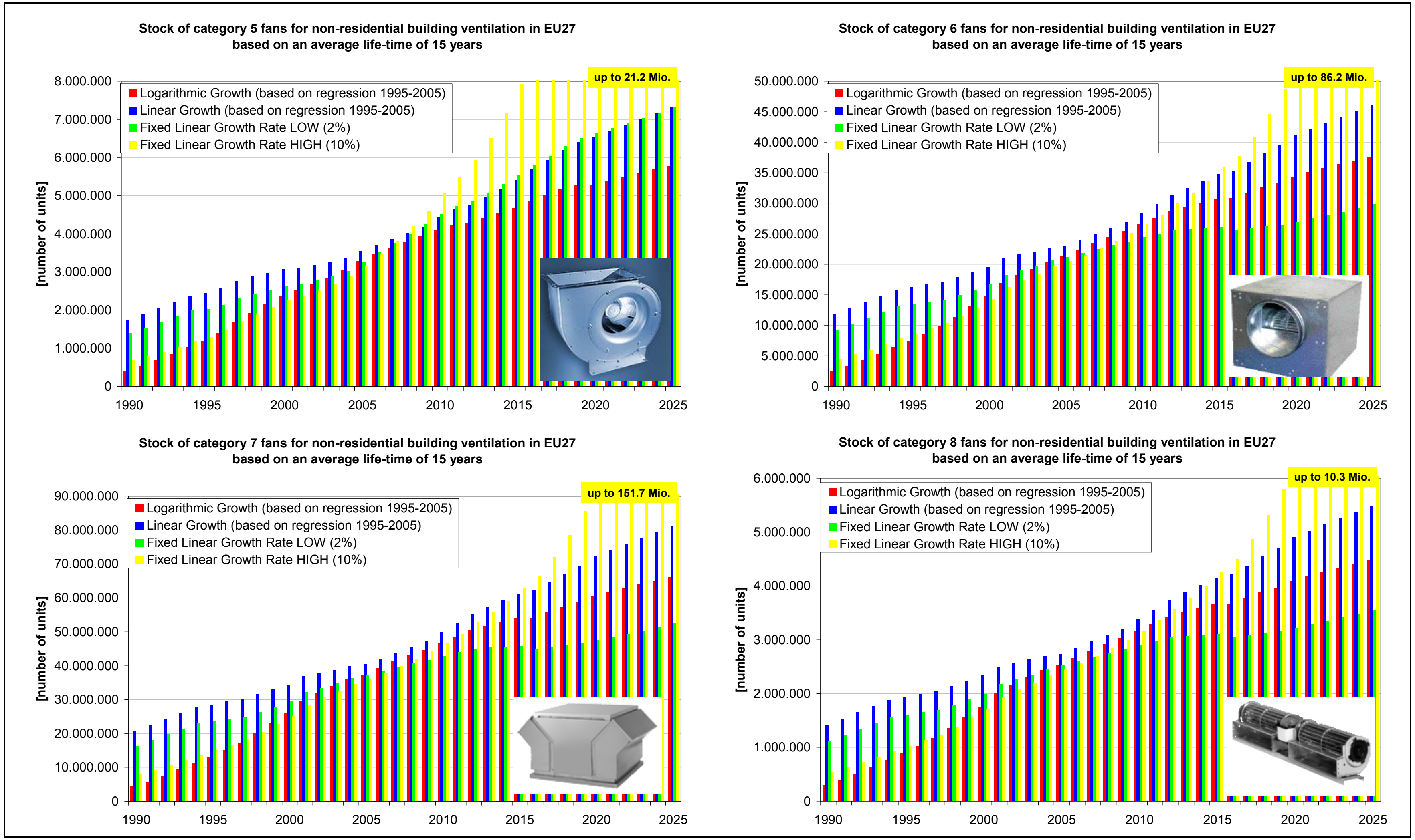


Figure 24: Number of products in use for non-residential building ventilation, product categories 5 to 8.

2.2.2 Average product life

No data could be found about life-time specifically relating to fans for ventilation in non residential buildings. In general it can be said that buildings usually have an economical life-time of 30 to 50 years. However, life-time of technical infrastructure, including fans, is usually shorter. As an example Table 38 summarizes economical life-time of industrial buildings and their components.

Table 38: Economical life time of industrial buildings and their components [Cory, 2005]

Buildings	40 years
Ducting, underground	50 years
Other ducting	20 years
Machines	15 years
Control equipment	10 years
instrumentation	10 years

The life-time of a fan is usually limited by its bearing, which will normally be replaced once during the time in service of the fan. The bearings for medium-sized fans are typically selected to give a basic rating life-time of 40,000 hours [Cory, 2005]. Therefore the total number of operating hours for the fan could be between 80,000 to 100,000 hours. Some fans might even be used for many hours more than that, if the bearings do not fail. However, the assumption for the base case is that the average life-time of a fan for non-residential building ventilation is 15 years, based on [Cory, 2005] and that the fan will operate 4,000 hours a year.

2.2.3 Total sales / real EU consumption

Figure 25 shows the number of products sold in EU27 per year for each product category based on apparent consumption derived from Eurostat data and on the model assumptions in chapter 0 (Annex). In 2005 all of the product categories exceed the 200.000 threshold except cross-flow fans (category 8: 182,428 units in 2005). According to Figure 25, in the market for non-residential building ventilation, most products sold seem to be roof fans (category 7), box fans (category 6) and axial fans > 300Pa (category 2). In 2001 for roof fans the sales even exceed 4 Million units, box fans come close to 2.5 Million units and axial>300Pa exceed 2 Million units. The sales of forward curved centrifugal fans (category 3) are highest in 2005 (more than 1 million units). The number of backward curved centrifugal fans (with and without housing, categories 4 and 5) continuously increases from 1995 to 2005 with more than 300,000 units sold in each category in 2005. The number of units sold of axial<=300Pa come close to 750,000 in 2005.

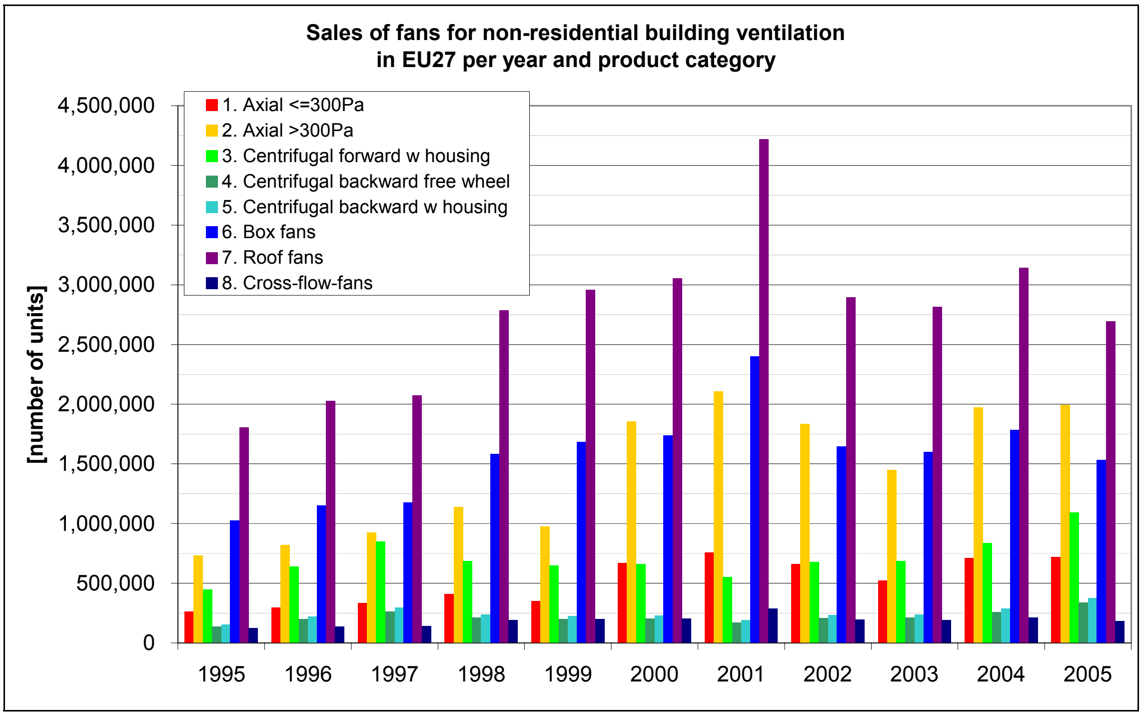


Figure 25: Sales of fans for ventilation in non-residential buildings in EU27 based on Eurostat figures and own estimates [Eurostat, 2006b; own estimates]

Eurovent-Cecomaf (the European Committee of Air Handling and Refrigeration Equipment Manufacturers) is also collecting data on sales of refrigeration and air handling equipment which is published annually since a number of years (Figure 26). Based on this data, the total sales volume for fans is about 1.2 Billion Euro and for fan coil units 410 Million Euros. However the data does not include all manufacturers and the coverage of the market might only be 60 to 70 %. Nevertheless the numbers are showing an increasing trend for fans and fan coil units between 2001 and 2006.

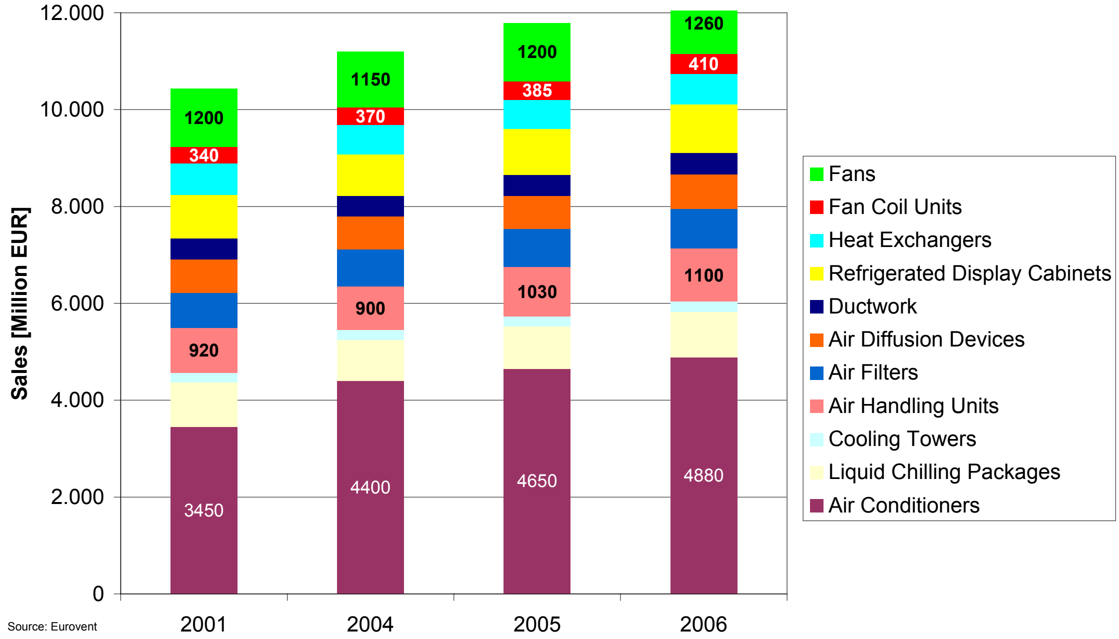


Figure 26: Sales of Fans and Air Handling Products [Eurovent, 2002, 2005, 2006, 2007]

The increase use of air conditioning in buildings increases also the number of fans to be used in ventilation systems. Therefore it can be assumed, that the total fan production will further increase. In addition to the fans itself, most products listed in the Eurovent statistics are containing fans. Even as prices of most air conditioning and ventilation products are decreasing due to the high competition on the international markets, the total sales volume is still increasing, meaning that the increase in number of units will be typically higher than the increase in sales volume (see also Figure 27).

2.2.4 Replacement and new sales

The number of new products entering the market depends on production, import and export per year as described above. However the impact on overall energy consumption for fans in non residential buildings will be different for replacement or new installations. Replacements will not affect the number of installed units but will increase the average efficiency of the stock due to technical improvement of the products, therefore reducing overall energy consumption. Fans going into new installations will usually also have higher efficiency than the average stock but will in any case increase overall energy consumption due to the increasing number of installed products. Their will be also demolition of buildings which are going to reduce the installed stock of fans. However it is more likely that demolished buildings will be replaced by new buildings and therefore new fans will be installed. So we can treat this as fan replacements in existing buildings.

2.3 Market trends

There are assumed to be four major trends in the fans market for building ventilation:

- product type: increasing use of aerofoil fans
- materials: use of plastics is getting more popular
- application: dual use fans (combination of ventilation and smoke extraction) is becoming more popular
- drive: increasing use of frequency converters and direct drives

Moreover trends concerning buildings can have a major influence on the group of fans under consideration and the development of the fans market. For example, usually new buildings are equipped with air-conditioning, which implies increasing demand for fans. Also demand for mechanical ventilation is increasing. Furthermore, as described above, the EU Energy Performance of Buildings directive could give rise to an increasing interest in energy efficiency of fans for the future.

The manufacturers, which are supposed to be the major market players for ventilation fans in non residential buildings, are shown in Table 39, broken down by product type.

Table 39: Main European manufacturers of fan types to be considered

Fan Type	Manufacturers			
Axial	ebmpapst FläktWoods Munters Ziehl-Abegg	Elta Helios Nuaire Zitron	Exafan Hydria Rosenberg	FläktSolyvent Ventec Multi-Fan Soler&Palau
Centrifugal	Comefri Nicotra	ebmpapst Soler&Palau	FläktSolyvent Ventec Ziehl-Abegg	Gebhardt Zitron
Other	FläktWoods	Gebhardt	Helios	Maico

2.4 Consumer expenditure base data

Prices will depend on type, style and size of fan as well as its application. There may also be considerable differences between the European Member States concerning product prices. Due to Far East imports an increasing price pressure in the European market can be expected. As an indication in Figure 27 the specific value of axial, centrifugal and other fans, calculated based on Eurostat production figures, is shown. The numbers show a decreasing trend, with axial fans apparently being the cheapest among those fan products, while the category „other“ fans (29.23.20.70) seems to include the most expensive fan products.

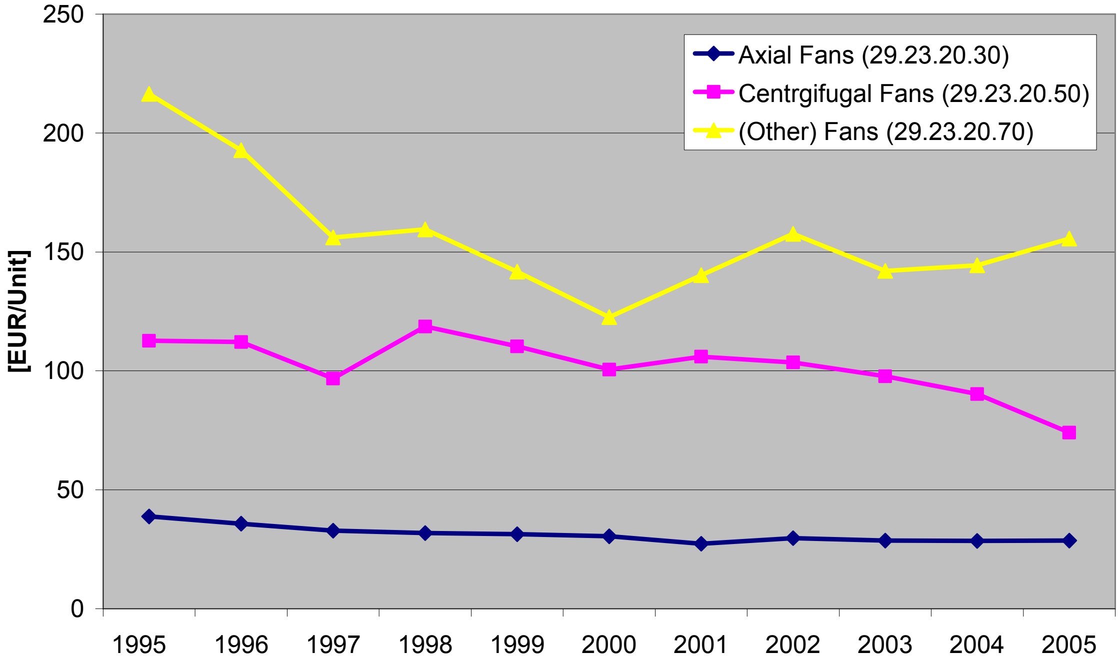


Figure 27: Specific value of fans produced in EU27 1995-2005 [Eurostat, 2006b]

In Figure 28 to Figure 34 overall gross prices of fan products of EuP category 1 to 7 are shown. For category 8 products (cross-flow fans) no data in prices could be found for the relevant sizes above 125W. The prices shown are taken from several manufacturers catalogues and include all necessary drive components and other accessories. However the price of the same product can lie typically comprise 50 and 150 % of the list price of a manufacturer. The rebates used on the list price will depend on the importance of the final costumer. So, larger companies will typically get a lower bit than smaller companies.

From Figure 28 to Figure 34 two general observations can be made:

- for each fan type prices increase linear with motor size (power input)
- there is a wide spread of prices within each category depending on different design and quality of the products

The latter point can especially be observed for roof fans (category 7, Figure 34), where designs can be very different (axial, centrifugal or mixed flow, different designs of housing etc.).

The installation costs for the fan alone will typically make of 50 to 100 % of the purchase costs, however the installation cost of the fan are typically small compared to the total cost of the ventilation system.

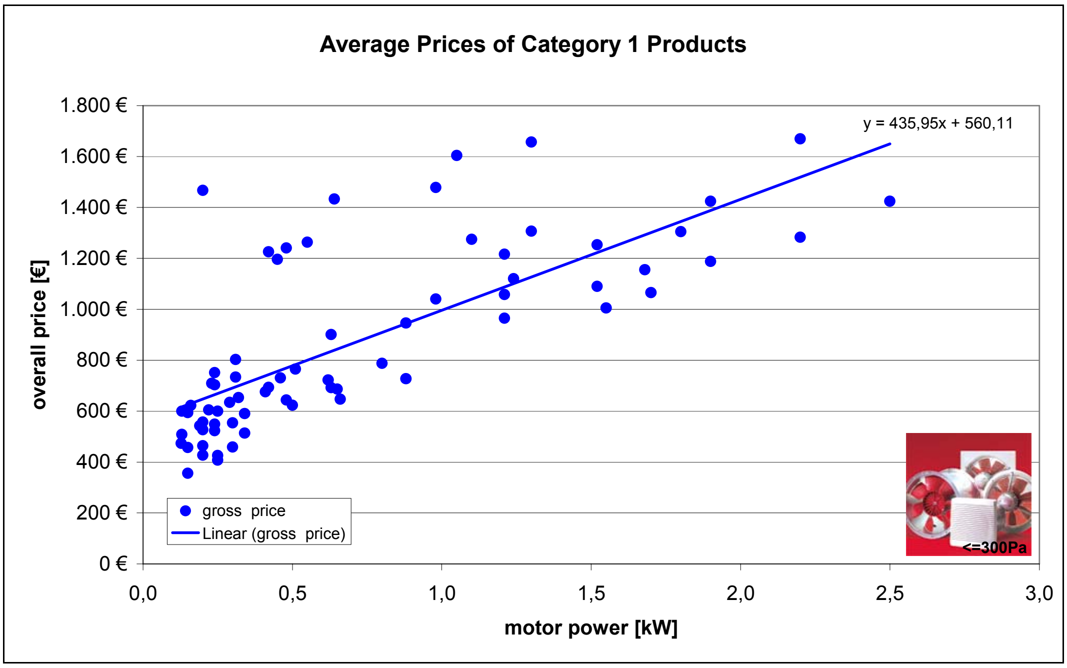


Figure 28: Overall Prices of Category 1 Products [Source: Manufacturers' price lists]

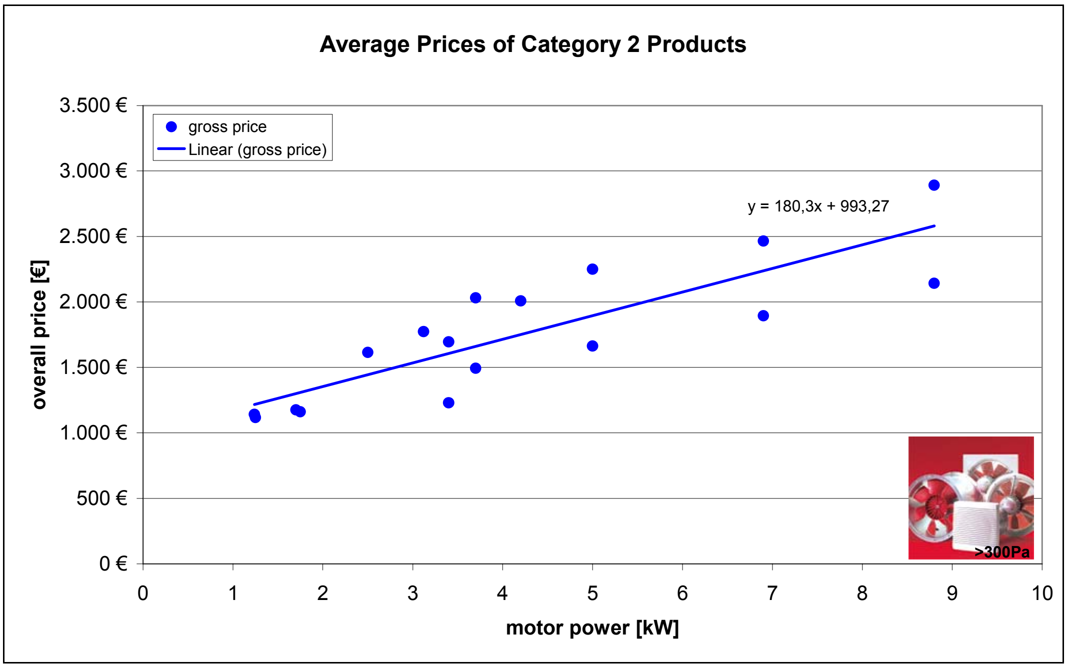


Figure 29: Overall Prices of Category 2 Products [Source: Manufacturers' price lists]

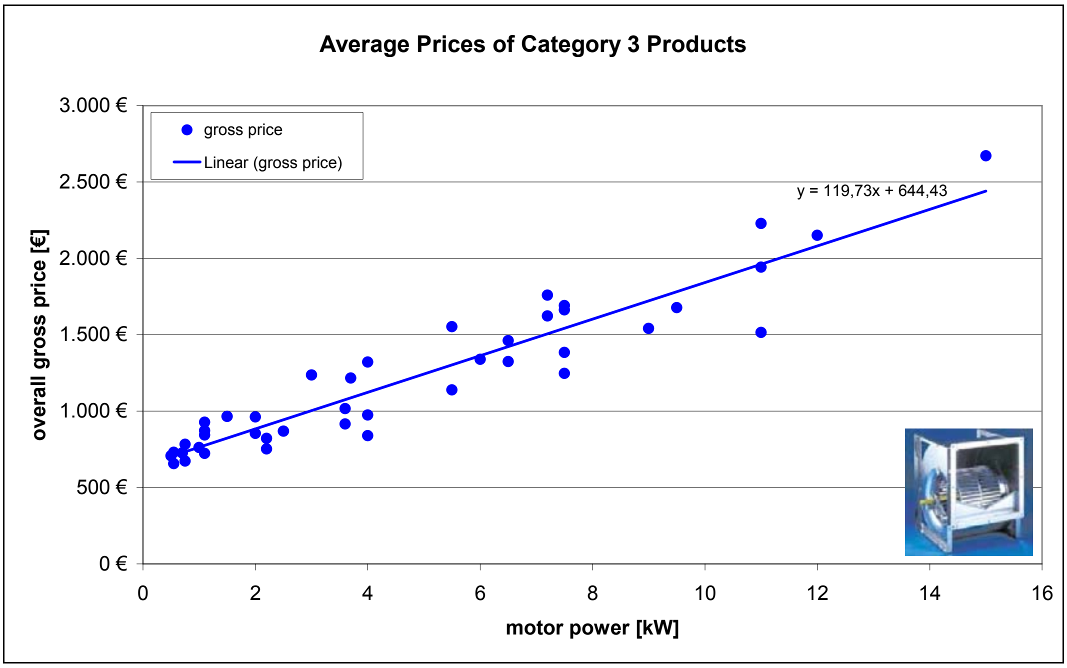


Figure 30: Overall Prices of Category 3 Products [Source: Manufacturers' price lists]

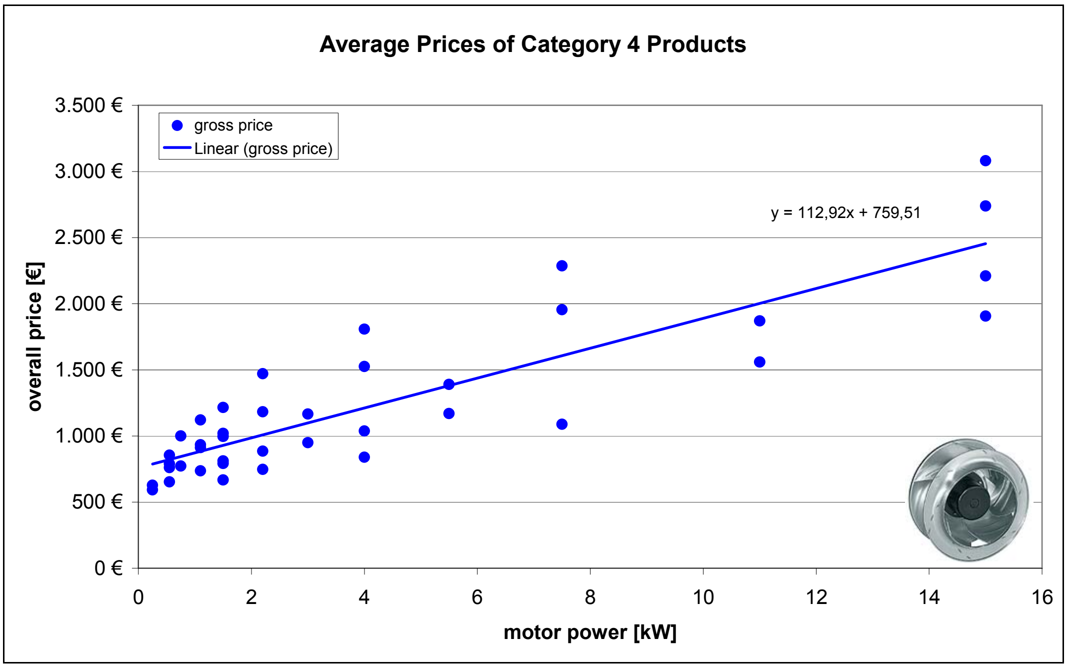


Figure 31: Overall Prices of Category 4 Products [Source: Manufacturers' price lists]

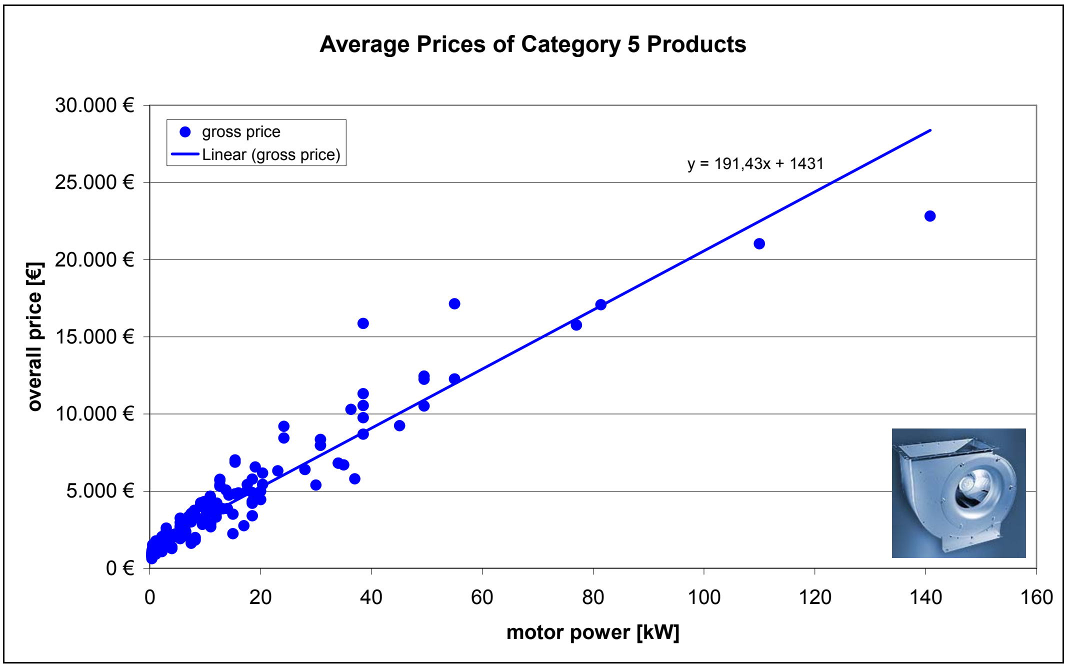


Figure 32: Overall Prices of Category 5 Products [Source: Manufacturers' price lists]

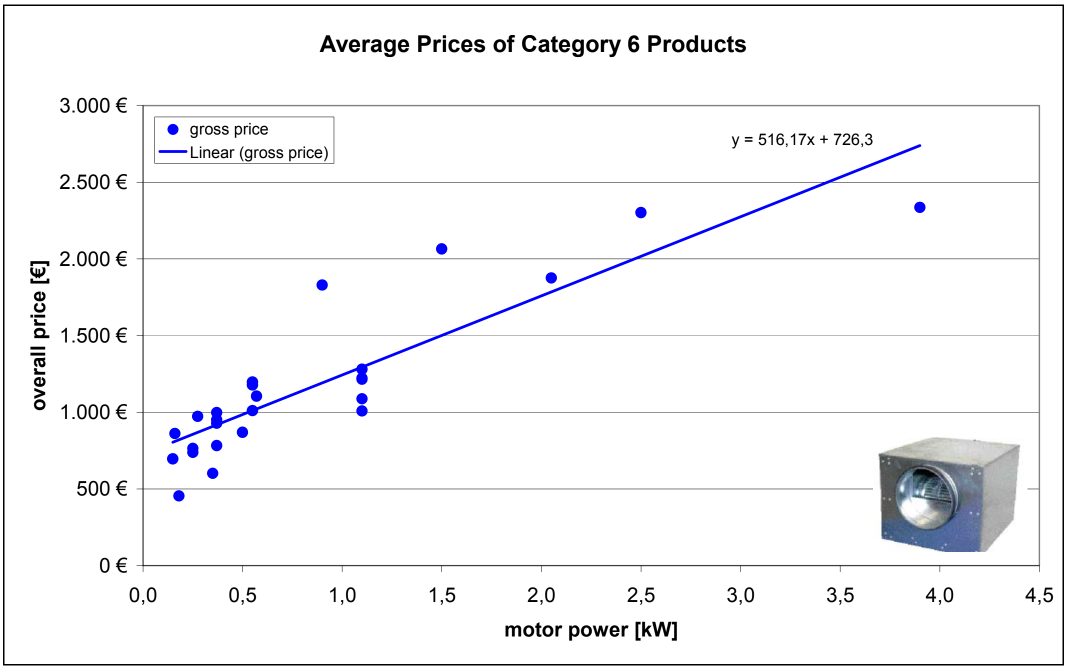


Figure 33: Overall Prices of Category 6 Products [Source: Manufacturers' price lists]

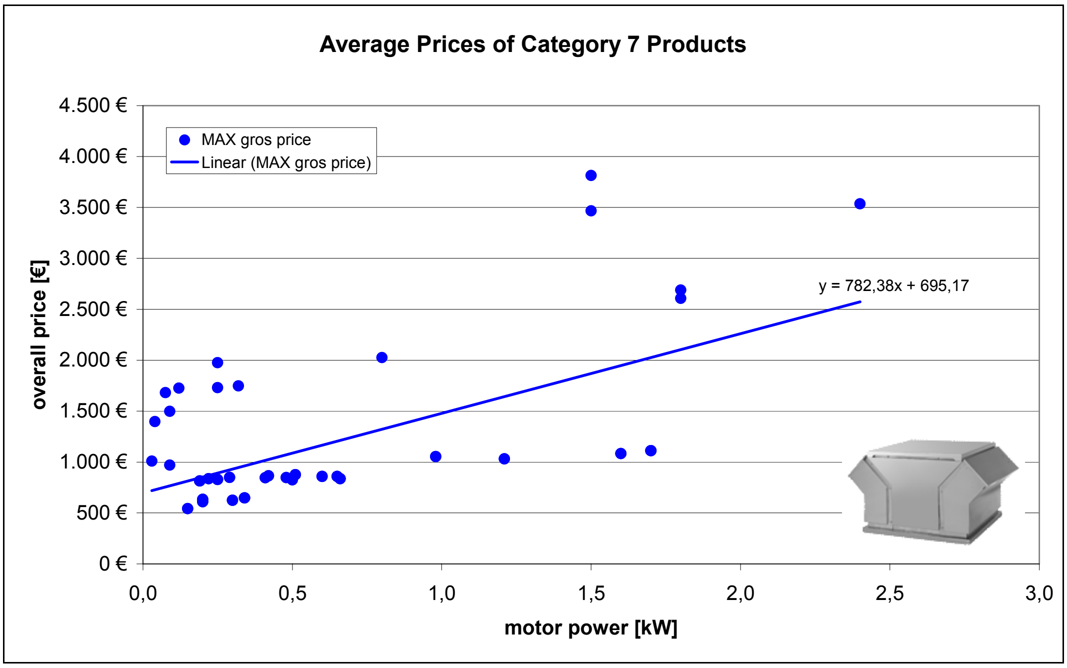


Figure 34: Overall Prices of Category 7 Products [Source: Manufacturers' price lists]

During the use phase energy cost of a fan depends on energy consumption and electricity price. Based on data available for past years [BMWA, 2005] average electricity prices in Europe are estimated to be at around 0.15 €/kWh (households) or 0.07 €/kWh (industry). In the latest publication of Eurostat, an electricity price for household consumers is given for EU-27 with 0.1067 Euro/kWh (2006) and for industry with 0.0752 Euro/kWh (2006). The electricity price used in the calculations had been harmonised between the sub studies in lot 11. However there is no special electricity rate for the tertiary sector, in which the products of the sub study are used. We have therefore decided to use the electricity rates for industry, bearing in mind that the rates in the tertiary sector are typically a bit higher than in industry. Based on the average electricity rate in industry in EU-27 as given by Eurostat, Table 40 summarises electricity rates used in this study.

Table 40: Electricity rates used in this study

Base case electricity rate	7.5 ct/kWh
High price scenario electricity rate	15 ct/kWh
Low price scenario electricity rate	5 ct/kWh

When using the averaged electricity process throughout Europe life cycle costing can be however very different in the individual member states, as in 2006 the industrial electricity prices have been ranging from 4.09 ct/kWh in Latvia to 9.98 ct/kWh in Ireland, which is a difference of more than 100 % (Table 41). Therefore a sensitivity analysis of the results is made for changes in the electricity rates.

Table 41: Industrial electricity prices in Europe [Eurostat]

		2005	2006
EU (27 countries)		0.0673	0.0752
EU (25 countries)		0.0673	0.0755
EU (15 countries)		0.0682	0.0766
Euro area		:	:
Euro area (12 countries)		0.0714	0.0774
Belgium		0.0695	0.0830
Bulgaria		0.0429	0.0460
Czech Republic		0.0601	0.0731
Denmark		0.0646	0.0724
Germany (including ex-GDR from 1991)		0.0780	0.0871
Estonia		0.0472	0.0511
Ireland		0.0896	0.0998
Greece		0.0645	0.0668
Spain		0.0686	0.0721
France		0.0533	0.0533
Italy		0.0843	0.0934
Cyprus		0.0787	0.1114
Latvia		0.0409	0.0409
Lithuania		0.0498	0.0498
Luxembourg (Grand-Duché)		0.0752	0.0845
Hungary		0.0701	0.0753
Malta		0.0706	0.0711
Netherlands		0.0806	0.0855
Austria		0.0621	0.0653
Poland		0.0506	0.0543
Portugal		0.0713	0.0817
Romania		0.0769	0.0773
Slovenia		0.0611	0.0651
Slovakia		0.0703	0.0773
Finland		0.0527	0.0517
Sweden		0.0462	0.0587
United Kingdom		0.0570	0.0799
Croatia		0.0556	0.0596

Summary Chapter 2:

- Eurostat statistics for the relevant Prodcom numbers highly incomplete and faulty
- For some EU countries statistics leads to negative apparent consumption of products
- Number of fans per product category calculated based on a transparent model due to the fact that much statistical information is missing.
- Collection of data from Eurostat, Eurovent and national statistics

3 Consumer Analysis and Local Infrastructure

Fans for non residential buildings are applied in commercial, industrial and agriculture buildings. The user and/or uses of the ventilation fans in these three areas are quite different. In the commercial sector, the building owner and the business owner is often not the same, meaning that the first have to pay the investment for the fan and the second has to pay the electricity and maintenance bill during operation, given little incentive to look for high efficient fans. For the industrial buildings one of the main barriers for investments in high efficiency fans is the competition with investments in production technologies. Even if fans for ventilation should be handled as infrastructure, pay back rates are typically required which are very low (typically below 24 month), even if the fan will operate for the next 10 years in the system. Table 42 summarises some of the important differences.

Table 42: Consumer behaviour for ventilation

	Industrial Ventilation	**Commercial Ventilation**	**Agriculture Ventilation**
Owner structure	purchase and operate	purchase	purchase and operate
Company type (purchase)	mainly SME	large companies	single persons and SME, some large companies
Pay back requirements	typically 6-24 month	typically lowest investment	typically 24-60 month

Besides the different consumer behaviours it is also very important to understand the different actors which are involved when dealing with the different product categories as defined in chapter 1.1.5. The product categories had been defined based on functional parameters of the product. The products however do not have the same kind of customers. The two main categories of customers are final end users and OEM's. Whereas the first will not only pay for the product but also for the operating costs on the long run the second group of customers is typically more interested in the first cost of the product. A manufacturer of an air handling unit is often selected based on price only, therefore he has an interest to include products as cheap as possible even at the cost of much lower efficiencies. The remaining question is whether minimum efficiency standards should be set for the component fan separately or should only the final product (e.g. the air handling unit) be regulated. For domestic appliances so far only the product (e.g. washing machine) is labelled and might be subject to MEPS but not the individual components such as pumps, fans or motors. However especially for the OEM market MEPS seems to be the only way to achieve a push in efficiencies.

For the end user products however, customers are much more sensitive to energy efficiency issues. Life cycle cost calculations are becoming more popular and therefore MEPS can fasten the knowledge and uptake of more efficient product.

Table 43: Typical customers for each type of product

Product Category	Direction of flow	Type	Typical Customer
1	Axial	<= 300 Pa (static pressure)	End user
2	Axial	> 300 Pa (static pressure)	End user/OEM
3	Centrifugal	forward curved (with housing)	OEM
4	Centrifugal	backward curved (free-wheel)	OEM
5	Centrifugal	backward curved (with scroll housing)	OEM
6	Other	Box fans	End user
7	Other	Roof fans	End user
8	Other	Cross-flow fans	End user

3.1 Real life efficiency

The overall efficiency of a fan product will be considerably less than the peak efficiency of the fan wheel alone due to losses in transmissions, motors and control. Moreover, the fan may be selected at a duty point other than that for its peak efficiency, in the interest of cost, size; outlet velocity, noise etc. (see also Table 3). Typically fans in use are over-dimensioned leading to lower efficiencies than would actually be possible.

Usually, the working point of a fan is given in terms of volume flow and pressure rise at a given rotational speed. The line containing all the operating points forms the performance or characteristic curve of the fan (Figure 35). Normally, a fan operates in a system that also has a characteristic curve in terms of volume flow and pressure drop. The matching of the two characteristic curves determines the operating point of a given fan in a given system [Radgen, 2002].

Manufacturers offer sophisticated software for the selection of appropriate fans. However the correct selection requires that the behaviour of the building HVAC system is perfectly known in terms of pressure losses and air demand. If the fans are selected on wrong assumptions, the fan could in practice operate far away from its design point and will therefore operate at a much lower efficiency than was calculated during the selection.

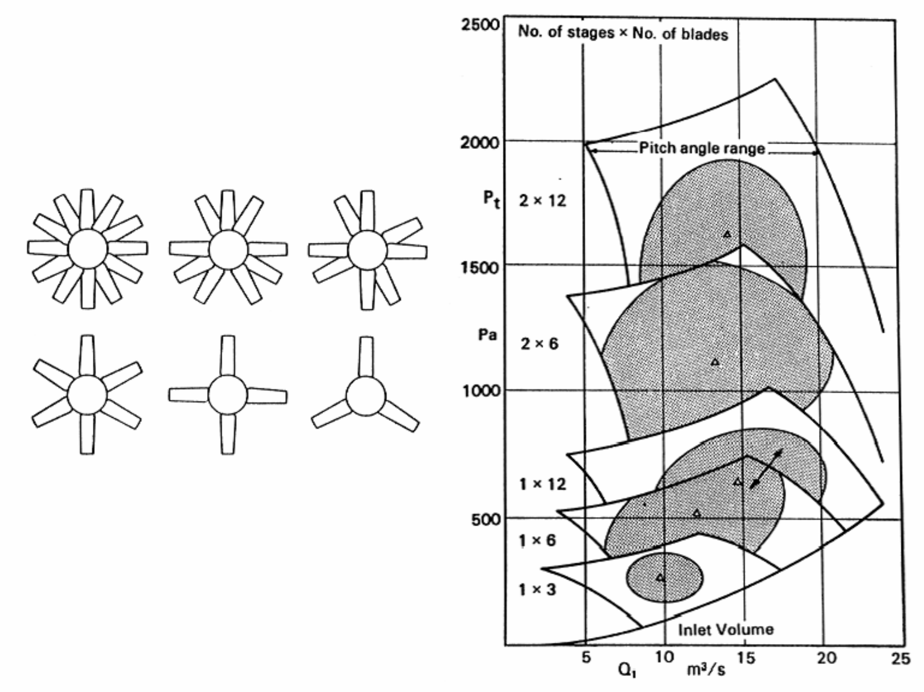


Figure 35: Comparison of performance curves for different blade and stage numbers [Radgen, 2002]

3.2 End-of-life behaviour

3.2.1 Repair and maintenance practice

Proper cleaning and servicing of fans is important as efficiency of fan and motor will both deteriorate if this is not carried out. Thereby, aspects of maintenance should already be taken into account when selecting the fan. Generally, inspection and maintenance should be carried out at regular periods. Frequency and scope of inspection measures depend on the type as well as the operating conditions of a fan, which can vary widely. Issues such as vibration, pressure and power consumption should be checked at every inspection. If deviations from normal operation are observed, additional investigation should be carried out [Cory, 2005].

Table 44 summarizes possible measures for routine maintenance.

Table 44: Routine maintenance for fans [Cory, 2005]

Period	Measure
every shift	• When taking over plant at beginning of shift, operators should check that all bearings are cool.
every week	• Check for undue vibration. If present, stop fan at earliest opportunity, check impeller for any dirt build-up on the blades, and clean as necessary.
every 6 months	• Consult motor manufacturer's manual and carry out instructions • Examine V-belt pulleys for any chipping, tensions of rope or • Check coupling alignment and condition.
every 12 months	• Examine impellers, Fan bearings, inlet spigots/venture. Check V-belts and pulleys or coupling element(s). If any wear, replace as necessary. • Check clearance at impeller, level or shaft, and general alignment. Adjust as necessary. • Check all H.D. bolts for tightness. • Refer to motor and control gear manufacturer's maintenance instructions and act accordingly. • Grease-lubricated bearings should be cleaned out and grease renewed.

3.2.2 Present fractions to recycling, re-use and disposal

It is assumed that at their end-of-life, fans are usually disposed of without further use. However as the fan manufacturers are typically not involved in the actions at the end of life of the fan, no information is available. However as the materials use in the production of the fans can be recycled such as steel, aluminium or copper wire, a large share of the material is recovered for further use. Care should be taken for products that are containing electronic circuits such as fans with EC drives. However their number is still very small. Based on the fact that metals can be very easily recycled and that it will pay to recover the copper from the motor and the steel from the casing, wheel and the motor, products are typically getting dismantled at the scrap yard. However as the disposal has only a very small impact on the life cycle eco impact we are going to use the standard values as set in the model. This will give for the fans an overestimation of the impacts as lower recycling rates and therefore more waste production is assumed in the model.

3.3 Local infrastructure

The public infrastructure relevant in this section is the electricity supply system. Consequences for local infrastructure would only arise when improved fan efficiency and hence reduced fan power consumption leads to a reduced need for electrical infrastructure.

Fans for non residential applications can be easily transported with standard logistics. The cost of transport is small if larger numbers are transported at the same time. However care should be taken not to underestimate the cost of storing a large number of fans at a warehouse. So it will be typically not cost effective to store two types of the same product, only having different efficiencies and costs. Manufacturers have therefore developed their logistics often in such a way, that standard products can be delivered within 24 hours after the order has been placed.

Summary Chapter 3:

- Discussion of differences in consumer groups and behaviours for different products
- Fan products require regular inspection but only little spare parts
- Metallic material fractions are typically recycled at the end of life

4 Technical Analysis Existing Products

The technical analysis was conducted by using the EuP spreadsheet model. This requires input on production phase (Bill of Materials of the products), distribution phase, use phase (power input, life-time etc.) and end-of-life. For example, model runs have been made for an 800 mm axial fan driven by an AC motor with a power consumption of 1.6 kW, operating at 5,000 full load hours a year. For this fan the detailed bill of materials has been included in the Excel model. We analysed then the importance of the different phases of the lifetime on the resources and waste consumption and the emissions to air. Figure 36 shows the results of the model run.

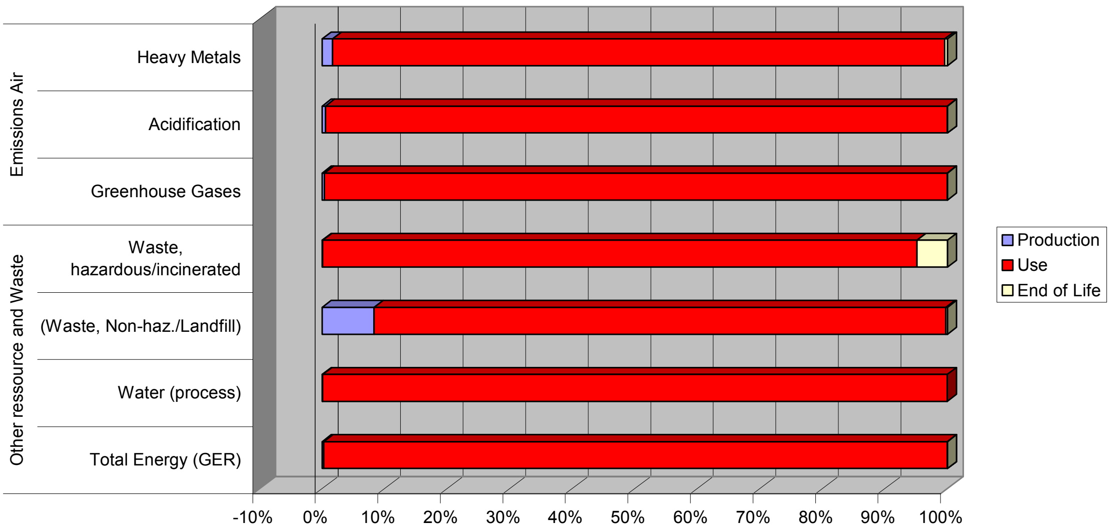


Figure 36: Share of the different life-cycle phases regarding the eco-impact of an axial fan

As can be clearly seen, more than 90 % of the eco-impact in all categories is coming from the use phase. Most of these emissions (e.g. heavy metals) are not caused by the fan itself, but are indirect emissions resulting from energy consumption during fan operation, i.e. the main part of the emissions can be assigned to the underlying power generation mix. Care should be taken when comparing the different categories of environmental impacts as they do not have all the same importance and this is explicitly beyond the scope of this study anyway. Absolute values will be given for the defined base case fans.

Due to the clear predominance of the use phase within the life-cycle in terms of eco-impact, the main focus for the analysis was on the use phase and not on the production, distribution or end of life phase.

4.1 Production phase

For the study we have been collecting the Bill of Materials (BOM) for different product types and sizes. However most manufacturers have not been able or have not been willing to provide the necessary data for the BOMs. Based on the data received, model

runs based on individual products had shown that the use phase and herein energy usage has the most important impact in ecological terms. For confidentiality reasons no detailed material input data or model results are provided here. The input and output data of the model runs for the average product of each category are included in the Annex. However based on catalogue data about the materials fans are made of, BOMs of different products were estimated. Even with a reduced precision of the BOMs, the total results will not be affected significantly due do the low importance of the production phase.

Data on the weight of the products is presented by product category in Figure 37 to Figure 44. It has to be pointed out that the diagram for product categories 3 and 5 fans also include data for belt driven fans which do not include the weight of the motor driving the fan. For these products the weight of motor has to be added to the weight of the fan. The diagrams with the product weight have been added to enable insight into the total material use depending on product size. A large share of the total weight of the products is related to the motor and is therefore mainly copper and other active material. As can be seen, for example in Figure 37 or Figure 43 fan products with motors with more poles are generally heavier. However, motors with more poles are usually advantageous in terms of noise.

Please note that the line indicated as „Logaritmisch (all)“ stands for logarithmical mean line based on all data points.

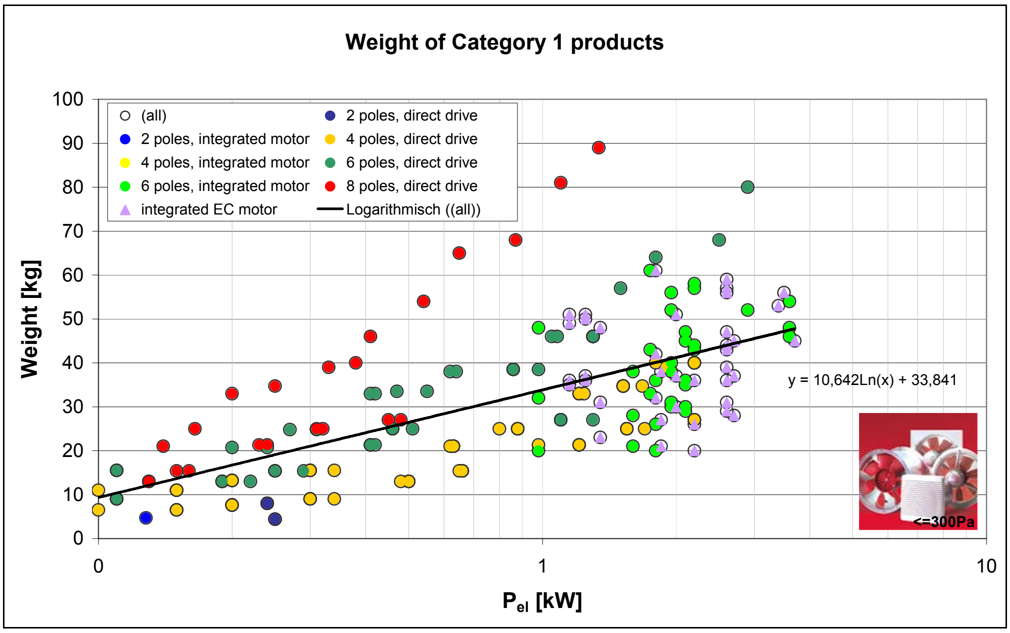


Figure 37: Weight of category 1 products over electrical power input [Source: Manufacturers' product catalogues]

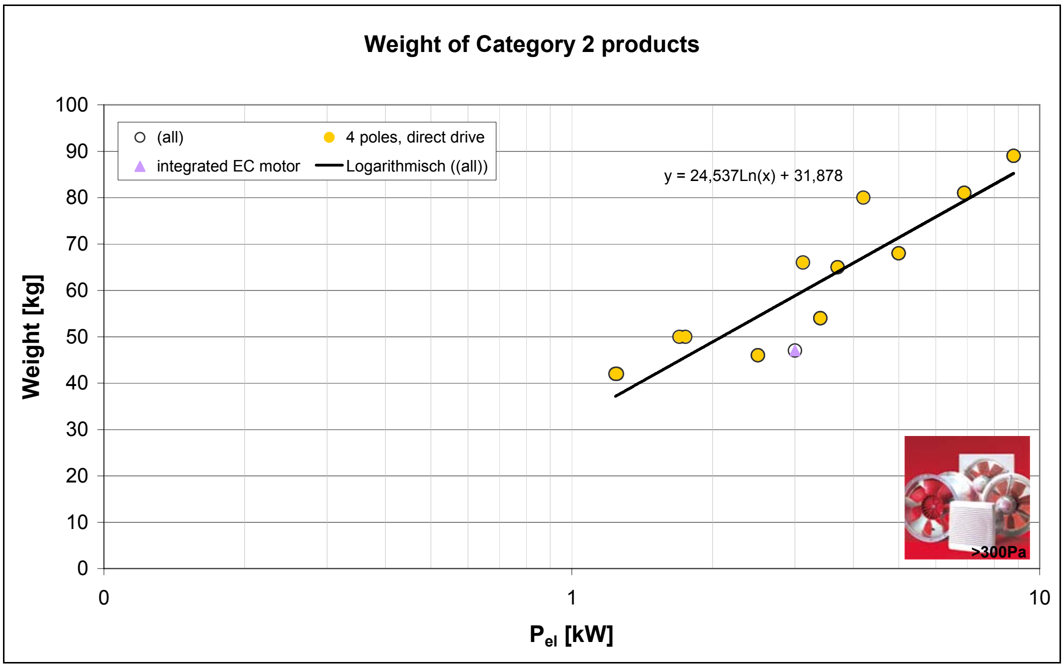


Figure 38: Weight of category 2 products over electrical power input [Source: Manufacturers' product catalogues]

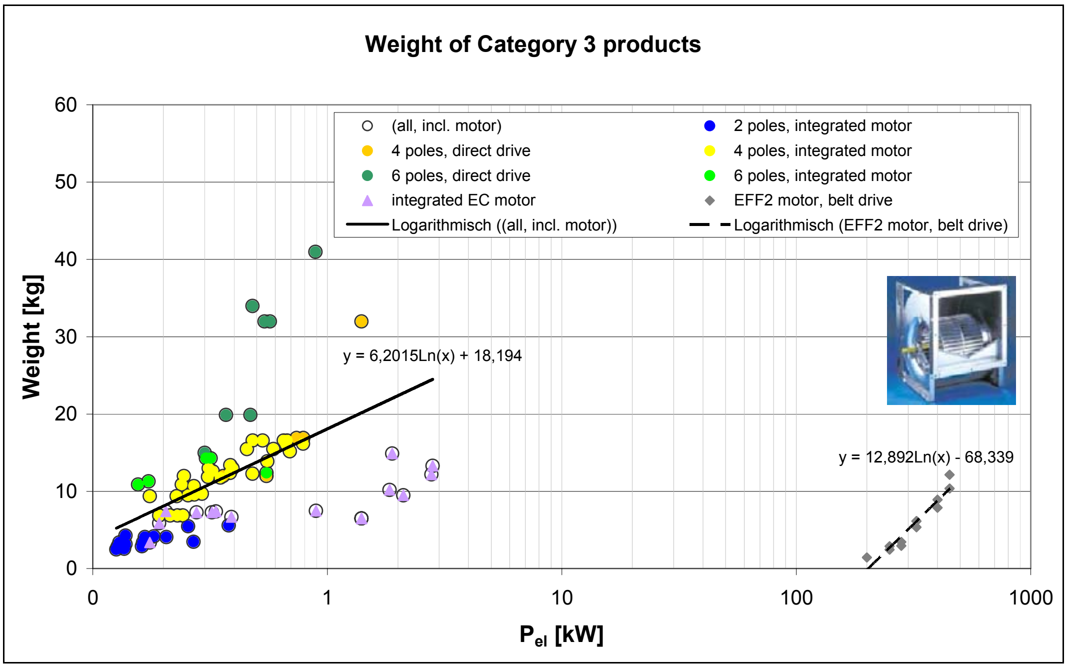


Figure 39: Weight of category 3 products over electrical power input [Source: Manufacturers' product catalogues]

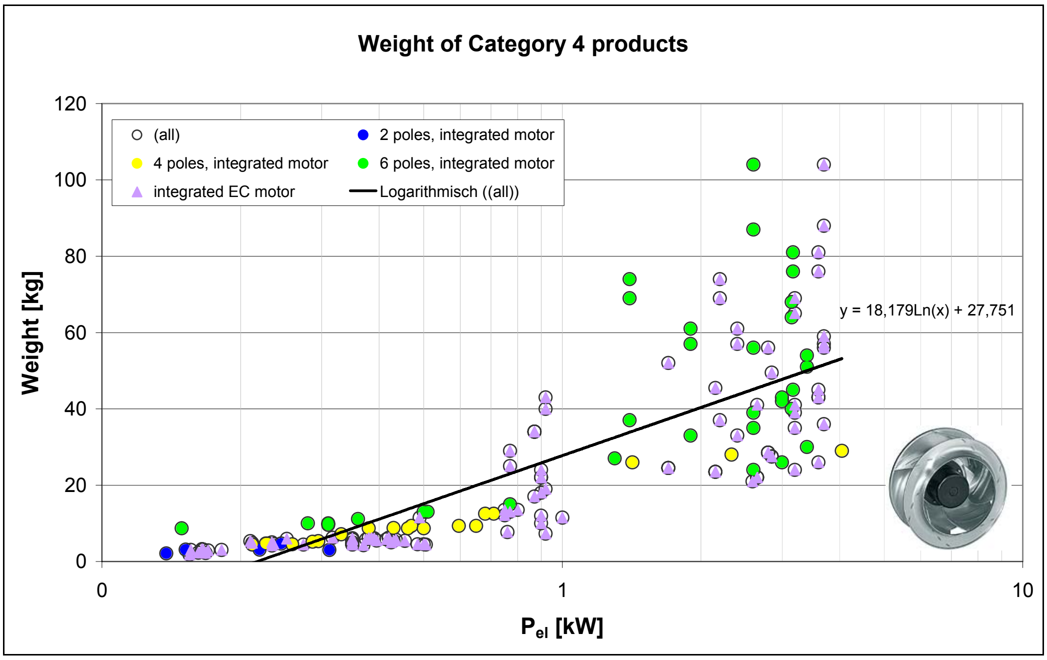


Figure 40: Weight of category 4 products over electrical power input [Source: Manufacturers' product catalogues]

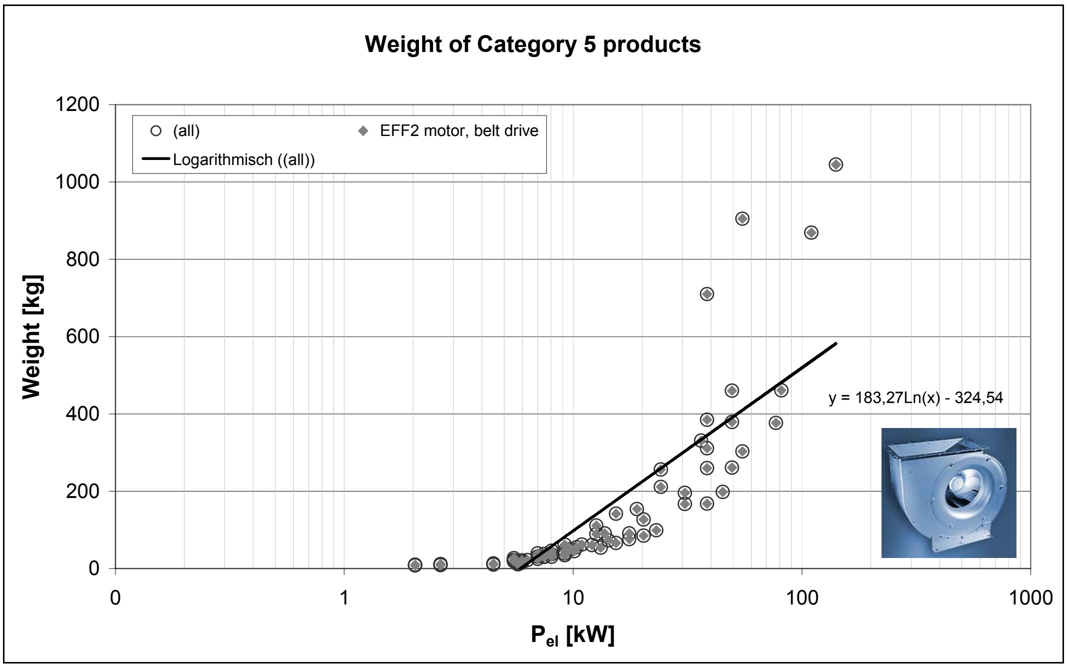


Figure 41: Weight of category 5 products over electrical power input [Source: Manufacturers' product catalogues]

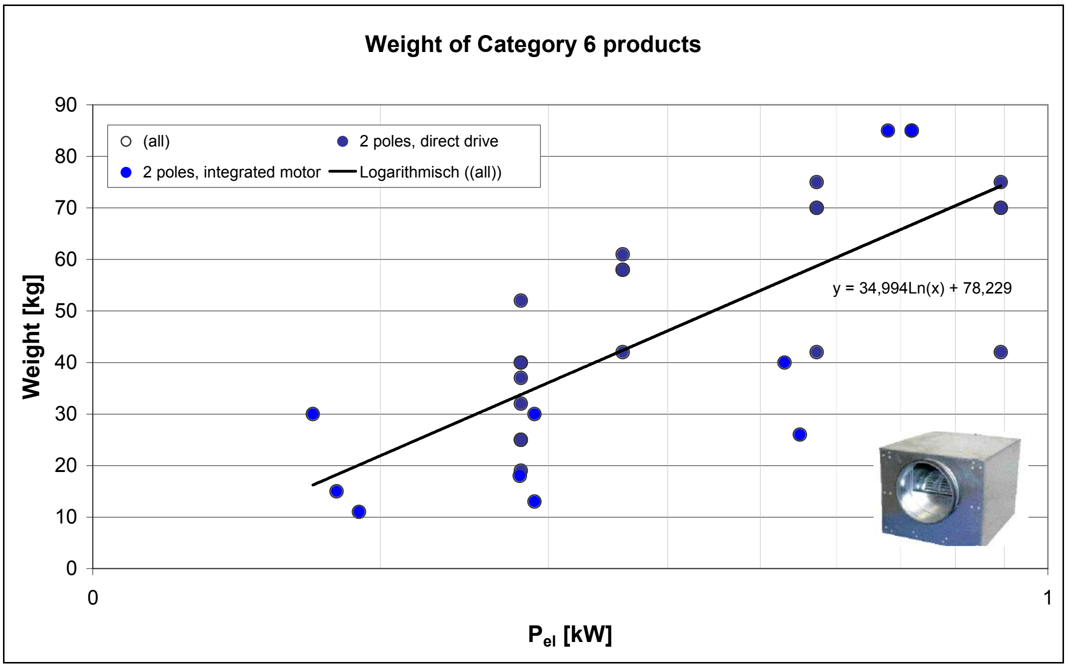


Figure 42: Weight of category 6 products over electrical power input [Source: Manufacturers' product catalogues]

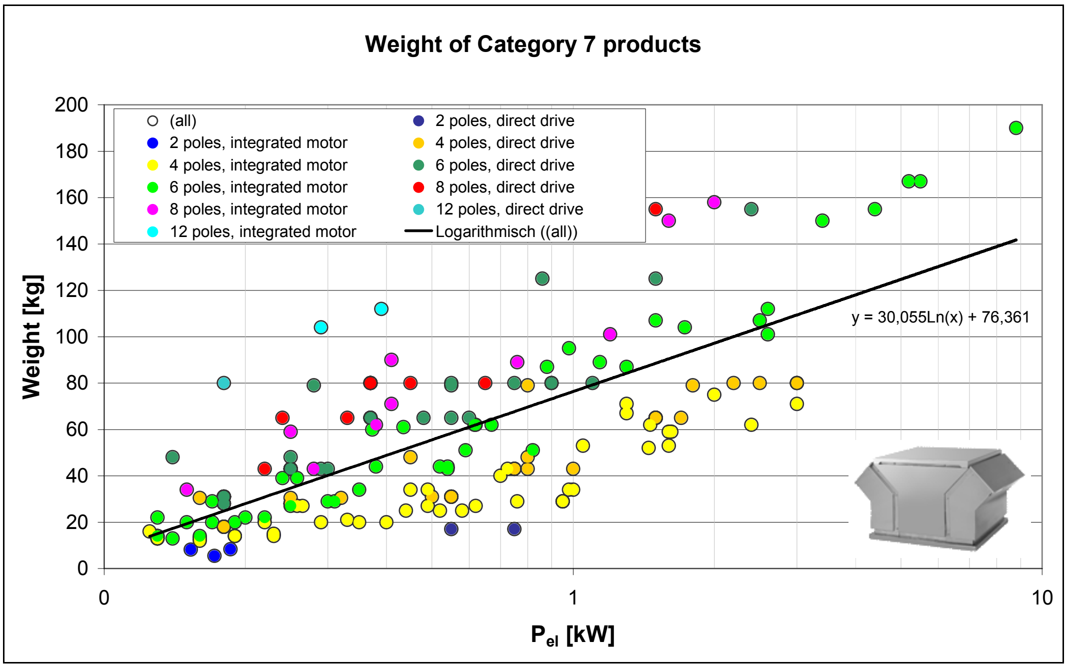


Figure 43: Weight of category 7 products over electrical power input [Source: Manufacturers' product catalogues]

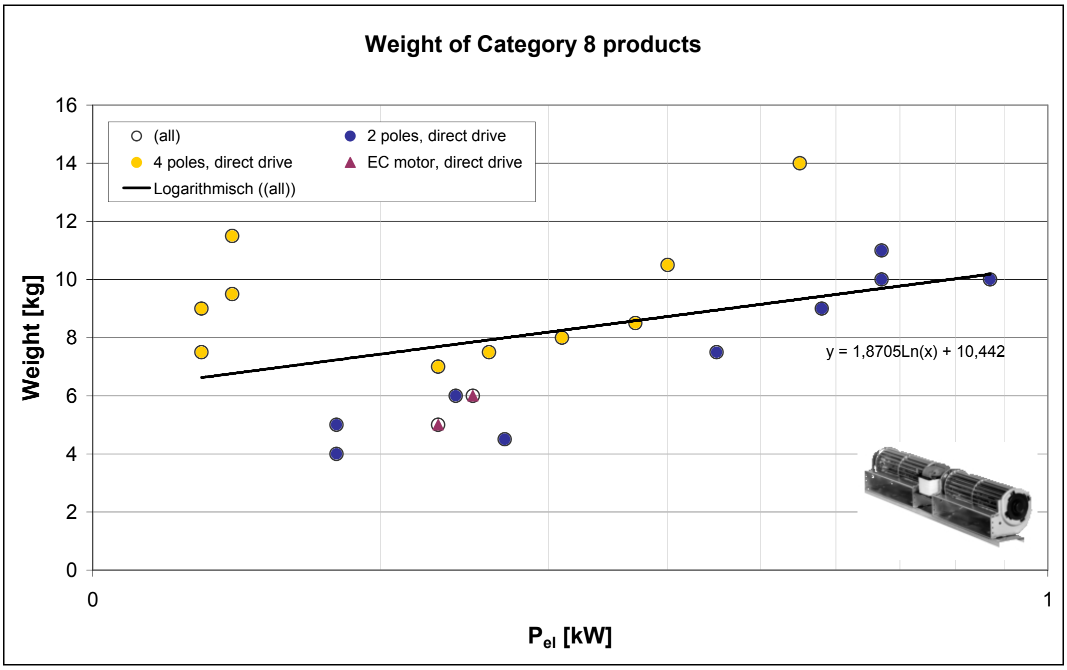


Figure 44: Weight of category 8 products over electrical power input [Source: Manufacturers' product catalogues]

4.2 Distribution phase

Type of packaging for distribution depends on destination of shipment, size of the fans and number of products to be shipped. Typically several units of fans are packaged in ferrous pallet cages, which are re-used many times. Wooden euro pallets are also used for shipment of one or more units. These can also be re-used. For shipment abroad wooden boxes are frequently used, which can contain not only one but several fans. It is assumed that within Europe these wooden boxes are also re-used. Outside Europe they are presumably scrapped or re-used for other purposes. Smaller fans (single units) can be packaged in cardboard boxes.

4.3 Use phase (product)

The performance of a fan cannot easily be described by a single figure. To the fan user there are mainly two quantities, which are of interest – the flow rate and the pressure rise. Both can vary over a wide range, but they do have a fixed relationship of one to the other, which is shown on the so-called characteristic curve of a fan. It will usually be plotted for a fixed rotational speed, although for some direct driven fans with integral motors an 'inherent-speed' curve may be preferred as with increasing load the motor may run more slowly.

For the characteristic curve usually the volumetric flow rate is plotted along the baseline (x axis) whilst the fan pressure rise is plotted as the ordinate (y axis). It is preferable to draw as additional ordinates the absorbed power, efficiency and noise level. For

both axial and centrifugal fans, the shape of these curves is very much dependent on the physical parameters of the impeller. Thus for centrifugal units, the blade inclination – forward curved, radial, backward curved etc. – is of importance as are the ratio of inlet to outside diameter and the axial width of the blades. With axial fans the hub to tip ratio and the blade configuration – chord length, pitch angle, solidity and vortex design (forced, free or arbitrary) will all define the shape of the characteristic curve [Cory, 2005].

4.3.1 Fan efficiency

In general, the efficiency of a product is defined by the ratio of the useful work obtained to the required input power. The work done by a fan is the product of the flow rate (m^3/s) and the pressure rise (N/m^2 or Pa). The product is then obtained in W (watts). The efficiency can then be calculated by dividing the work done by the fan by the actual power absorbed in watts.

The power consumption depends on the requested air flow rate, the fan pressure and the efficiency of the fan components. Based on the product definition in this lot it includes the efficiency of the fan wheel, the transmission (if applicable), the motor and the control (if applicable).

$$P = \frac{Q \cdot p}{\eta_{fan} \cdot \eta_{transmission} \cdot \eta_{motor} \cdot \eta_{control}}$$

Where: Q = air flow rate (m^3/s)
p = fan pressure (kPa)
η_{fan} = fan efficiency
$\eta_{transmission}$ = transmission efficiency
η_{motor} = motor efficiency
$\eta_{control}$ = efficiency of fan control system

The peak efficiency of the fan lies at a specific point or duty on the characteristic curve, i.e. at a specific combination of volume flow and pressure rise. Where an additional efficiency curve is added the so-called 'best efficiency point' (b.e.p.) can be identified easily. At this point for a particular fan design the lowest power consumption is achieved. From an energy efficiency viewpoint this should also be the operating point of the fan. Additionally, good bearing, motor, transmission and control efficiencies are desirable in terms of energy efficiency [ISO/DIS 5801, 2005 (Annex E)].

Fans can however be operated at other points than b.e.p. For example, to reduce capital cost a smaller fan running at a higher rotational speed can be chosen, even if the efficiency will be lower and the noise level higher. Such duties will be to the right of the b.e.p. Less common is the choice of an oversized fan which will operate to the left of the b.e.p. when the fan could be 'stalled' with increased noise, vibration and unsteady flow.

As the overall efficiency of a fan product depends on all parts in the chain from motor drive to the fan, the final energy use of the fan is dependent on how well its components are matched, not just the fans peak efficiency. The overall efficiency is a multipli-

cation of all involved parts efficiencies, which means that the result always will be lower than the least efficient part of the chain, and that all parts are important.

In the following a short example for this is given: Starting with the fan and looking as an example at centrifugal fans with backward curved impeller blades, it can be seen in Figure 45 and Figure 46 that the peak efficiency of the fan would be high. But as the fan will not always be operating at this point, the efficiency will not always be so good.

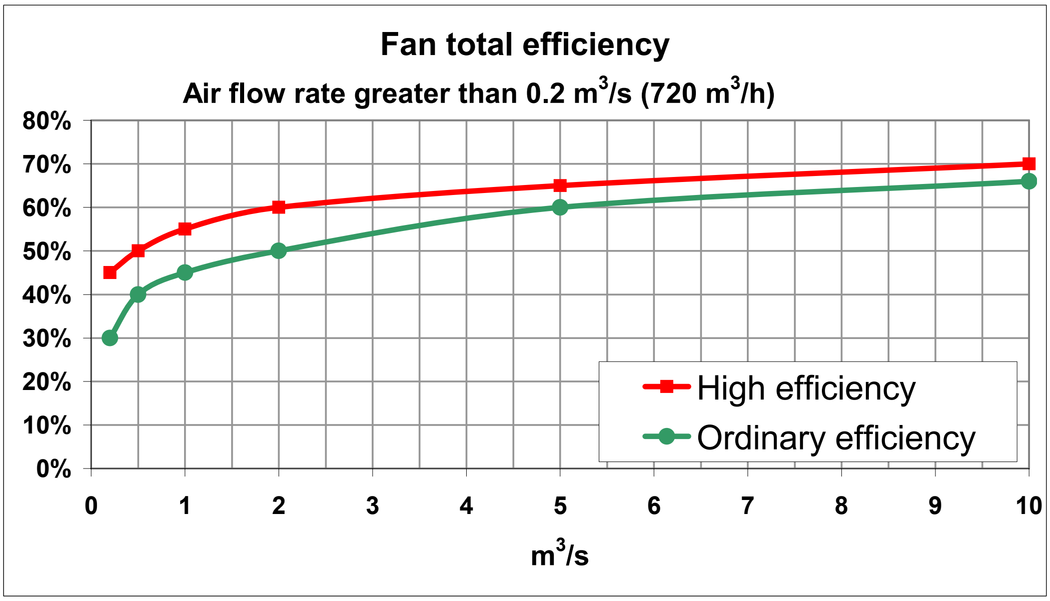


Figure 45: Peak load overall efficiency of a centrifugal fan at an air flow rate greater then 0.2 m3/s [Radgen, 2002]

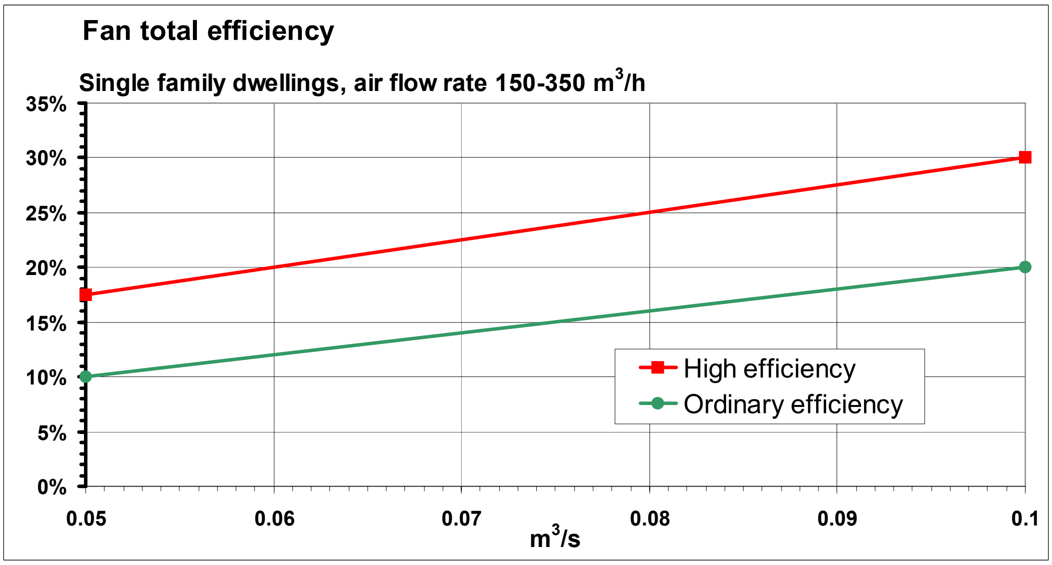


Figure 46: Peak load overall efficiency of a centrifugal fan (single family dwelling) [Radgen, 2002]

A common transmission used in fan drives is the V-belt drive. Its peak efficiency is, depending on the size of the drive in the region of 80 to 95 %. If the drive is used at part load, the efficiency will fall further, especially for smaller sizes. An example of a 2 kW V-belt drive is shown in Figure 47. It should be mentioned however that with modern raw edged belt drives correctly selected an efficiency of 95% should always be achievable. Often a minimum of 2 belts is specified when one would be sufficient. Also prevalent is over belting for direct on line starting. A 'soft' start and fewer belts would be preferable. Frequently over-belting is specified so that there is less need to ensure correct tension.

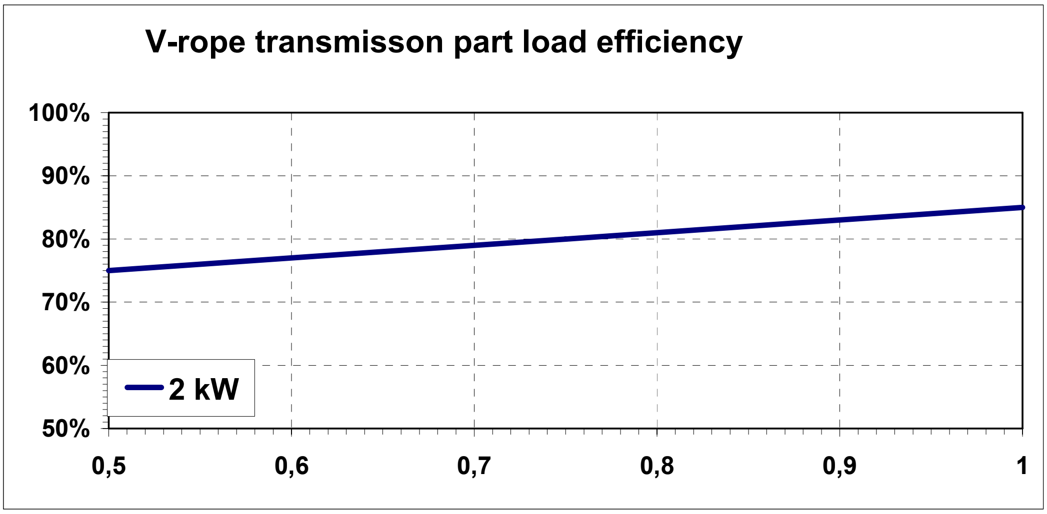


Figure 47: Part load efficiency of a 2 kW V-belt transmission [Radgen, 2002]

The motor peak efficiency is also very dependent on the size of the motor and could be in range of 65 % to 98 %. Figure 48 is an example of the part load characteristic of motors in the range 1 to 2 kW. The great influence of the operating conditions on all parts in the chain highlights the importance of good system design.

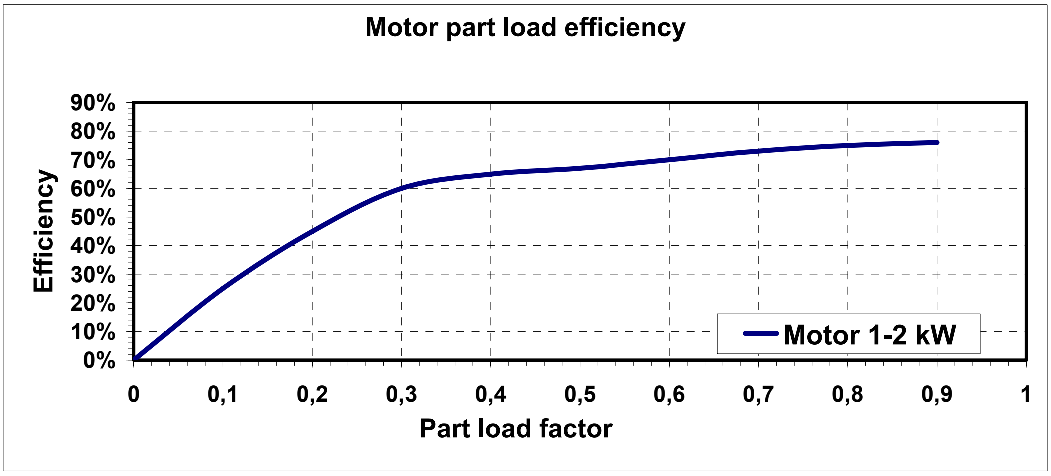


Figure 48: Motor part load efficiency [Radgen, 2002]

The following example shows how varying just one parameter can have a great effect on the overall system efficiency:

Assume that the designer of a fan drive, just to be on the safe side, increases the design air flow rate 30 %, just in case the need for air flow rate was miscalculated. As can be seen in Figure 49, when the flow rate increases from 1 to 1.3 m^3/s the pressure drop increases from 650 Pa to 1100 Pa.

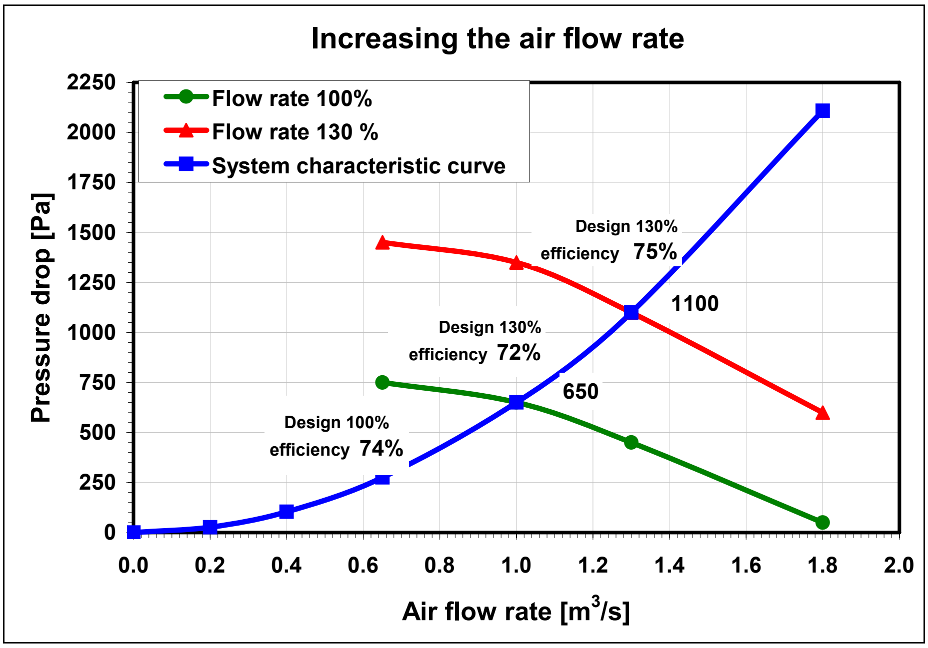


Figure 49: Increasing the air flow rate [Radgen, 2002]

As the power is derived from the airflow rate raised to the power of 3, the transmission and the motor have to be rated for a power 2.2 times higher. This means that when the fan will operate at 1 m^3/s the transmission and the motor will run at a part load of 45 % (1/2.2 x 100). In this case when the fan is designed to operate at 1.3 m^3/s but operating at 1 m^3/s its efficiency will be 3 % lower (75-72 %) at 1 m^3/s. But a well designed fan rated for 1 m^3/s would have an efficiency of 74 %, which means that the difference between the fan optimised for 1.3 m^3/s but operating at 1 m^3/s will be 2 % (74-72 %).

With reference to Table 45 and Table 46 and it can be seen that the transmission efficiency will drop from about 85 % to 75 %, and the motor efficiency from about 77 % to 70 % when running at 1 m^3/s. This means that the overall efficiency will drop from about 49 % to about 38 %, (table 14).

Table 45: Fan system efficiency away from the design point

Operation / design	Fan efficiency optimised 100 %	Transmission efficiency optimised 100 %	Motor efficiency optimised 100 %	Total efficiency optimised 100 %
100 % / 130 %	72 %	75 %	70 %	38 %
100 % / 100 %	74 %	85 %	77 %	48 %

The electric power required to run at 1 m^3/s will, due to the lower efficiency, rise from 1.33 to 1.7 kW, which is an increase of almost 30 % (28 %), (table 15).

Table 46: Energy saving potential by correct sizing of fan systems

air flow rate Q m/s	P_{motor} [kW] Design 100 %	P_{motor} [kW] Design 130 %	Increase %
1	1.33	1.7	28 %

With such a high increase in energy consumption the best thing to do is normally to change to a fan drive that is designed for the actual flow rate. One doesn't have to run many operating hours to pay for the replacement with a product with higher efficiency with the saved energy costs. If one will have the possibility to increase the flow rate in the future then it's often better to replace the fan drive when the higher airflow rate is needed.

To summarize it can be concluded that it is normally very cost effective to put great effort in to establishing the accurate operating conditions and to optimise all parts in the fan system. Too large safety margins or over sizing of the fan drive could be very expensive.

4.3.2 Efficiency characteristics of specific fan types

i. Axial flow fans

The most common variant of this type of fan comes in a direct driven form with an impeller mounted on the shaft extension of an air stream rated induction motor. The fan blades can be of either fixed or adjustable pitch and may be of aerofoil or curved plate section. Efficiencies at b.e.p. range between about 60 and 75 % according to size, tip clearance, vortex choice and pitch angle. The air leaves the impeller with a degree of swirl. In the more sophisticated fans this may be removed by guide vanes, which recover the swirl energy and convert it into useful static pressure. They thereby can increase the peak efficiency to about 85 % for the larger fan sizes.

ii. Propeller fans

These are a simplified form of axial fans which are for example used in the agricultural sector. Instead of a duct-type casing, they come in the form of a partition type fan and often are supplied with an integral motor. The overall efficiency varies widely according

to size and speed, operation usually being below the threshold Reynolds[19] Number for this type. Thus efficiencies below 30 % have been noted for the smaller fans (160 mm diameter) and up to 65 % for 800 mm diameter fans. Blades are usually of single thickness plate, but there has been a recent trend to aerofoil sections and scimitar shapes.

iii. Forward curved bladed centrifugal fans

These impellers are considerably smaller for a given duty than all other designs. Flow rates can be as high as 2.5 times that of the same size of backward bladed fan. This is not always an advantage as casing losses, which are a function of velocity squared, will therefore be six times as great. Thus with an impeller total efficiency of 92 % (the theoretical optimum), the fan efficiency would still be down to about 75 %. However even this figure is way above what is commercially available. On large indirect drive units the peak efficiency seems to be about 65 %. However the performance of the smaller fans manufactured for fan coil unites and for ‘boxed’ extract fans diverge considerable from the fan laws. Strict geometric similarity is difficult to maintain and absolute roughness also becomes a consideration. Indirect driven units of 160mm diameter have been noted with efficiencies as low as 40 %, especially where the impellers are of a simple ladder strip construction. Even smaller units down to 125mm diameter with integral inside out motors have been noted with overall efficiencies as low as 25 %.

iv. Backward curved bladed centrifugal fans

Fans of this type have the highest efficiencies but come with three sub-variants of the blades [Cory, 2005]:

1. flat backward inclined where efficiencies up to 80 % are possible
2. single thickness backward curved with efficiencies up to about 85 %
3. Aerofoil section backward curved with efficiencies up to 91 %.

Fans of this type are often used in double inlet double width (DIDW) form in Air Handling Units. They are able to develop pressures of up to 2000 Pa and have the non-overloading power characteristic required.

v. Roof extract units

These come with many different impeller types – propeller, axial, mixed flow or backward bladed centrifugal. Efficiency is usually less than for normal cased fans due to the increased tip clearances necessary and/or the absence of a volute to recover the high velocity pressure.

4.3.3 Efficiency Analysis

During our work we encountered a number of critical issues regarding the analysis of the use phase and in particular efficiency of fans which can in principle be handled in

---

19 In fluid mechanics, the Reynolds number is the ratio of inertial forces to viscous forces. It quantifies the relative importance of these two types of forces for given flow conditions. Thus, it is used to identify different flow regimes, such as laminar or turbulent flow.

different ways. These ways are all technically sound and there are always good arguments to take one approach or the other. However, the overall target of the EuP approach should be kept in mind when making a decision for one approach or the other.

The main critical issues regarding efficiency analysis of fans are presented in the following, before efficiency data for the EuP fan categories are presented.

4.3.3.1 Efficiency over Specific Speed or Power

Fan efficiency data can be presented as a function of the specific speed or the electric power consumption. To decide on this issue we collected the advantages and disadvantages for both ways which are based on discussions with stakeholders and our own research. Table 47 lists the arguments for both approaches.

Table 47: Plotting efficiency over power or specific speed

	Plotting efficiency over power	**Plotting efficiency over specific speed**
Advantage	☺ Users are thinking in power or volume flow rather than specific fan speed ☺ Gives a clear relation to energy consumption of the product	☺ Is linked to fundamentals of fluid mechanics ☺ Is used for Chinese fan MEPS
Disadvantage	☹ leaves the relation between pressure and volume flow partly unclear	☹ interpretation of data typically only possible for fan experts

To get an even better understanding, Figure 50 shows as an example plot for the best efficiency point of a number of centrifugal fans from different manufacturers. In the upper part the static efficiency is plotted over the electric power consumption P1 and in the lower part as a function of the specific speed. The data points in the diagram with the specific speed are more clustered. More insight can be gained from the graph of efficiency over electric power consumption. In this diagram the spread of efficiencies for different products is different depending on the power size. For small power sizes the efficiency difference of similar products is much larger. This is strongly linked to the importance of motor efficiencies at smaller power. In the upper power range the possible benefit of improved products seems to be much smaller.

Based on our research have therefore come to the conclusion, that the power consumption is an adequate and appropriate way to be used to describe minimum energy performance standards for fans in each product category.

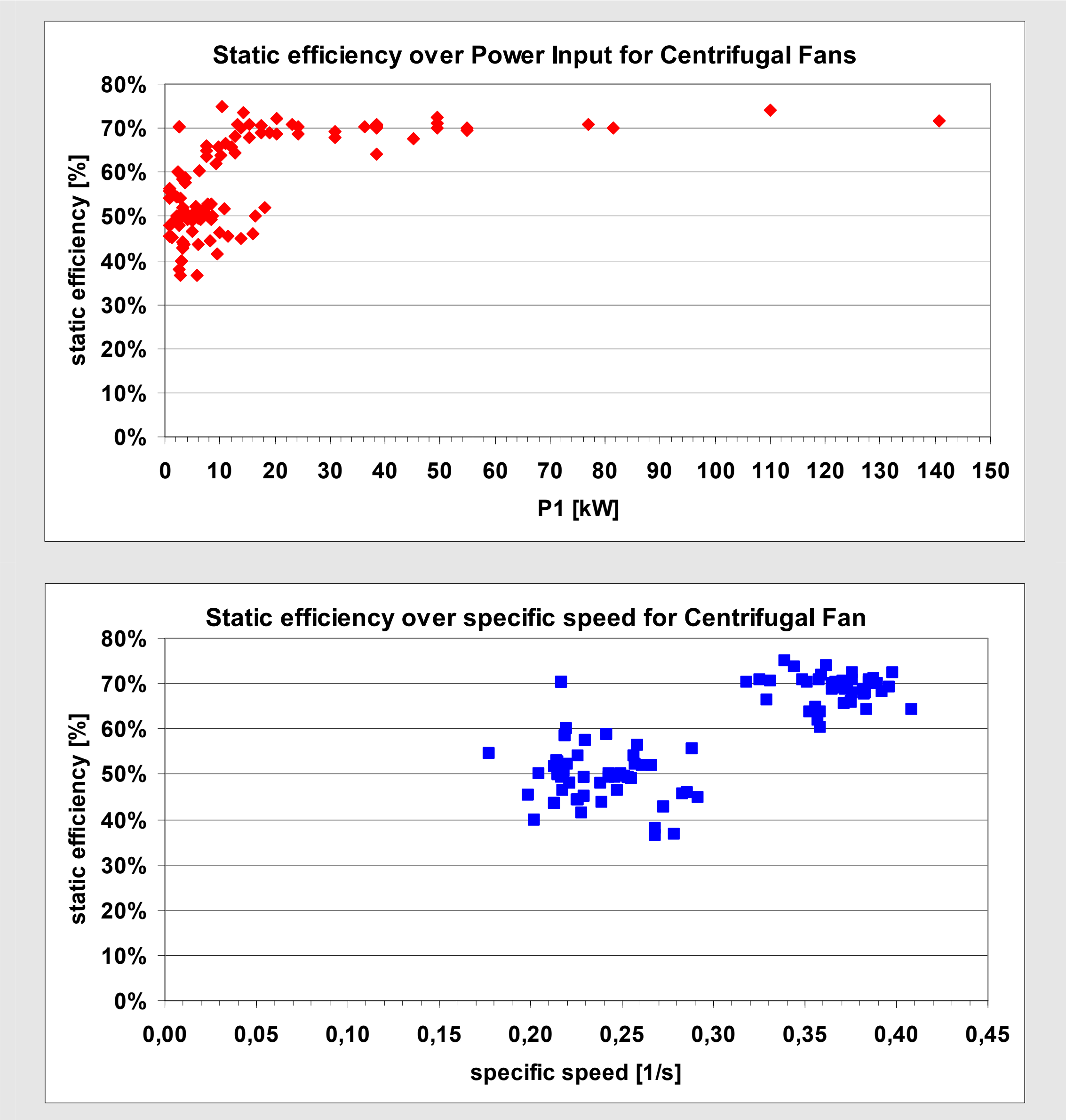


Figure 50: Example plot of data for centrifugal fans including transmission and motor (only best efficiency points)

4.3.3.2 Static efficiency or total efficiency

A second important point when analysing fans is the question, of whether the static pressure or the total pressure should be taken as the basis for the efficiency calculation. This question is more important for axial fans than for centrifugal fans, as the share of the dynamic pressure is much higher for axial fans with static pressure typically below 300 Pa. The advantage of using total pressure is the fact that it can only decrease, whereas the static pressure can increase and decrease through alterations in the fan and the fan system, depending on the dynamic pressure.

The dynamic pressure caused by the airflow can be converted into static pressure by a diffuser. However, in the context of the EuP Directive the fan is analysed as the product without the additional components downstream, i.e. the dynamic part of the pressure is always lost. For example a centrifugal free wheel installed in an air handling unit will have a dynamic and a static pressure at the outlet of the fan. The air is released into a larger chamber of the air handling unit; therefore the dynamic part is fully lost. On the other hand, for fans which do not have to work against a large pressure difference (free air flow) such as air extract units the static pressure and therefore the static efficiency will be rather small. Table 48 summarizes the arguments for the use of static or total efficiency.

Table 48: Using static or total efficiency for comparison of products

	Static Efficiency (based on static pressure)	**Total Efficiency (based on total pressure)**
Advantage	☺ Static pressure typically used for fan selection ⇨ linked to static efficiency ☺ used in a large number of manufacturers catalogues ☺ Pinpoints more clearly high efficiency products ☺ Can be calculated from catalogue data	☺ decreases only ☺ seems to be preferred in ISO 5801 but static and total pressure included
Disadvantage	☹ can increase or decrease in the system ☹ can be at some operating points zero for free air delivery (e.g. exhaust fans) ☹ Will lead to lower efficiencies which could lead to controversial discussions about products	☹ Can be manipulated e.g. by changing tip to hub ratio of axial fans ☹ Energy content of the dynamic pressure is typically lost in the system without any further use

In our view the most important point to be taken into consideration is the fan selection approach which should be in line with the efficiencies. As the selection process for ventilation fans is typically based on the static pressure, which the fan has to deliver to overcome the resistance of the system, it seems to be more logical to use the static efficiency for the MEPS. This is also supported by the fact that a large number of fan manufacturers present in their product catalogues data based on static pressure. However as the dynamic pressure is more important for the axial fans, care should be taken that the lower static efficiency values of axial fans are not misinterpreted in such a way, that they are generally less efficient. Even very good products will have efficiencies which are not very high. It should also be noted that if static efficiency is used, then the test configuration must be stated, as static pressure varies considerably according to installation category (free inlet/free outlet; ducted inlet/free outlet; free inlet/ducted outlet; ducted inlet/ducted outlet).

4.3.3.3 Peak efficiency only or mix of operating points

As it is well known, fans typically do not operate at their best efficiency point as air requirements in ventilation systems vary not only by season of the year or outside temperature but also by occupancy and technical equipment (such as PC, Server, printing, lighting). Therefore the ventilation system typically is working at different operating points during the year. For the overall efficiency of the fan this means that not only a high peak efficiency at the design point is important but also to have high efficiencies at part load conditions. However the concept of labelling only peak efficiencies is already well known and used for electric motors. It would also avoid defining the relevant part load conditions which in the context of non-residential building ventilation could be quite different for a theatre, a lecture hall or a department store (see also chapter 4.3.4). Table 49 summarizes argument for both approaches.

Table 49: Peak efficiency or average efficiency at different operating points

	Using only peak efficiency for labelling/MEPS	**Using efficiencies at different load levels for labelling/MEPS**
Advantage	☺ More easily to be understood by „consumers“ ☺ Similar to other products such as electric motors ☺ Will be sufficient to achieve a push to higher efficiency products	☺ Will be closer to real use of the products ☺ Difficult to select relevant part load conditions
Disadvantage	☹ May discourage products with integrated speed control	☹ Requires more efforts for the determination of the data ☹ Difficult to handle if the motor is not included in the package tested, as efficiency drops are typically dominated by the motor and not the fan.

4.3.3.4 Efficiency Analysis of Existing Products

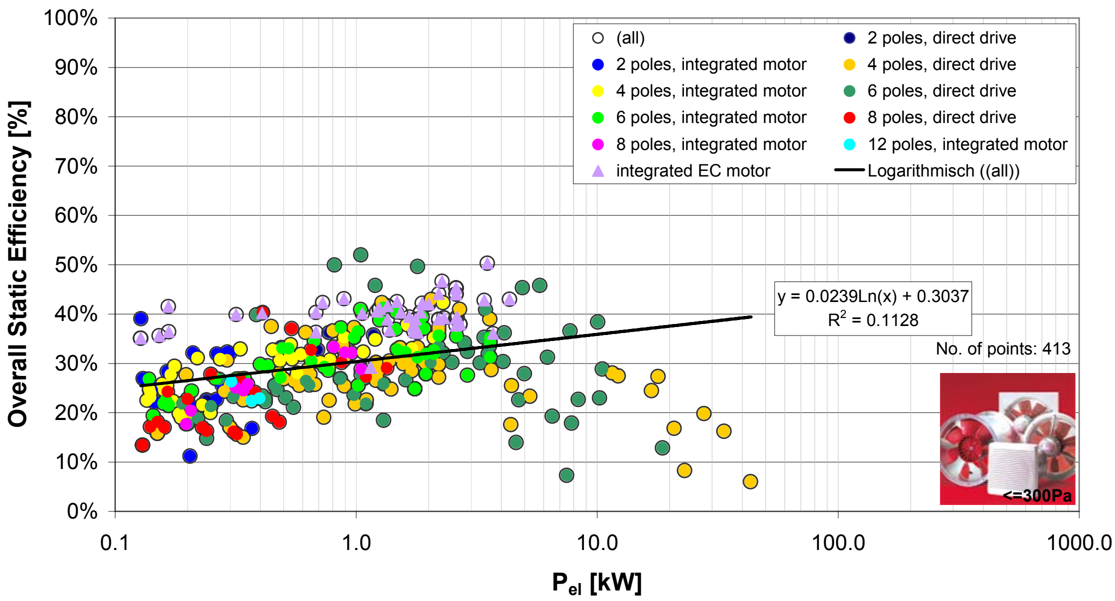
Based on the arguments discussed in the previous sections our decision has been to focus the efficiency analysis of existing fan products on overall static efficiency (i.e. fan efficiency incl. motor and transmission losses based on static pressure) over electrical power input to the motor (P_{el}) at the best efficiency point (BEP) of the fan.

In Figure 51 to Figure 58 overall static efficiency over electrical power input by EuP fan category are shown. The data for calculation of the efficiency points shown has been extracted from various catalogues of 9 different European fan manufacturers from Germany, Great Britain, Italy, Slovenia, Spain and Sweden. Additionally, in chapter 0 (Annex) efficiency data for the same products over fan size (impeller diameter or inlet diameter) is shown.

For category 1 products (axial fans, static pressure <=300 Pa, Figure 51) 413 products have been analysed and a large scatter of efficiency points can be observed. Efficiencies for products with the same power input can vary up to +-30 %-points. This large

diversion in efficiencies can lead to the conclusion that large efficiency improvement potentials are existent in currently used products. Furthermore it is noticeable that in Figure 51 for products with an electrical power input of approximately 4 kW and more a significant drop in overall static efficiency can be observed. For larger fans the proportion of the dynamic pressure typically increases.

Overall Static Efficiency of Category 1 Products



In addition their might be some data delivered by the manufacturers which do not give the best efficiency point but instead close to free outlet conditions. As manufacturers often use the total efficiency at free outlet conditions. In these cases the static pressure is zero or close to zero and the static efficiency is therefore low. So based on our knowledge we can assume that overall static efficiencies of larger fans are higher than shown in the data collected.

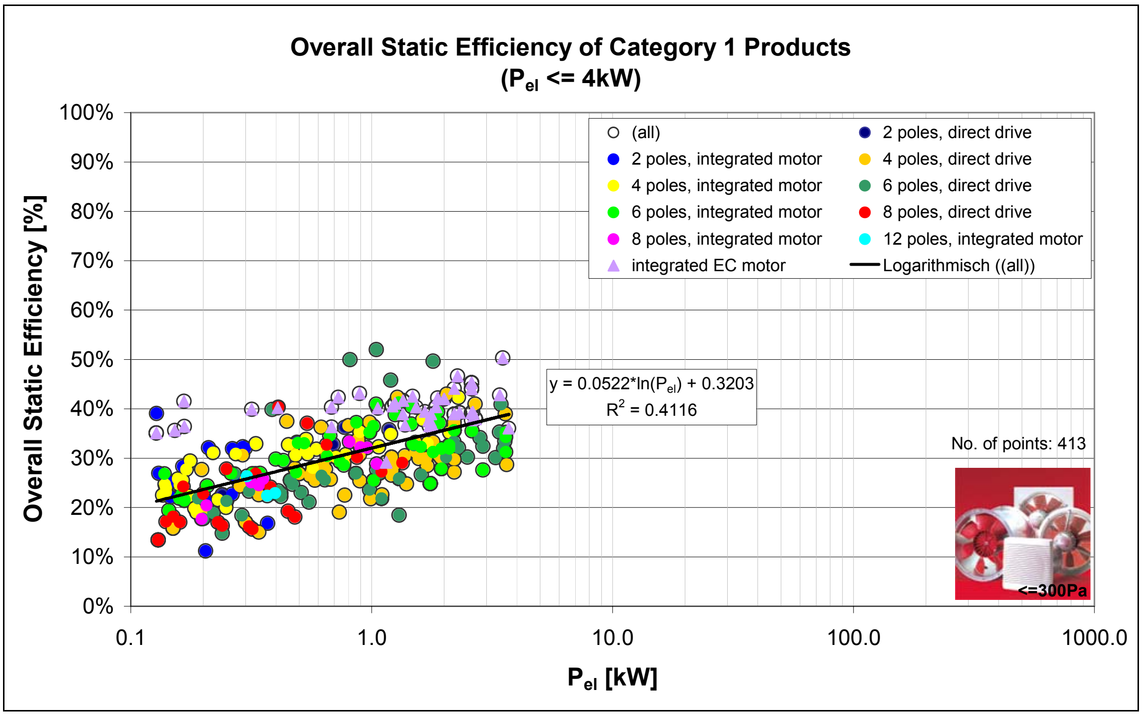


Figure 51: Overall static efficiency over electrical power input of existing category 1 fan products (axial fans, static pressure <= 300Pa)

In Figure 52 105 efficiency points for EuP category 2 (axial fans, static pressure > 300Pa) are shown. Looking at this picture it seems that efficiency tends to decrease with increasing power input, although not as strong as observed in Figure 51. As discussed for category 1, products above this could be due to the increasing proportion of dynamic pressure. However, the spread again is up to nearly 30 %-points for the same power input.

For category 3 products (centrifugal fans, forward curved blades, with housing) in Figure 53 152 efficiency points are shown. It can be seen that the spread is much wider for smaller products, whereas for larger products (approximately 2 kW and above) the efficiencies are closer. This might be due to the fact that the larger products analysed are mainly used with belt drive, where standard motors are used. On the contrary, for smaller products specialised fan motors are more commonly used.

For the centrifugal backward curved free wheel (category 4, Figure 54), which are mainly used in air handling units, the spread of points looks quite similar to the forward curved fans, although efficiencies are generally higher than for forward curved type of fan. For category 5 products (centrifugal, backward curved with scroll housing, Figure 55) 118 efficiency points for belt driven fans are shown. The efficiencies are more or less in the same range as for the backward curved without housing of the same power input with direct drive.

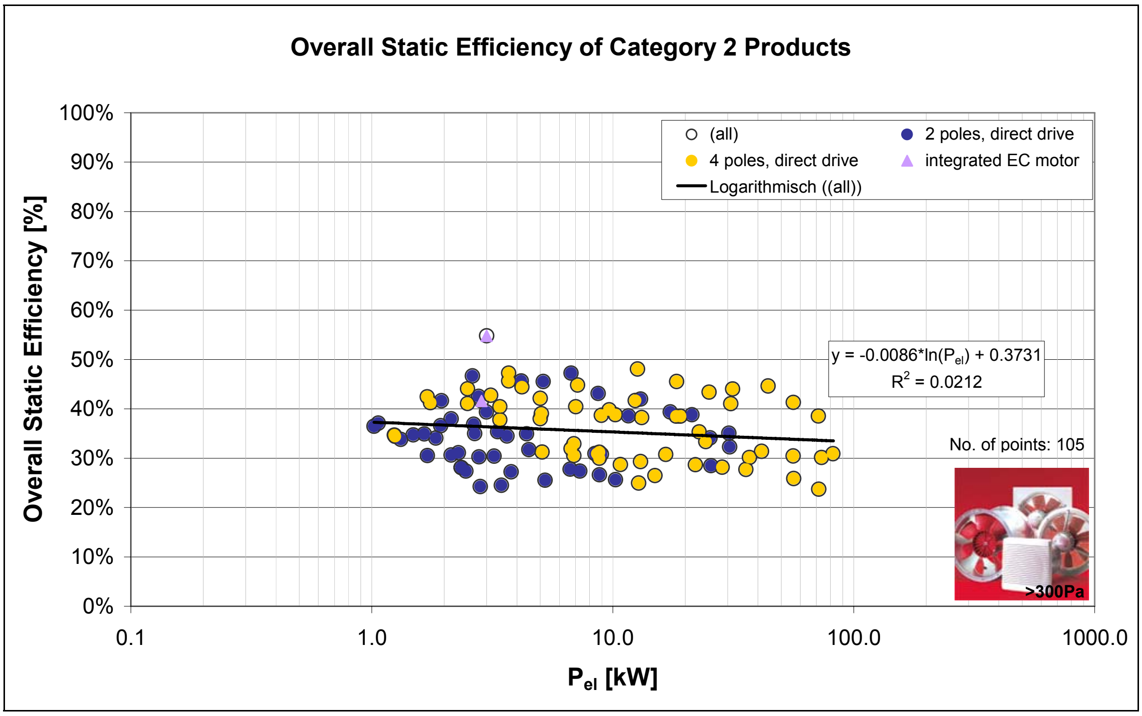


Figure 52: Overall static efficiency over electrical power input of existing category 2 fan products (axial fans, static pressure> 300Pa)

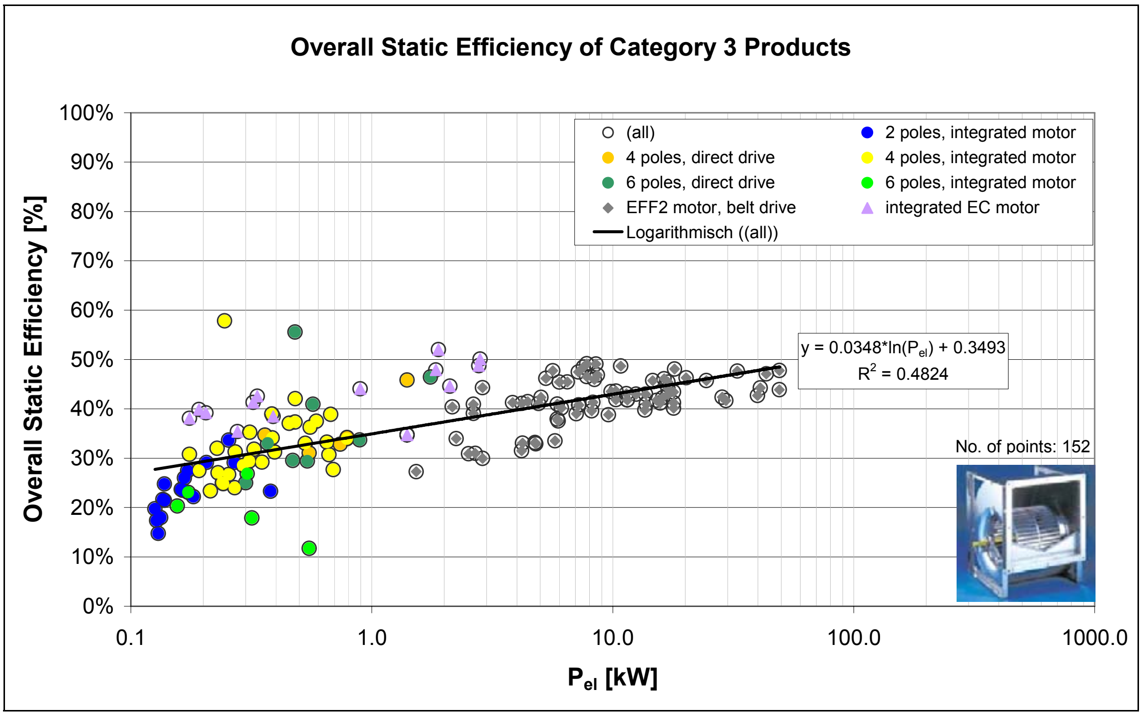


Figure 53: Overall static efficiency over electrical power input of existing category 3 fan products (centrifugal fans, forward curved blades, with housing)

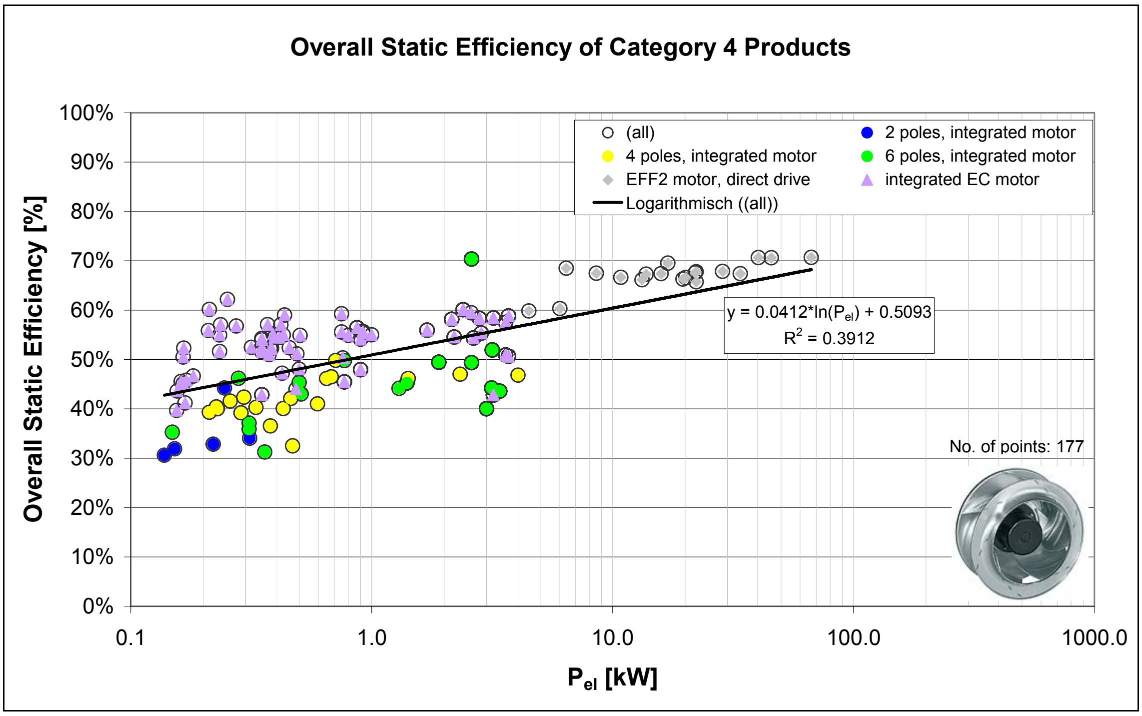


Figure 54: Overall static efficiency over electrical power input of existing category 4 fan products (centrifugal fans, backward curved blades, free wheel)

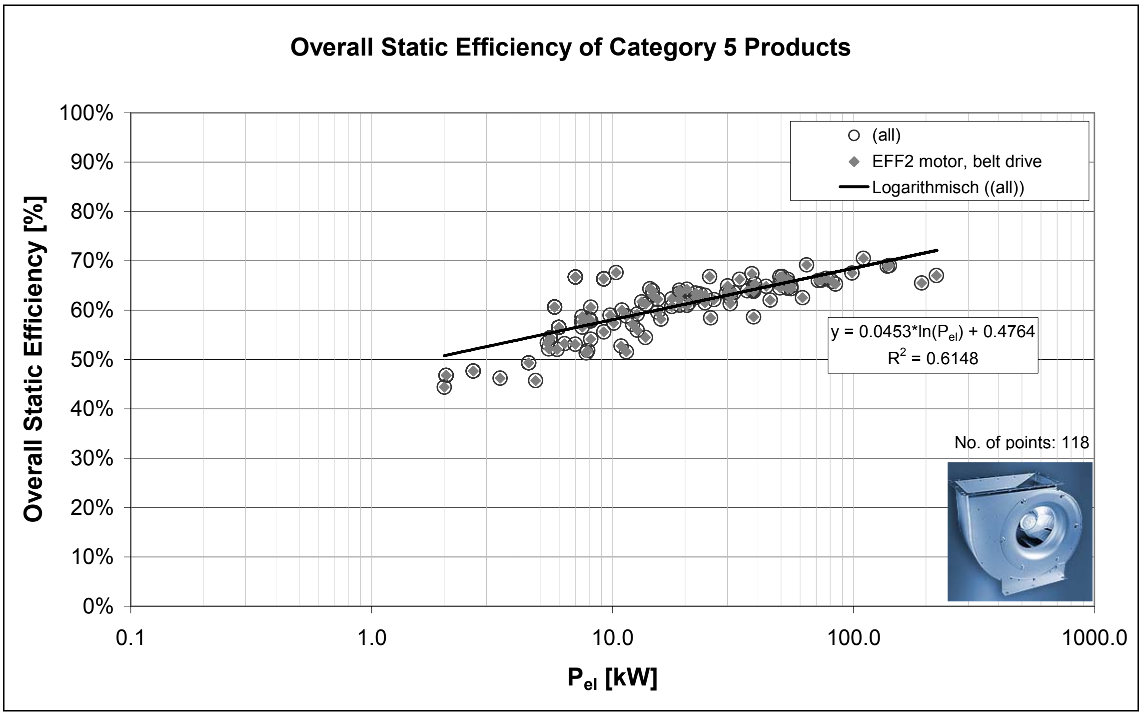


Figure 55: Overall static efficiency over electrical power input of existing category 5 fan products (centrifugal fans, backward curved blades, with scroll housing)

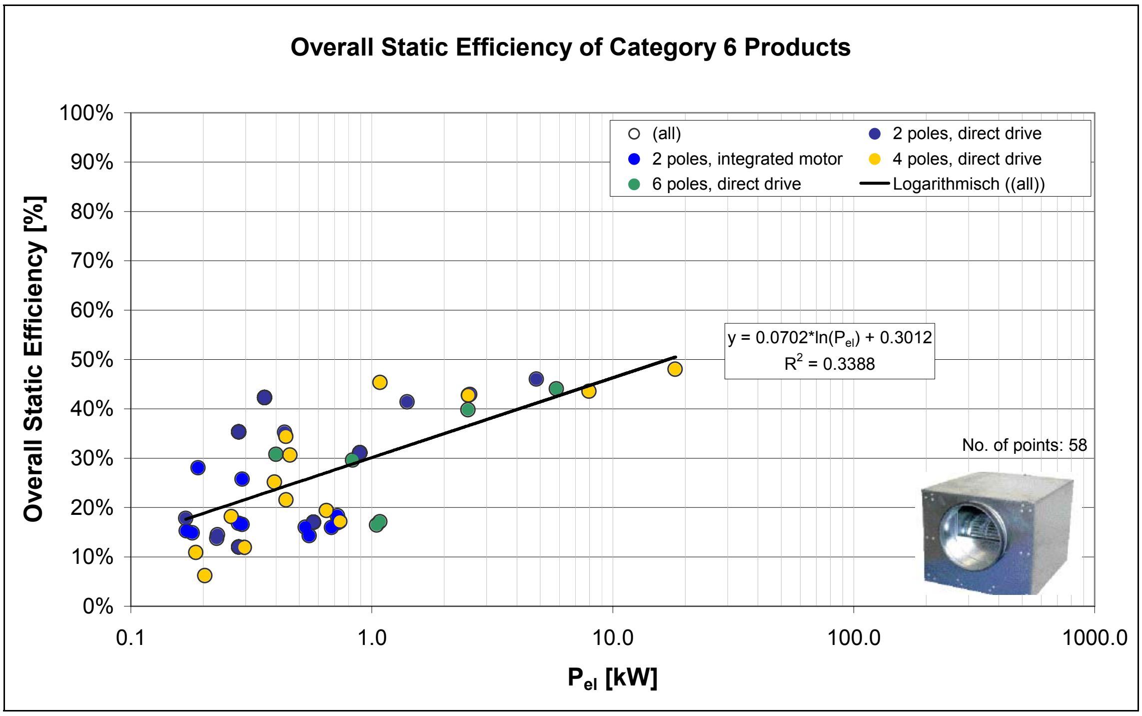


Figure 56: Overall static efficiency over electrical power input of existing category 6 fan products (box fans)

For the box fans (category 6, Figure 56) useful data could be extracted for only 58 products. The data shows a large spread as well as increasing efficiency with increasing power input. Although only few data is shown it can be seen that there are efficiency improvement potentials for existing products.

For roof fans (category 7, Figure 57) the spread of efficiencies at the same power input is the widest compared to all other categories analysed. Differences of up to 40 %-points can be observed. These large differences might be due to the wide variety of designs available in this category. Differences in design can be either regarding impeller (axial, centrifugal, mixed flow) or regarding the housing with different designs of inlet/outlet.

For cross-flow fans (category 8, Figure 58) useful data for only 21 products could be extracted. However, it can clearly be seen that the efficiency of these products is worst compared to all other product categories. Also, decreasing efficiency with increasing power input can be observed, although the reason for this could be that the data sample might not be representative.

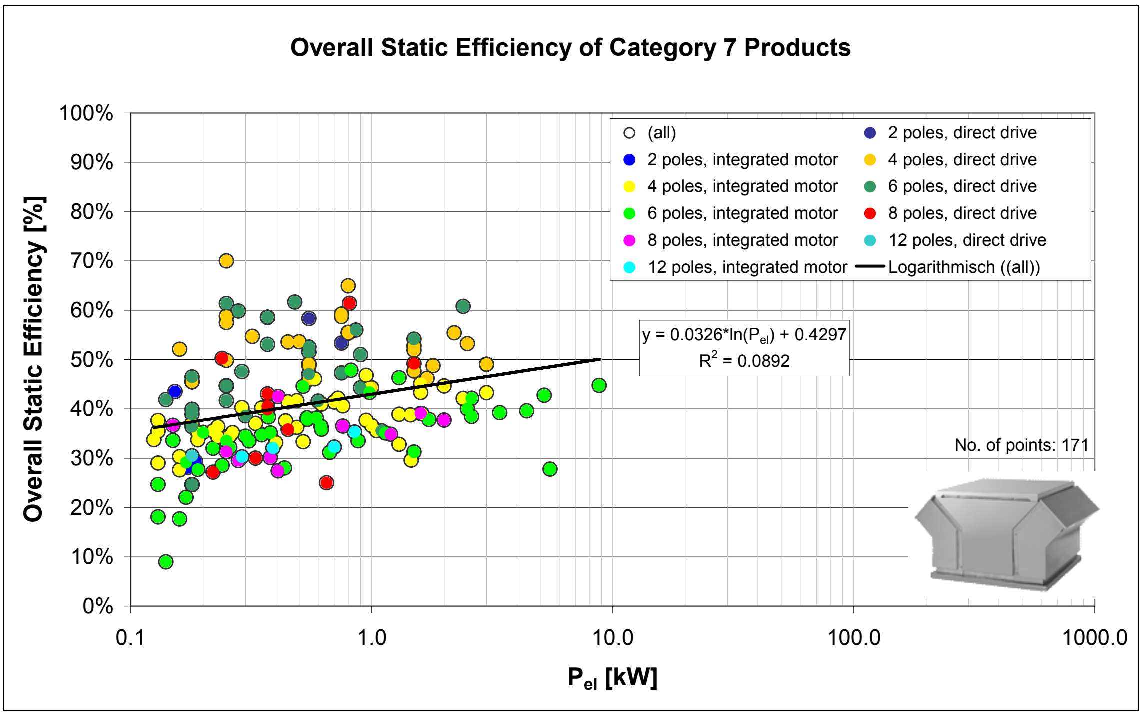


Figure 57: Overall static efficiency over electrical power input of existing category 7 fan products (roof fans)

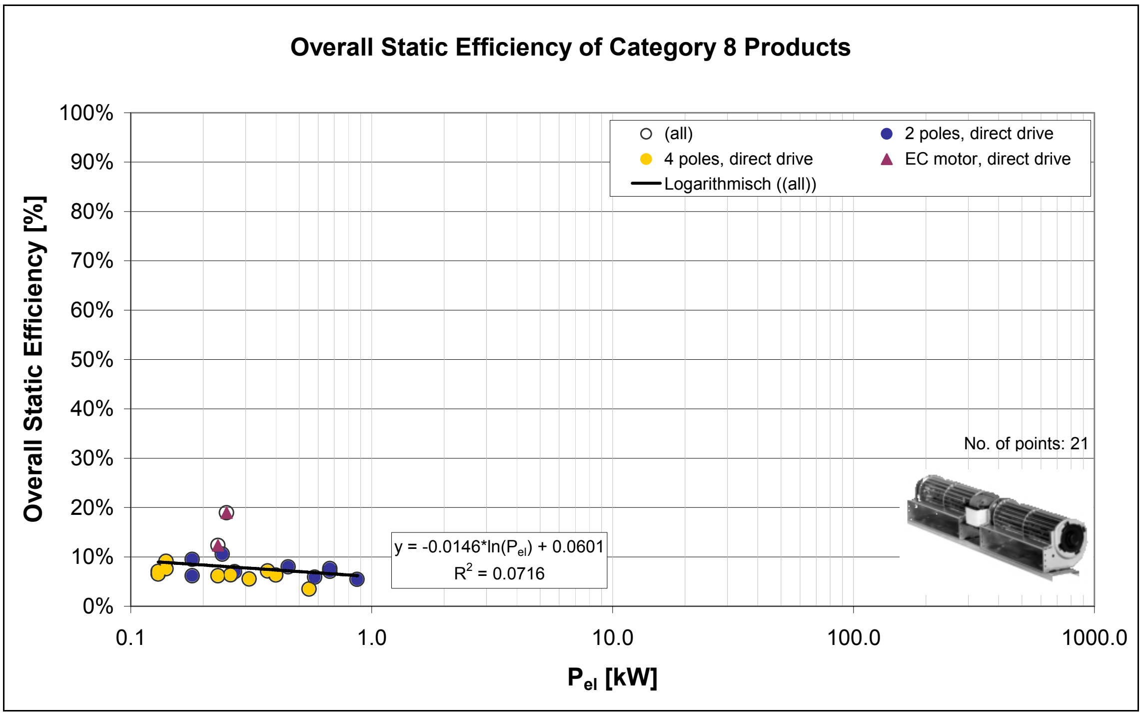


Figure 58: Overall static efficiency over electrical power input of existing category 8 fan products (cross-flow fans)

4.3.4 Usage patterns

For a realistic analysis of the product categories for different applications different usage patterns will have to be considered, in particular differences in use of fans for ventilation in residential vs. non residential buildings. Peculiarities of the agricultural sector will also have to be considered. The assumptions made will have significant influence on the results of the calculations for energy usage of individual fan types and will therefore also have a significant impact on the estimated total electricity consumption and saving potentials.

Overall energy consumption in fans for ventilation is highly dependent on the use pattern of the ventilation system. Large differences in use patterns exist between residential and non residential building and the application in the agriculture industry.

4.3.4.1 Use pattern in non residential buildings

Non residential building covers a broad range of building types which have many similarities in the technologies use for ventilation but could differ significantly in the way the building is used. The variety of applications ranges from concert halls in which fans are used only in the evening for some hours, to school building which might be used only in the morning, over to office buildings where the ventilation is mainly required during work times. In addition there are also workshops in which there is a three shift production, making it necessary to operate the ventilation system round the clock. The values given in Table 50 however only indicate the total number of operating hours per year. They do not give an indication at which load the systems typically work. As the ventilation is used to exchange the air and to remove heat, humidity and other contaminants, the required air flow varies typically over the year with higher ventilation rates during summer time.

Table 50: Estimated fan operating hours by building types [Recknagel, 2005]

	Annual Operating hours		
Building type	Minimum	Average	Maximum
Office buildings (≈10 h/d * 260 d/a) [+-400]	2200	2600	3000
Hospitals (≈24 h/d * 365 d/a) [+-500]	8000	8380	8760
Work shops 3-shift (≈24 h/d * 312 d/a) [+-200]	7288	7488	7688
Work shops 1-shift (≈9 h/d * 260 d/a) [+-200]	2140	2340	2540
Department store (≈10 h/d * 312 d/a) [+-400]	2720	3120	3520
Concert hall (≈4 h/d * 150 d/a) [+-100]	500	600	700
Overall Average	***3808***	***4088***	***4368***

For non residential buildings, the required air flow rate is in addition often regulated to such extend, that minimum air exchange rates are recommended or set by law. Table 51 give typical air exchange rates for different building uses.

Based on this use patterns the calculation of the annual energy consumption must take into account the part load operation of the fans due to changing ventilation requirements. So fans will typically run only during a short time of the year at full load. How-

ever the peak efficiency is a good indicator for the quality of the product and facilitates control and testing if only peak efficiencies are compared.

Table 51: Typical air exchange rates in buildings [Recknagel, 2005]

Type of room	Hourly air exchange required	Type of room	Hourly air exchange required
Toilet	5-8 times	libraries	3-5 times
Office rooms	3-6 times	restaurants	5-10 times
Lecture halls	8-10 times	department stores	4-6 times
Cinemas and theatres	4-6 times	schools	4-5 times

4.3.4.2 Use pattern in agriculture applications

As in non residential buildings part load operation is very common in agriculture applications. Ventilation is mainly used to remove heat and the required ventilation rate is therefore highly dependent on the outdoor temperatures. During winter time the forced ventilation is not in every case necessary reducing the number of operating hours per year. As the ventilation rate is temperature dependent, the systems are often working at part load to compensate changes in outdoor temperatures over a day. As fans have to be designed to remove safely the heat at the maximum specified outdoor temperature part load operation is very common.

As the quality has typically a direct impact on the product quantity (e.g. reduced milk production) or quality (meet), ventilation is a key concern in the agriculture business and electricity costs for ventilation an important aspect. In agriculture applications therefore already exists a high awareness about efficiency issues, which is also confirmed by the specialist certification scheme of AMCA and the fan test report of the German agriculture Society [DLG, n.d.].

4.4 Use phase (system)

4.4.1 Ventilation systems for buildings

In the context of this study, one important factor about the energy consumption for the ventilation system is the way in which the building is ventilated. In principle four different kinds of ventilation systems can be identified:

- Natural ventilation
- Fan assisted exhaust ventilation
- Fan assisted supply ventilation
- Fan assisted balanced ventilation.

The different kinds of ventilation systems are shown in Figure 59. Natural ventilation does not need any fans and is therefore out of the scope of this study, which includes fans for ventilation but not other ventilation systems. Fan assisted exhaust and fan assisted supply ventilation is using only a fan at one side which requires typically higher pressure differences to be overcome by the fan. Both systems are common on the

market with axial fans more widely used than centrifugal fans. The disadvantage of these systems is the difficulty in recovering the heat from the air leaving the building. Also as the pressure difference is higher in such systems, and can more easily lead to discomfort because of the possible under or over pressure in the building compared to the ambient conditions outside the building.

In the case of the fan assisted balanced ventilation heat recovery can be implemented in a simple way with a heat exchanger, as heat can be recovered from the outgoing air and used to preheat the incoming air.

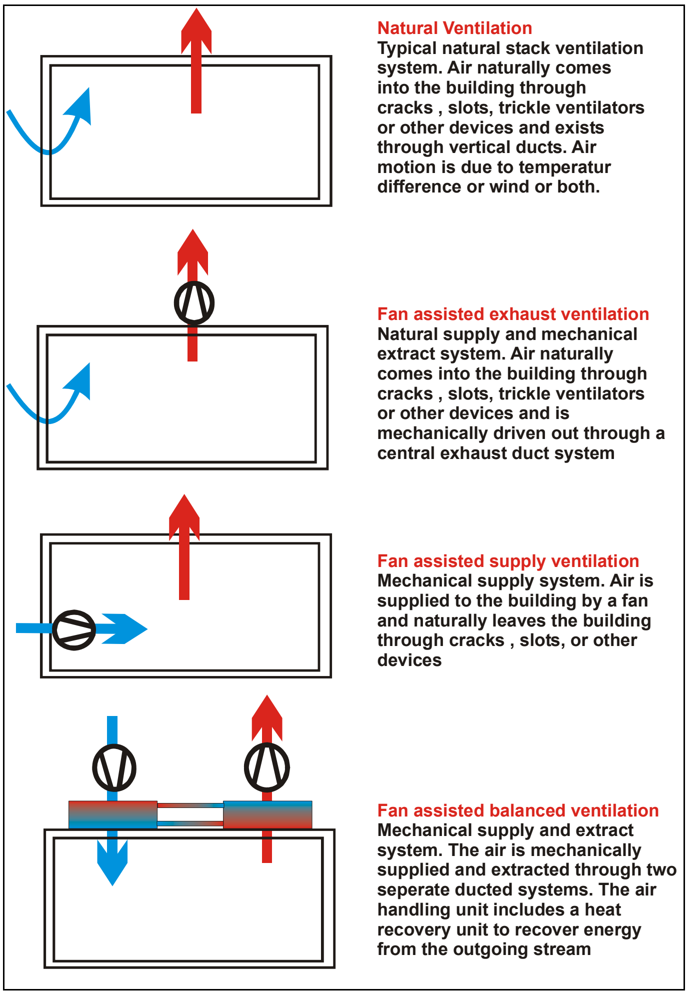


Figure 59: Types of building ventilation

It should be noted also, that the efficiency of the system and the pressure distribution depends on the way the air is brought to and away from the fan. Figure 60 shows the four possible variations. In the simplest case, the fan is neither attached to an inlet system nor to an outlet air distribution system, leading to a poor overall efficiency due to the loss of the dynamic pressure after the fan. The best system will have an inlet and outlet ducting or guides.

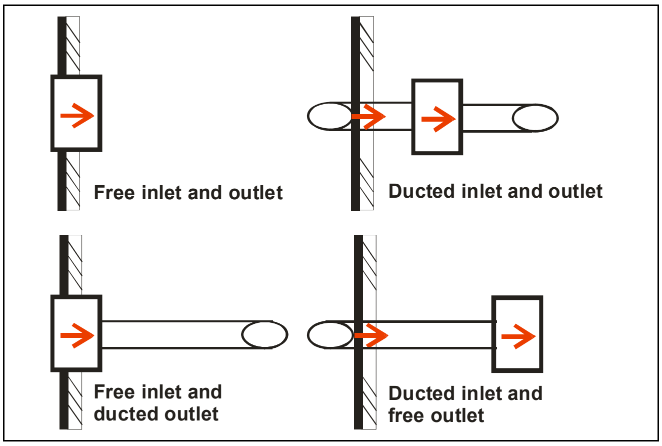


Figure 60: Principle fan arrangements for ventilation

4.4.2 System efficiency

The system efficiency is an additional step further away from the fan product as defined earlier. The fan product is installed in a building ventilation system. How the fan product performs is a question of not only the fan product but of its implementation in the ventilation system, of which the most important one is the ducting in the building, including filters, grids, balancers, heat exchangers and so on. The system to which the fan is attached is of importance when considering overall efficiency of the ventilation system. As air moves through a ducted system, pressure is lost by friction of the air against the duct walls, by turbulence at bends, dampers and changes of duct cross-section. There will also be pressure losses through heaters, filters and other items of equipment. The loss of pressure due to all these sources is summated to give the 'system resistance'.

When a fan is connected to a system, the operating point will stabilise where the two performance curves of fan and system intersect. Therefore, to achieve operation at or near the b.e.p. requires both the system designer and the fan manufacturer to be accurate in their calculations.

Therefore, large improvements can be achieved regarding energy efficiency by optimizing not only the fan itself but also the surrounding system including other components [Radgen, 2002]. Even if the fan and the motor are typically the most important parts of the product in terms of investment, the energy consumption is not determined by the efficiency of the fan wheel and the motor alone.

The overall efficiency of a system can be calculated as the product of the efficiencies of the different parts of the system:

$$\eta_{overall} = \prod_{i=1}^{n} \eta_i$$

The overall efficiency can never be higher than the lowest efficiency of one component or part in the system. So even if the fan has a very high efficiency, the system efficiency could be very poor and consequently the energy consumption of the ventilation system would be very high.

As an example, Figure 61 shows different ways to control air flow and pressure for fans in HVAC systems. In Figure 62 the power requirement using different control strategies is compared.

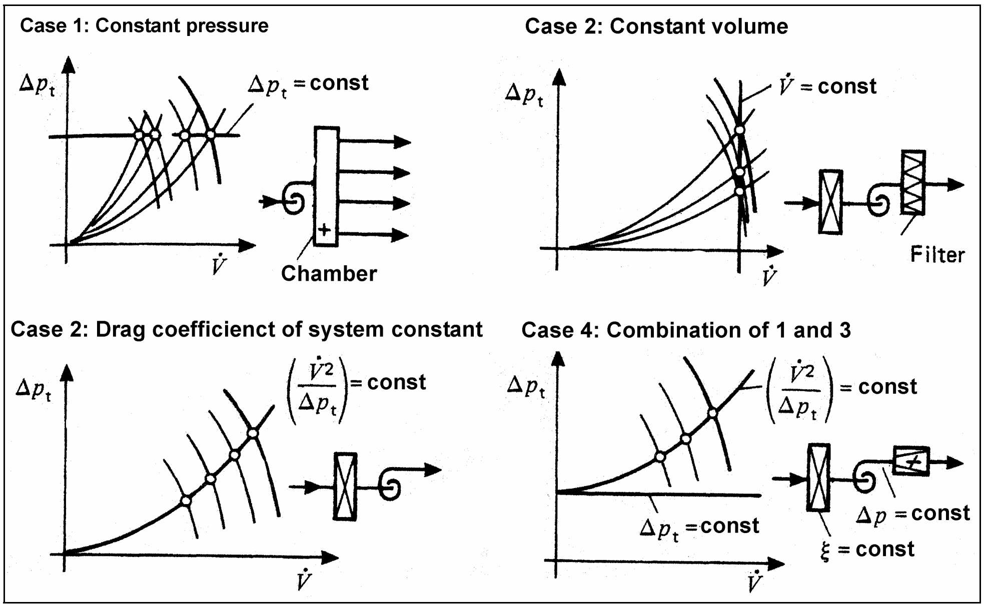


Figure 61: Different control strategies for fans [Hönmann et al., 1990]

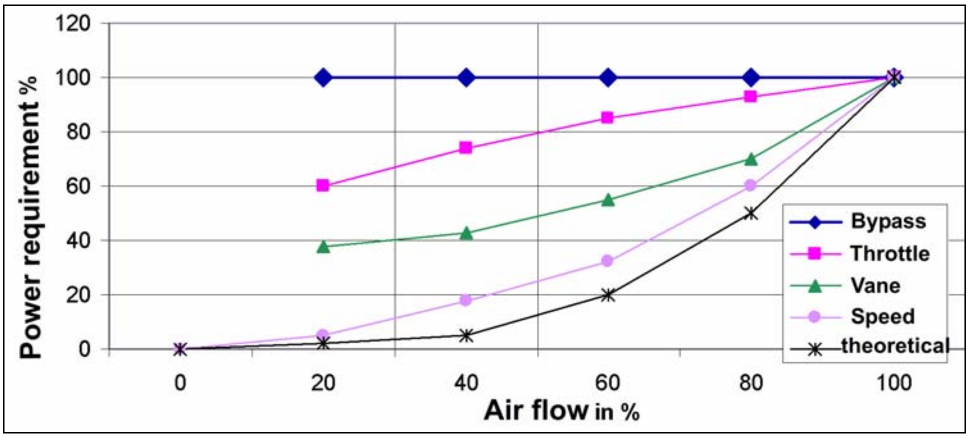


Figure 62: Power consumption and control strategy [LGA, 2002]

4.5 End-of-life phase

Currently fans are not especially collected for re-use, recycling or special waste treatment. However if buildings are demolished, the metal fractions of the installed components which have a value based on the amount of materials. The value of the materials can often be recovered if the product is dismantled to its main metal fractions.

As none of the products under consideration is aimed to be used in households they do not fall under the WEEE Directive (see section 1.3.1) [European Commission, 2002].

Summary Chapter 4:

- Demonstrated that the use phase dominates all phases in terms of eco-impact and life cycle costs
- Data collection of product weights per product category
- Analysis of the impact of efficiencies of different product parts
- Decision that fan efficiencies are presented over power
- Decision that fan efficiencies used are the overall static efficiency of the product (including all parts as defined in the previous chapter)
- Decision that comparison of products will be based on peak efficiency only
- Data collection for overall static efficiency for all 8 product categories
- Information on usage patterns for the product
- Discussion of the importance of system efficiency in addition to the product efficiency.

5 Definition of the Base Case

During the project we have been working together with manufacturers to get the technical data for the different product categories. Based on this information and own research we have developed the base case for each product category, i.e. "average products" which do not represent a single product from one manufacturer but are based on information about several products.

5.1 Product-specific inputs

In the following results of the EuP spreadsheet model for the base cases of the different fan categories are shown. It has to be kept in mind that the results shown are based on average products as derived from BOM data delivered by fan manufacturers and data on total weight, motor BOMs and information on material use in product catalogues. Table 52 summarizes the data on average electricity input and average weight for the base case of each product category.

Table 52: Base case electrical power input and weight for each product category

Prod. Cat.	Direction of flow	Type	**BASE CASE**	
			Electrical Power Input [kW]	**Weight [kg]**
1	Axial	<= 300 Pa (static pressure)	0.8	47
2	Axial	> 300 Pa (static pressure)	1.3	55
3	Centrifugal	forward curved blades (with casing)	0.44	10.7
4	Centrifugal	backward curved blades (no casing)	3.76	38.6
5	Centrifugal	backward curved blades (with scroll housing)	3.82	77.4
6	Other	Box fans	0.37	9.9
7	Other	Roof fans	1.2	60.4
8	Other	Cross-flow fans	0.42	7.8

The material composition has been drastically reduced as the main materials copper, aluminium and steel make up typically more than 90 % of the total weight of the products. For all products and all categories it can be shown, that the impact of the use phase is highly dominant. Therefore a change in the amount of materials used or a change in materials, e.g. changing aluminium against copper has only negligible impact on the overall environmental impact.

5.1.1 Average BOM Category 1

The average product has a power of about 0.8 kW and a weight of 47 kg. The different parts of the fan product, chassis, stator and rotor are mainly produced from copper, aluminium and steel.

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: INPUTS
Assessment of Environmental Impact

Nr	Product name	Date	Author
1	**Average EU Product Category 1 (axial < 300 Pa)**	**07.09.2007**	**Peter Radgen**

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Copper Component (mainly motor)	2000,0	4-Non-ferro	**28-Cu winding wire**
2	Chasis,Stator, Rotor	9000,0	4-Non-ferro	**27-Al diecast**
3	Chasis,Stator, Rotor	35000,0	3-Ferro	**22-St tube/profile**
4	Others	1000,0	2-TecPlastics	**11-PA 6**
5				

Figure 63: Materials use for the production of average category 1 product

For the manufacturing the default values of the tool are used. The volume of the packaged product is derived from the typical impeller size which leads to 0.2 m^3.

Pos nr	MANUFACTURING Description	Weight in g	Percentage Adjust	Category index (fixed)
201	**OEM Plastics Manufacturing** (fixed)	1000		20
202	**Foundries Fe/Cu/Zn** (fixed)	0		34
203	**Foundries Al/Mg** (fixed)	9000		35
204	**Sheetmetal Manufacturing** (fixed)	0		36
205	**PWB Manufacturing** (fixed)	0		53
206	**Other materials** (Manufacturing already included)	37000		
207	**Sheetmetal Scrap** (Please adjust percentage only)	0	**25%**	37

Pos nr	DISTRIBUTION (incl. Final Assembly) Description		Answer	Category index (fixed)	
208	**Is it an ICT or Consumer Electronics product <15 kg ?**		NO	59	0
209	**Is it an installed appliance (e.g. boiler)?**		NO	60	1
				62	1
210	**Volume of packaged final product in m^3**	in m3	0,2	63	0
				64	1

Figure 64: Manufacturing and distribution of average category 1 product

The main impact which is related to the use phase of the product is based on data as derived in described model. The average power of a category 1 product has been calculated to be 800 W and 2000 operating hours a year.

Pos nr	USE PHASE Description		unit	Subtotals
211	Product Life in years	15	years	
	Electricity			
212	On-mode: Consumption per hour, cycle, setting, etc.	0,80	kWh	1600
213	On-mode: No. Of hours, cycles, settings, etc. / year	2000	#	
214	Standby-mode: Consumption per hour	0	kWh	0
215	Standby-mode: No. Of hours / year	0	#	
216	Off-mode: Consumption per hour	0	kWh	0
217	Off-mode: No. Of hours / year	0	#	
	TOTAL over Product Life	24,00	MWh (=000 kWh)	65

Figure 65: Energy consumption during use phase of average category 1 product

The total number of fans for each product category has been calculated with a transparent approach (see chapter 0). Based on the model results the total number of fans sold into the European market in 2005 has been 349,352 Units. Please not that based on the assumptions made in the model, the accuracy of the numbers is limited and therefore it would be possible to calculate with 350'000 units. However we decided to use the numbers as calculated in the model for all base case calculations. At a lifetime of the product of 15 years one could assume that the European stock of this category of product is at maximum 15 times as larger as the yearly consumption. As the number of fans sold in Europe still continues to increase and was lower in previous years. The stock is assumed to be 10 times the annual sales in Europe. Even if this might be not very precise it is sufficient to make such estimates, as even the overall number of units sold annually is highly uncertain. The price is base on average list prices and would be around 450 Euro with an additional 50 Euro for installation and acquisition. Electricity rate has been fixed at 7.5 ct/kWh as described earlier.

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	15	years
B	Annual sales	0.718075	mln. Units/year
C	EU Stock	7.18075	mln. Units
D	Product price	450	Euro/unit
E	Installation/acquisition costs (if any)	50	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.075	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs		Euro/ unit
M	Discount rate (interest minus inflation)	5.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	10.38	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

Figure 66: Input for EU Totals and LCC calculation of category 1 products

Version 5 VHK for European Commission 28 Nov. 2005 | Document subject to a legal notice (see below))

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: **RESULTS**
Assessment of Environmental Impact

Table . Life Cycle Impact (per unit) of Average EU Product Category 1 (axial < 300 Pa)

Nr	Life cycle Impact per product:	Date	Author
1	Average EU Product Category 1 (axial < 300 Pa)	39332	Peter Radgen

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**1000**			900	100	**1000**	**0**
3	Ferro	g			**35000**			1750	33250	**35000**	**0**
4	Non-ferro	g			**11000**			550	10450	**11000**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**0**			0	0	**0**	**0**
	Total weight	g			**47000**			3200	43800	**47000**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1496	99	**1596**	**323**	**252064**	222	35	**187**	**254169**
9	of which, electricity (in primary MJ)	MJ	175	60	**235**	**1**	**252002**	0	0	**0**	**252238**
10	Water (process)	ltr	16	1	**17**	**0**	**16800**	0	0	**0**	**16817**
11	Water (cooling)	ltr	219	28	**247**	**0**	**672002**	0	2	**-2**	**672248**
12	Waste, non-haz./ landfill	g	75030	311	**75342**	**182**	**292933**	2881	1	**2880**	**371337**
13	Waste, hazardous/ incinerated	g	21	0	**21**	**4**	**5807**	900	0	**900**	**6731**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	103	6	**109**	**21**	**11002**	17	2	**14**	**11146**
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	913	24	**937**	**61**	**64903**	33	3	**30**	**65931**
17	Volatile Organic Compounds (VOC)	g	5	0	**5**	**4**	**96**	1	0	**1**	**106**
18	Persistent Organic Pollutants (POP)	ng i-Teq	729	0	**729**	**1**	**1659**	20	0	**20**	**2409**
19	Heavy Metals	mg Ni eq.	211	0	**211**	**9**	**4336**	63	0	**63**	**4620**
	PAHs	mg Ni eq.	172	0	**172**	**11**	**509**	0	0	**0**	**692**
20	Particulate Matter (PM, dust)	g	83	4	**87**	**684**	**1563**	288	0	**288**	**2622**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	175	0	**175**	**0**	**1627**	18	0	**18**	**1820**
22	Eutrophication	g PO4	4	0	**4**	**0**	**8**	1	0	**1**	**12**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

Figure 67: Life Cycle Impact of Average EU Product category 1

The importance of the use phase on the overall environmental impacts can be clearly seen, if the data is presented graphically, Figure 74.

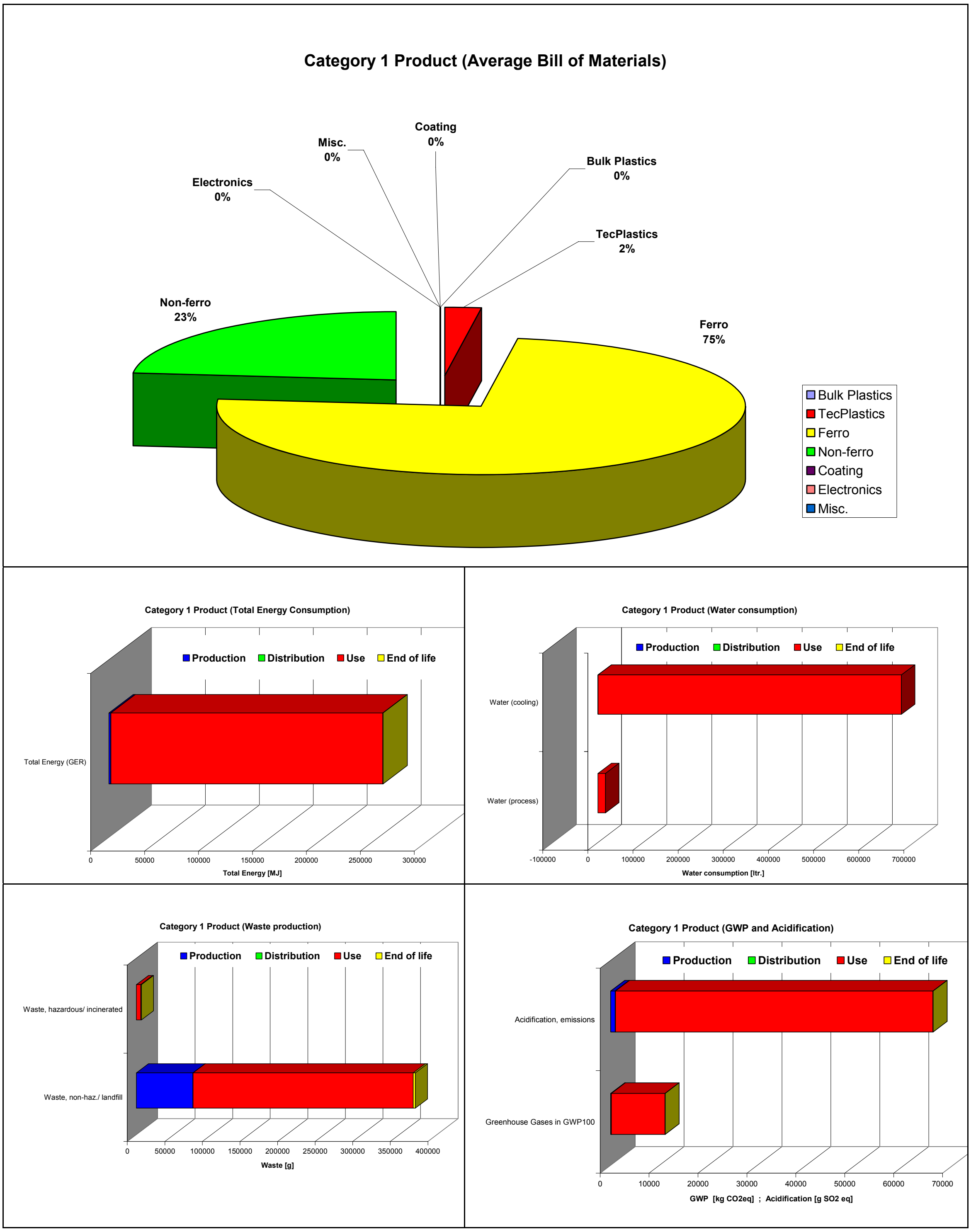


Figure 68: Results of the environmental impact assessment by phase of product life cycle

5.1.2 Average BOM Category 2

The average product has a power of about 1.3 kW and a weight of 55 kg. The different parts of the fan product, chassis, stator and rotor are mainly produced from copper, aluminium and steel.

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS — EuP EcoReport: INPUTS — Assessment of Environmental Impact

Nr	Product name	Date	Author
2	Average EU Product Category 2 (axial > 300 Pa)	07.09.2007	Peter Radgen

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Copper Component (mainly motor)	2700,0	4-Non-ferro	28-Cu winding wire
2	Chasis,Stator, Rotor	12000,0	4-Non-ferro	27-Al diecast
3	Chasis,Stator, Rotor	39000,0	3-Ferro	22-St tube/profile
4	Others	1300,0	2-TecPlastics	11-PA 6

Figure 69: Materials use for the production of average category 2 product

For the manufacturing the default values of the tool are used. The volume of the packaged product is derived from the typical impeller size which leads to 0.2 m^3.

Pos nr	MANUFACTURING Description	Weight in g	Percentage Adjust	Category index (fixed)	
201	OEM Plastics Manufacturing (fixed)	1300		20	
202	Foundries Fe/Cu/Zn (fixed)	0		34	
203	Foundries Al/Mg (fixed)	12000		35	
204	Sheetmetal Manufacturing (fixed)	0		36	
205	PWB Manufacturing (fixed)	0		53	
206	Other materials (Manufacturing already included)	41700			
207	Sheetmetal Scrap (Please adjust percentage only)	0	25%	37	
Pos nr	**DISTRIBUTION (incl. Final Assembly) Description**		**Answer**	**Category index (fixed)**	
208	Is it an ICT or Consumer Electronics product <15 kg ?		NO	59	0
209	Is it an installed appliance (e.g. boiler)?		NO	60	1
				62	1
210	Volume of packaged final product in m^3	in m3	0,2	63	0
				64	1

Figure 70: Manufacturing and distribution of average category 2 product

The main impact which is related to the use phase of the product is based on data as derived in described model. The average power of a category 2 product has been calculated to be 1.3 W and 2000 operating hours a year.

Pos nr	USE PHASE Description		unit	Subtotals
211	Product Life in years	15	years	
	Electricity			
212	On-mode: Consumption per hour, cycle, setting, etc.	1,32	kWh	2640
213	On-mode: No. Of hours, cycles, settings, etc. / year	2000	#	
214	Standby-mode: Consumption per hour	0	kWh	0
215	Standby-mode: No. Of hours / year	0	#	
216	Off-mode: Consumption per hour	0	kWh	0
217	Off-mode: No. Of hours / year	0	#	
	TOTAL over Product Life	39,60	MWh (=000 kWh)	65

Figure 71: Energy consumption during use phase of average category 2 product

Base on the model to the developed model to break down the total number of fans introduced in the market in 2005 970421 Units of this kind of products are sold into the European market each year. At a lifetime of the product of 15 years one could assume that the European stock of this product is at maximum 15 times as larger as the yearly consumption. As the number of fans sold in Europe still continues to increase and was lower in previous years. The stock is assumed to 10 times the annual sales in Europe. Even if this might be not very precise it is sufficient to make such estimates, as even the overall number of units sold annually is highly insecure. The price is base on average list prices and would be around 600 Euro with an additional 50 Euro for installation and acquisition. Electricity rate has been fixed at 7.5 ct/kWh as described earlier.

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	15	years
B	Annual sales	1.994653	mln. Units/year
C	EU Stock	19.94653	mln. Units
D	Product price	600	Euro/unit
E	Installation/acquisition costs (if any)	50	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.075	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs		Euro/ unit
M	Discount rate (interest minus inflation)	5.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	10.38	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

Figure 72: Input for EU Totals and LLC calculation of category 2 products

Version 5 VHK for European Commission 28 Nov. 2005 Document subject to a legal notice (see below))

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: RESULTS
Assessment of Environmental Impact

Table . Life Cycle Impact (per unit) of Average EU Product Category 2 (axial > 300 Pa)

Nr	Life cycle Impact per product:	Date	Author
2	Average EU Product Category 2 (axial > 300 Pa)	39332	Peter Radgen

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**1300**			1170	130	**1300**	**0**
3	Ferro	g			**39000**			1950	37050	**39000**	**0**
4	Non-ferro	g			**14700**			735	13965	**14700**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**0**			0	0	**0**	**0**
	Total weight	g			**55000**			3855	51145	**55000**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1865	131	**1997**	**323**	**415868**	267	47	**221**	**418408**
9	of which, electricity (in primary MJ)	MJ	198	79	**277**	**1**	**415803**	0	0	**0**	**416080**
10	Water (process)	ltr	21	1	**22**	**0**	**27720**	0	0	**0**	**27742**
11	Water (cooling)	ltr	285	37	**322**	**0**	**1108803**	0	3	**-3**	**1109122**
12	Waste, non-haz./ landfill	g	94564	411	**94975**	**182**	**483046**	3372	2	**3370**	**581573**
13	Waste, hazardous/ incinerated	g	27	0	**27**	**4**	**9582**	1170	0	**1170**	**10782**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	127	7	**135**	**21**	**18150**	20	3	**17**	**18322**
15	Ozone Depletion, emissions	mg R-11 eq.				negligible					
16	Acidification, emissions	g SO2 eq.	1199	31	**1230**	**61**	**107085**	39	4	**35**	**108411**
17	Volatile Organic Compounds (VOC)	g	6	0	**6**	**4**	**157**	1	0	**1**	**168**
18	Persistent Organic Pollutants (POP)	ng i-Teq	881	0	**881**	**1**	**2734**	23	0	**23**	**3639**
19	Heavy Metals	mg Ni eq.	264	0	**264**	**9**	**7147**	76	0	**76**	**7496**
	PAHs	mg Ni eq.	229	0	**229**	**11**	**832**	0	0	**0**	**1072**
20	Particulate Matter (PM, dust)	g	103	5	**108**	**684**	**2464**	348	0	**348**	**3604**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	220	0	**220**	**0**	**2683**	22	0	**22**	**2926**
22	Eutrophication	g PO4	4	0	**4**	**0**	**13**	1	0	**1**	**19**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

Figure 73: Life Cycle Impact of Average EU Product category 2

The importance of the use phase on the overall environmental impacts can be clearly seen, if the data is presented graphically, Figure 74.

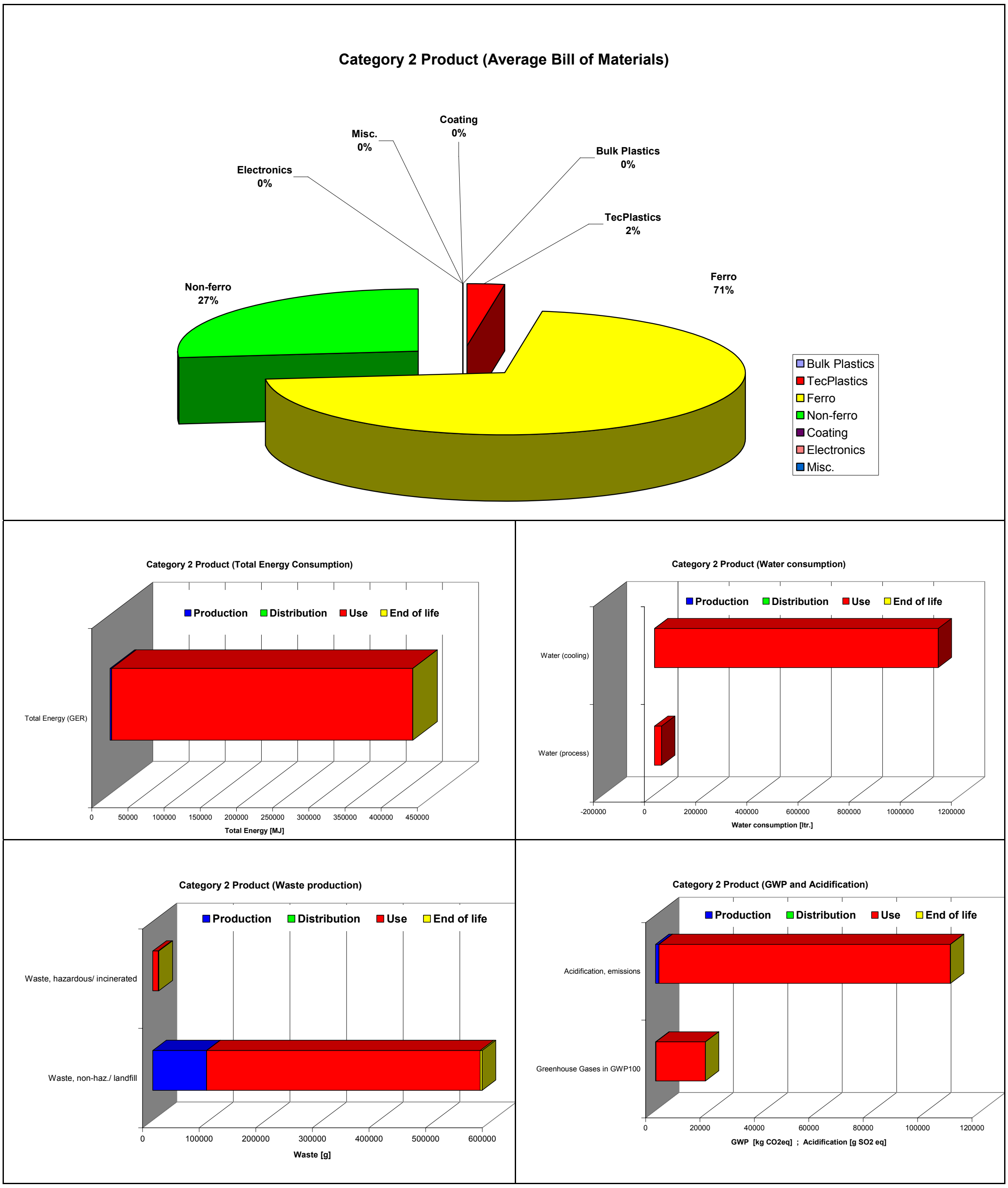


Figure 74: Results of the environmental impact assessment by phase of product life cycle (category 2)

5.1.3 Average BOM Category 3

The average product has a power of about 0.44 kW and a weight of 10.7 kg. The different parts of the fan product, chassis, stator and rotor are mainly produced from copper, aluminium and steel.

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: INPUTS
Assessment of Environmental Impact

Nr	Product name	Date	Author
3	**Average EU Product Category 3 (centrifugal forward)**	**07.09.2007**	**Peter Radgen**

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Copper Component (mainly motor)	1000,0	4-Non-ferro	**28-Cu winding wire**
2	Chasis,Stator, Rotor	890,0	4-Non-ferro	**27-Al diecast**
3	Chasis,Stator, Rotor	4980,0	3-Ferro	**22-St tube/profile**
4	Casing	3500,0	3-Ferro	**21-St sheet galv.**
5	Others	300,0	2-TecPlastics	**11-PA 6**

Figure 75: Materials use for the production of average category 3 product

For the manufacturing the default values of the tool are used. The volume of the packaged product is derived from the typical impeller size which leads to 0.1 m^3.

Pos nr	MANUFACTURING Description	Weight in g	Percentage Adjust	Category index (fixed)	
201	**OEM Plastics Manufacturing (fixed)**	300		**20**	
202	**Foundries Fe/Cu/Zn (fixed)**	0		**34**	
203	**Foundries Al/Mg (fixed)**	890		**35**	
204	**Sheetmetal Manufacturing (fixed)**	3500		**36**	
205	**PWB Manufacturing (fixed)**	0		**53**	
206	**Other materials (Manufacturing already included)**	5980			
207	**Sheetmetal Scrap (Please adjust percentage only)**	875	**25%**	**37**	
Pos nr	**DISTRIBUTION (incl. Final Assembly) Description**		**Answer**	**Category index (fixed)**	
208	**Is it an ICT or Consumer Electronics product <15 kg ?**		NO	**59**	**0**
209	**Is it an installed appliance (e.g. boiler)?**		NO	**60**	**1**
				62	**1**
210	**Volume of packaged final product in m^3**	in m3	0,1	**63**	**0**
				64	**1**

Figure 76: Manufacturing and distribution of average category 3 product

The main impact which is related to the use phase of the product is based on data as derived in described model. The average power of a category 3 product has been calculated to be 440 W and 3000 operating hours a year.

Pos nr	USE PHASE Description		unit	Subtotals
211	Product Life in years	15	years	
	Electricity			
212	On-mode: Consumption per hour, cycle, setting, etc.	0,44	kWh	1320
213	On-mode: No. Of hours, cycles, settings, etc. / year	3000	#	
214	Standby-mode: Consumption per hour	0	kWh	0
215	Standby-mode: No. Of hours / year	0	#	
216	Off-mode: Consumption per hour	0	kWh	0
217	Off-mode: No. Of hours / year	0	#	
	TOTAL over Product Life	19,80	MWh (=000 kWh)	65

Figure 77: Energy consumption during use phase of average category 3 product

Base on the model to the developed model to break down the total number of fans introduced in the market in 2005 784059 Units of this kind of products are sold into the European market each year. At a lifetime of the product of 15 years one could assume that the European stock of this product is at maximum 15 times as larger as the yearly consumption. As the number of fans sold in Europe still continues to increase and was lower in previous years. The stock is assumed to 10 times the annual sales in Europe. Even if this might be not very precise it is sufficient to make such estimates, as even the overall number of units sold annually is highly insecure. The price is base on average list prices and would be around 750 Euro with an additional 50 Euro for installation and acquisition. Electricity rate has been fixed at 7.5 ct/kWh as described earlier.

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	15	years
B	Annual sales	1.09168	mln. Units/year
C	EU Stock	10.9168	mln. Units
D	Product price	750	Euro/unit
E	Installation/acquisition costs (if any)	50	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.075	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs		Euro/ unit
M	Discount rate (interest minus inflation)	5.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	10.38	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

Figure 78: Input for EU Totals and LLC calculation of category 3 products

Version 5 VHK for European Commission 28 Nov. 2005 Document subject to a legal notice (see below))

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: RESULTS
Assessment of Environmental Impact

Table . Life Cycle Impact (per unit) of Average EU Product Category 3 (centrifugal forward)

Nr	Life cycle Impact per product:	Date	Author
3	Average EU Product Category 3 (centrifugal forward)	39332	Peter Radgen

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**300**			270	30	**300**	**0**
3	Ferro	g			**8480**			424	8056	**8480**	**0**
4	Non-ferro	g			**1890**			95	1796	**1890**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**0**			0	0	**0**	**0**
	Total weight	g			**10670**			789	9882	**10670**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	431	81	**513**	**187**	**207953**	55	12	**43**	**208697**
9	of which, electricity (in primary MJ)	MJ	35	47	**82**	**0**	**207901**	0	0	**0**	**207983**
10	Water (process)	ltr	5	1	**5**	**0**	**13860**	0	0	**0**	**13865**
11	Water (cooling)	ltr	66	20	**86**	**0**	**554401**	0	1	**-1**	**554486**
12	Waste, non-haz./ landfill	g	30773	380	**31153**	**117**	**241360**	654	0	**654**	**273283**
13	Waste, hazardous/ incinerated	g	6	0	**7**	**2**	**4791**	270	0	**270**	**5069**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	30	5	**34**	**13**	**9077**	4	1	**3**	**9127**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	373	20	**394**	**37**	**53542**	8	1	**7**	**53979**
17	Volatile Organic Compounds (VOC)	g	1	0	**1**	**2**	**79**	0	0	**0**	**83**
18	Persistent Organic Pollutants (POP)	ng i-Teq	185	9	**194**	**1**	**1365**	5	0	**5**	**1564**
19	Heavy Metals	mg Ni eq.	83	22	**105**	**6**	**3578**	16	0	**16**	**3704**
	PAHs	mg Ni eq.	22	0	**22**	**7**	**420**	0	0	**0**	**449**
20	Particulate Matter (PM, dust)	g	23	3	**26**	**342**	**1320**	71	0	**71**	**1759**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	47	0	**47**	**0**	**1341**	5	0	**5**	**1393**
22	Eutrophication	g PO4	1	0	**1**	**0**	**6**	0	0	**0**	**8**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

Figure 79: Life Cycle Impact of Average EU Product category 3

The importance of the use phase on the overall environmental impact can be clearly seen, if the data is presented graphically, Figure 74.

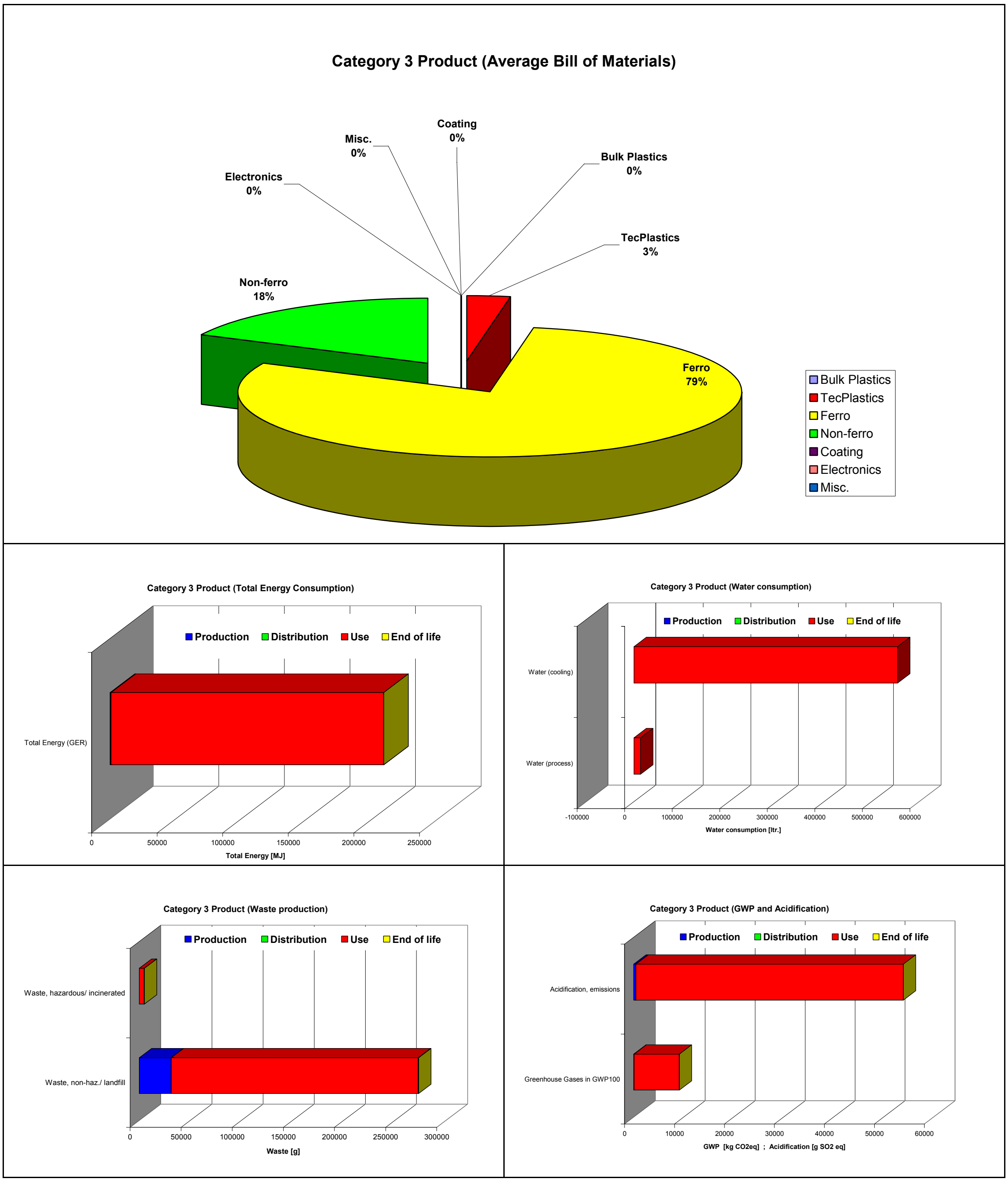


Figure 80: Results of the environmental impact assessment by phase of product life cycle (category 3)

5.1.4 Average BOM Category 4

The average product has a power of about 3.76 kW and a weight of 38.6 kg. The different parts of the fan product, chassis, stator and rotor are mainly produced from copper, aluminium and steel.

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS — **EuP EcoReport: INPUTS** — **Assessment of Environmental Impact**

Nr	Product name	Date	Author
4	**Average EU Product Category 4 (centrifugal free wheel)**	**07.09.2007**	**Peter Radgen**

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Copper Component (mainly motor)	3000,0	4-Non-ferro	**28-Cu winding wire**
2	Chasis,Stator, Rotor	17500,0	4-Non-ferro	**27-Al diecast**
3	Chasis,Stator, Rotor	16900,0	3-Ferro	**22-St tube/profile**
4	Others	1217,0	2-TecPlastics	**11-PA 6**

Figure 81: Materials use for the production of average category 4 product

For the manufacturing the default values of the tool are used. The volume of the packaged product is derived from the typical impeller size which leads to 0.3 m^3.

Pos nr	MANUFACTURING Description	Weight in g	Percentage Adjust	Category index (fixed)
201	**OEM Plastics Manufacturing (fixed)**	1217		**20**
202	**Foundries Fe/Cu/Zn (fixed)**	0		**34**
203	**Foundries Al/Mg (fixed)**	17500		**35**
204	**Sheetmetal Manufacturing (fixed)**	0		**36**
205	**PWB Manufacturing (fixed)**	0		**53**
206	**Other materials (Manufacturing already included)**	19900		
207	**Sheetmetal Scrap (Please adjust percentage only)**	0	**25%**	**37**

Pos nr	DISTRIBUTION (incl. Final Assembly) Description		Answer	Category index (fixed)	
208	**Is it an ICT or Consumer Electronics product <15 kg ?**		NO	**59**	**0**
209	**Is it an installed appliance (e.g. boiler)?**		NO	**60**	**1**
				62	**1**
210	**Volume of packaged final product in m^3**	**in m3**	0,3	**63**	**0**
				64	**1**

Figure 82: Manufacturing and distribution of average category 4 product

The main impact which is related to the use phase of the product is based on data as derived in described model. The average power of a category 4 product has been calculated to be 3760 W and 3000 operating hours a year.

Pos nr	USE PHASE Description		unit	Subtotals
211	Product Life in years	15	years	
	Electricity			
212	On-mode: Consumption per hour, cycle, setting, etc.	3,76	kWh	11280
213	On-mode: No. Of hours, cycles, settings, etc. / year	3000	#	
214	Standby-mode: Consumption per hour	0	kWh	0
215	Standby-mode: No. Of hours / year	0	#	
216	Off-mode: Consumption per hour	0	kWh	0
217	Off-mode: No. Of hours / year	0	#	
	TOTAL over Product Life	169,20	MWh (=000 kWh)	65

Figure 83: Energy consumption during use phase of average category 4 product

Base on the model to the developed model to break down the total number of fans introduced in the market in 2005 242442 Units of this kind of products are sold into the European market each year. At a lifetime of the product of 15 years one could assume that the European stock of this product is at maximum 15 times as larger as the yearly consumption. As the number of fans sold in Europe still continues to increase and was lower in previous years. The stock is assumed to 10 times the annual sales in Europe. Even if this might be not very precise it is sufficient to make such estimates, as even the overall number of units sold annually is highly insecure. The price is base on average list prices and would be around 1400 Euro with an additional 140 Euro for installation and acquisition. Electricity rate has been fixed at 7.5 ct/kWh as described earlier.

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	15	years
B	Annual sales	0.337563	mln. Units/year
C	EU Stock	3.37563	mln. Units
D	Product price	1400	Euro/unit
E	Installation/acquisition costs (if any)	140	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.075	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs		Euro/ unit
M	Discount rate (interest minus inflation)	5.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	10.38	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

Figure 84: Input for EU Totals and LLC calculation of category 4 products

Version 5 VHK for European Commission 28 Nov. 2005 | Document subject to a legal notice (see below))

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: RESULTS
Assessment of Environmental Impact

Table . Life Cycle Impact (per unit) of Average EU Product Category 4 (centrifugal free wheel)

Nr	Life cycle Impact per product:	Date	Author
4	Average EU Product Category 4 (centrifugal free wheel)	39332	Peter Radgen

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**1217**			1095	122	**1217**	**0**
3	Ferro	g			**16900**			845	16055	**16900**	**0**
4	Non-ferro	g			**20500**			1025	19475	**20500**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**0**			0	0	**0**	**0**
	Total weight	g			**38617**			2965	35652	**38617**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1826	164	**1989**	**459**	**1776668**	206	46	**160**	**1779276**
9	of which, electricity (in primary MJ)	MJ	96	98	**194**	**1**	**1776602**	0	0	**0**	**1776796**
10	Water (process)	ltr	19	1	**21**	**0**	**118440**	0	0	**0**	**118461**
11	Water (cooling)	ltr	267	46	**313**	**0**	**4737603**	0	3	**-3**	**4737914**
12	Waste, non-haz./ landfill	g	86991	513	**87504**	**248**	**2060742**	2368	2	**2366**	**2150859**
13	Waste, hazardous/ incinerated	g	26	0	**26**	**5**	**40938**	1095	0	**1095**	**42064**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	118	9	**127**	**29**	**77535**	15	3	**12**	**77703**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	1293	39	**1332**	**86**	**457492**	31	4	**26**	**458936**
17	Volatile Organic Compounds (VOC)	g	3	0	**3**	**6**	**670**	1	0	**1**	**680**
18	Persistent Organic Pollutants (POP)	ng i-Teq	801	0	**801**	**1**	**11653**	16	0	**16**	**12471**
19	Heavy Metals	mg Ni eq.	228	0	**228**	**13**	**30492**	59	0	**59**	**30791**
	PAHs	mg Ni eq.	327	0	**327**	**16**	**3514**	0	0	**0**	**3856**
20	Particulate Matter (PM, dust)	g	103	6	**110**	**1026**	**9949**	268	0	**268**	**11352**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	219	0	**219**	**0**	**11457**	17	0	**17**	**11694**
22	Eutrophication	g PO4	3	0	**4**	**0**	**55**	1	0	**1**	**59**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

Figure 85: Life Cycle Impact of Average EU Product category 4

The importance of the use phase on the overall environmental impact can be clearly seen, if the data is presented graphically, Figure 86.

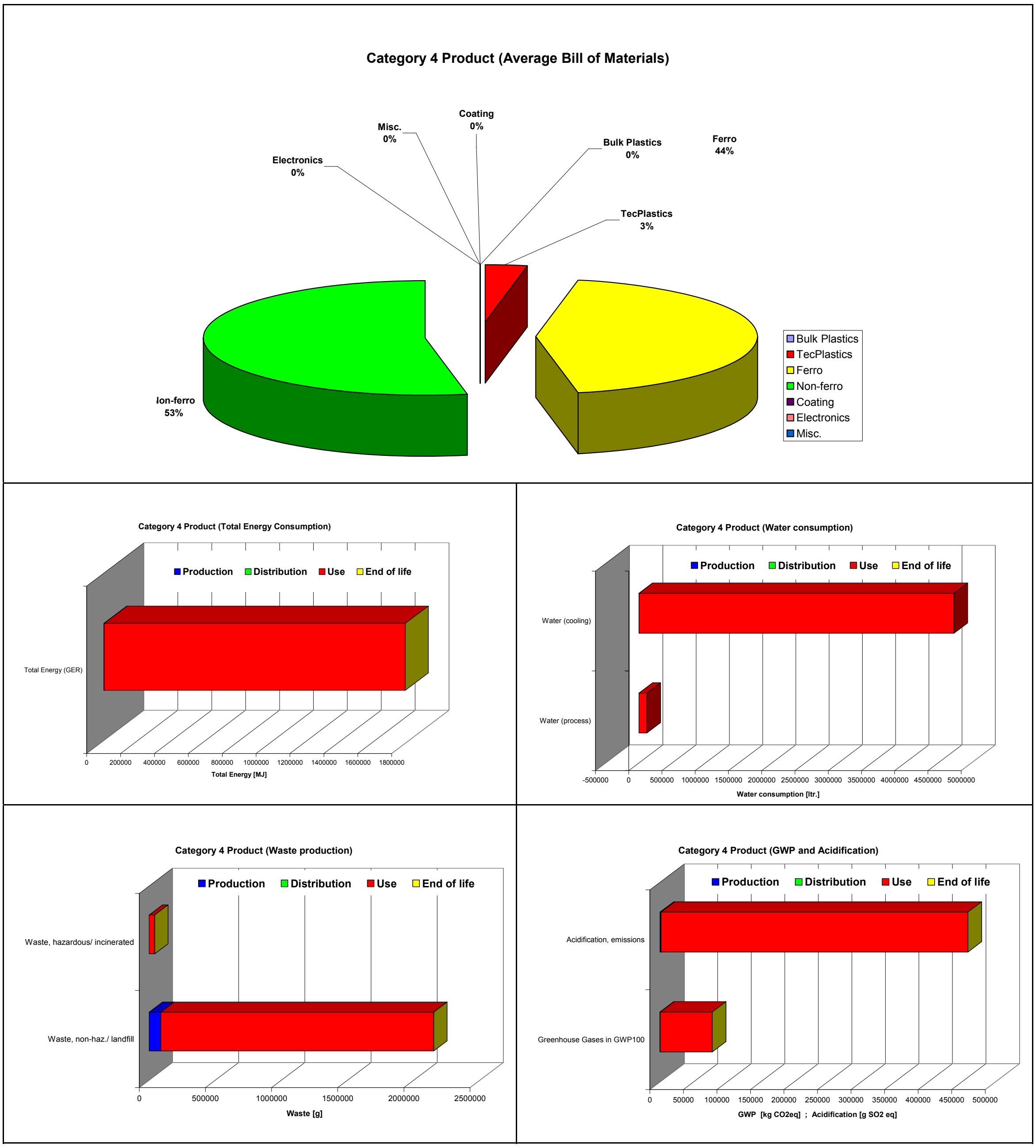


Figure 86: Results of the environmental impact assessment by phase of product life cycle (category 4)

5.1.5 Average BOM Category 5

The average product has a power of about 3.82 kW and a weight of 77.4 kg. The different parts of the fan product, chassis, stator and rotor and casing are mainly produced from copper, aluminium and steel.

Version 5 VHK for European Commission 28 Nov. 2005			Document subject to a legal notice (see below)
ECO-DESIGN OF ENERGY-USING PRODUCTS			**EuP EcoReport: INPUTS** **Assessment of Environmental Impact**
Nr	Product name	Date	Author
5	**Average EU Product Category 5 (centrifugal backward)**	**07.09.2007**	**Peter Radgen**

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Copper Component (mainly motor)	2850,0	4-Non-ferro	**28-Cu winding wire**
2	Chasis,Stator, Rotor	4500,0	4-Non-ferro	**27-Al diecast**
3	Casing	39300,0	3-Ferro	**22-St tube/profile**
4	Others	760,0	2-TecPlastics	**11-PA 6**
5	mainly motorparts	13150,0	3-Ferro	**24-Ferrite**
6	Motor	3250,0	7-Misc.	**56-Cardboard**
7	Chasis,Stator, Rotor	13600,0	3-Ferro	**23-Cast iron**

Figure 87: Materials use for the production of average category 5 product

For the manufacturing the default values of the tool are used. The volume of the packaged product is derived from the typical impeller size which leads to 1 m^3.

Pos nr	MANUFACTURING Description	Weight in g	Percentage Adjust	Category index (fixed)	
201	**OEM Plastics Manufacturing (fixed)**	760		**20**	
202	**Foundries Fe/Cu/Zn (fixed)**	13600		**34**	
203	**Foundries Al/Mg (fixed)**	4500		**35**	
204	**Sheetmetal Manufacturing (fixed)**	13150		**36**	
205	**PWB Manufacturing (fixed)**	0		**53**	
206	**Other materials (Manufacturing already included)**	45400			
207	**Sheetmetal Scrap (Please adjust percentage only)**	3288	**25%**	**37**	
Pos nr	**DISTRIBUTION (incl. Final Assembly) Description**		**Answer**	**Category index (fixed)**	
208	**Is it an ICT or Consumer Electronics product <15 kg ?**		NO	**59**	**0**
209	**Is it an installed appliance (e.g. boiler)?**		NO	**60**	**1**
				62	**1**
210	**Volume of packaged final product in m^3**	**in m3**	1	**63**	**0**
				64	**1**

Figure 88: Manufacturing and distribution of average category 5 product

The main impact which is related to the use phase of the product is based on data as derived in described model. The average power of a category 5 product has been calculated to be 3820 W and 3000 operating hours a year.

Pos nr	USE PHASE Description		unit	Subtotals
211	Product Life in years	15	years	
	Electricity			
212	On-mode: Consumption per hour, cycle, setting, etc.	3,82	kWh	11460
213	On-mode: No. Of hours, cycles, settings, etc. / year	3000	#	
214	Standby-mode: Consumption per hour	0	kWh	0
215	Standby-mode: No. Of hours / year	0	#	
216	Off-mode: Consumption per hour	0	kWh	0
217	Off-mode: No. Of hours / year	0	#	
	TOTAL over Product Life	171,90	MWh (=000 kWh)	65

Figure 89: Energy consumption during use phase of average category 5 product

Base on the model to the developed model to break down the total number of fans introduced in the market in 2005 270178 Units of this kind of products are sold into the European market each year. At a lifetime of the product of 15 years one could assume that the European stock of this product is at maximum 15 times as larger as the yearly consumption. As the number of fans sold in Europe still continues to increase and was lower in previous years. The stock is assumed to 10 times the annual sales in Europe. Even if this might be not very precise it is sufficient to make such estimates, as even the overall number of units sold annually is highly insecure. The price is base on average list prices and would be around 3000 Euro with an additional 300 Euro for installation and acquisition. Electricity rate has been fixed at 7.5 ct/kWh as described earlier.

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	15	years
B	Annual sales	0.37618	mln. Units/year
C	EU Stock	3.7618	mln. Units
D	Product price	3000	Euro/unit
E	Installation/acquisition costs (if any)	300	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.075	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs		Euro/ unit
M	Discount rate (interest minus inflation)	5.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	10.38	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

Figure 90: Input for EU Totals and LLC calculation of category 5 products

Version 5 VHK for European Commission 28 Nov. 2005 | Document subject to a legal notice (see below))

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: RESULTS
Assessment of Environmental Impact

Table . Life Cycle Impact (per unit) of Average EU Product Category 5 (centrifugal backward)

Nr	Life cycle Impact per product:	Date	Author
5	Average EU Product Category 5 (centrifugal backward)	39332	Peter Radgen

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**760**			684	76	**760**	**0**
3	Ferro	g			**66050**			3303	62748	**66050**	**0**
4	Non-ferro	g			**7350**			368	6983	**7350**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**3250**			163	3088	**3250**	**0**
	Total weight	g			**77410**			4517	72894	**77410**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	2306	329	**2635**	**1409**	**1805024**	311	72	**239**	**1809306**
9	of which, electricity (in primary MJ)	MJ	244	190	**435**	**3**	**1804954**	0	0	**0**	**1805392**
10	Water (process)	ltr	570	3	**573**	**0**	**120336**	0	0	**0**	**120908**
11	Water (cooling)	ltr	216	82	**298**	**0**	**4813203**	0	2	**-2**	**4813500**
12	Waste, non-haz./ landfill	g	130506	1498	**132004**	**706**	**2094057**	4745	1	**4744**	**2231511**
13	Waste, hazardous/ incinerated	g	17	0	**17**	**14**	**41592**	684	0	**684**	**42306**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	170	19	**189**	**85**	**78773**	23	5	**18**	**79064**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	1301	81	**1382**	**259**	**464792**	46	7	**39**	**466472**
17	Volatile Organic Compounds (VOC)	g	9	0	**10**	**21**	**681**	1	0	**1**	**712**
18	Persistent Organic Pollutants (POP)	ng i-Teq	1228	35	**1264**	**4**	**11843**	33	0	**33**	**13143**
19	Heavy Metals	mg Ni eq.	766	83	**849**	**36**	**30985**	90	0	**90**	**31960**
	PAHs	mg Ni eq.	97	0	**97**	**47**	**3567**	0	0	**0**	**3711**
20	Particulate Matter (PM, dust)	g	314	12	**327**	**3419**	**10107**	405	0	**404**	**14257**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	190	0	**190**	**1**	**11640**	26	0	**26**	**11857**
22	Eutrophication	g PO4	5	0	**5**	**0**	**56**	1	0	**1**	**62**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

Figure 91: Life Cycle Impact of Average EU Product category 5

The importance of the use phase on the overall environmental impacts can be clearly seen, if the data is presented graphically, Figure 92.

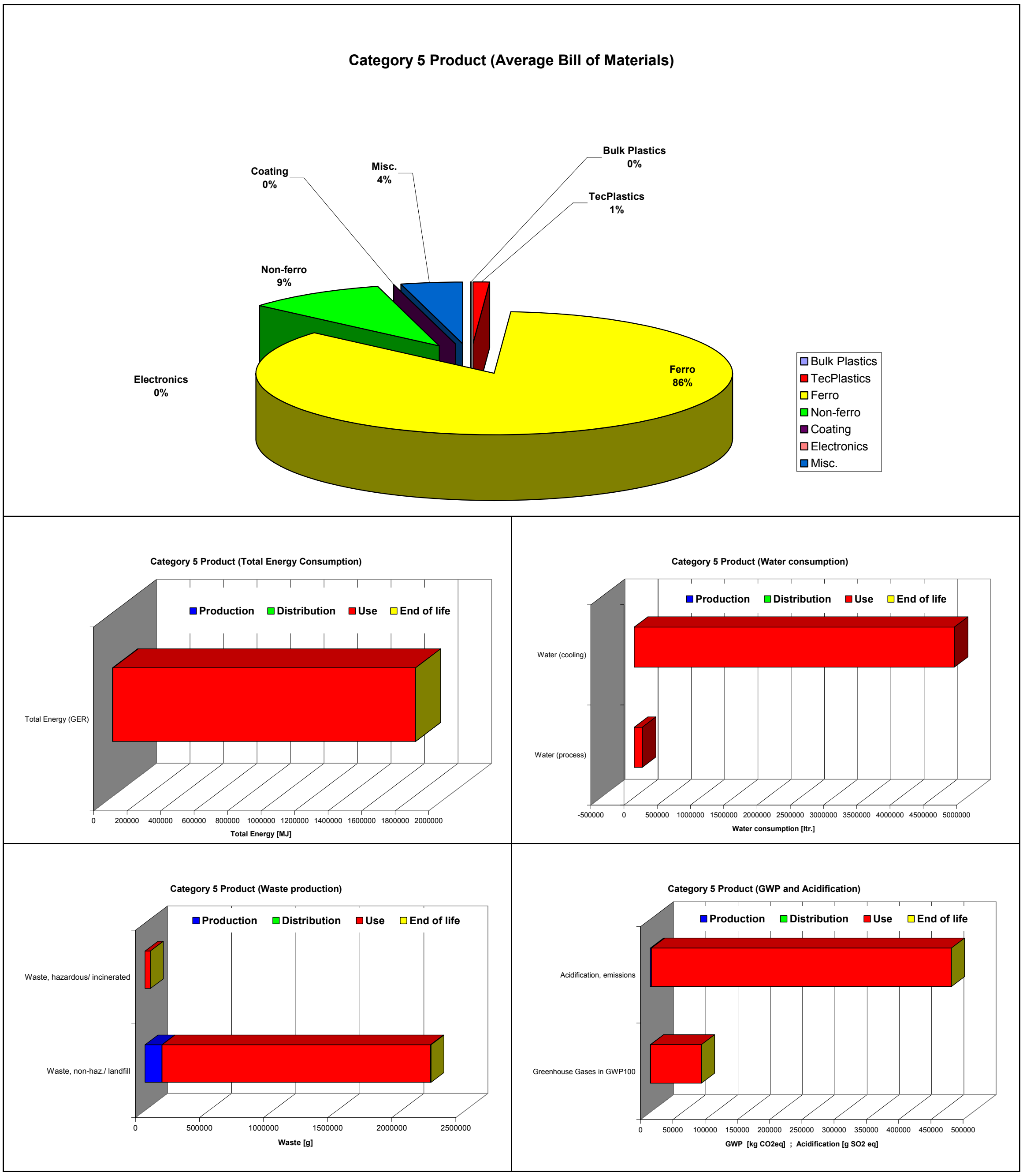


Figure 92: Results of the environmental impact assessment by phase of product life cycle (category 5)

5.1.6 Average BOM Category 6

The average product has a power of about 0.37 kW and a weight of 9.9 kg. The different parts of the fan product, chassis, stator and rotor and casing are mainly produced from copper, aluminium and steel.

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: INPUTS
Assessment of Environmental Impact

Nr	Product name	Date	Author
6	**Average EU Product Category 6 (box fan)**	**07.09.2007**	**Peter Radgen**

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Copper Component (mainly motor)	1000,0	4-Non-ferro	**28-Cu winding wire**
2	Chasis,Stator, Rotor	900,0	4-Non-ferro	**27-Al diecast**
3	Chasis,Stator, Rotor	4000,0	3-Ferro	**22-St tube/profile**
4	Others	500,0	2-TecPlastics	**11-PA 6**
5	mainly casing	3500,0	3-Ferro	**21-St sheet galv.**

Figure 93: Materials use for the production of average category 6 product

For the manufacturing the default values of the tool are used. The volume of the packaged product is derived from the typical impeller size which leads to 0.3 m³.

Pos nr	MANUFACTURING Description	Weight in g	Percentage Adjust	Category index (fixed)	
201	OEM Plastics Manufacturing (fixed)	500		20	
202	Foundries Fe/Cu/Zn (fixed)	0		34	
203	Foundries Al/Mg (fixed)	900		35	
204	Sheetmetal Manufacturing (fixed)	3500		36	
205	PWB Manufacturing (fixed)	0		53	
206	Other materials (Manufacturing already included)	5000			
207	Sheetmetal Scrap (Please adjust percentage only)	875	25%	37	
Pos nr	**DISTRIBUTION (incl. Final Assembly) Description**		**Answer**	**Category index (fixed)**	
208	Is it an ICT or Consumer Electronics product <15 kg ?		NO	59	0
209	Is it an installed appliance (e.g. boiler)?		NO	60	1
				62	1
210	Volume of packaged final product in m³	in m3	0,3	63	0
				64	1

Figure 94: Manufacturing and distribution of average category 6 product

The main impact which is related to the use phase of the product is based on data as derived in described model. The average power of a category 5 product has been calculated to be 370 W and 1715 operating hours a year.

Pos nr	USE PHASE Description		unit	Subtotals
211	Product Life in years	15	years	
	Electricity			
212	On-mode: Consumption per hour, cycle, setting, etc.	0,37	kWh	634,55
213	On-mode: No. Of hours, cycles, settings, etc. / year	1715	#	
214	Standby-mode: Consumption per hour	0	kWh	0
215	Standby-mode: No. Of hours / year	0	#	
216	Off-mode: Consumption per hour	0	kWh	0
217	Off-mode: No. Of hours / year	0	#	
	TOTAL over Product Life	9,52	MWh (=000 kWh)	65

Figure 95: Energy consumption during use phase of average category 6 product

Base on the model to the developed model to break down the total number of fans introduced in the market in 2005 647265 Units of this kind of products are sold into the European market each year. At a lifetime of the product of 15 years one could assume that the European stock of this product is at maximum 15 times as larger as the yearly consumption. As the number of fans sold in Europe still continues to increase and was lower in previous years. The stock is assumed to 10 times the annual sales in Europe. Even if this might be not very precise it is sufficient to make such estimates, as even the overall number of units sold annually is highly insecure. The price is base on average list prices and would be around 800 Euro with an additional 80 Euro for installation and acquisition. Electricity rate has been fixed at 7.5 ct/kWh as described earlier.

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	15	years
B	Annual sales	1.532397	mln. Units/year
C	EU Stock	15.32397	mln. Units
D	Product price	800	Euro/unit
E	Installation/acquisition costs (if any)	80	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.075	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs		Euro/ unit
M	Discount rate (interest minus inflation)	5.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	10.38	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

Figure 96: Input for EU Totals and LLC calculation of category 6 products

Version 5 VHK for European Commission 28 Nov. 2005 | Document subject to a legal notice (see below))

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: RESULTS
Assessment of Environmental Impact

Table . Life Cycle Impact (per unit) of Average EU Product Category 6 (box fan)

Nr	Life cycle Impact per product:	Date	Author
6	Average EU Product Category 6 (box fan)	39332	Peter Radgen

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**500**			450	50	**500**	**0**
3	Ferro	g			**7500**			375	7125	**7500**	**0**
4	Non-ferro	g			**1900**			95	1805	**1900**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**0**			0	0	**0**	**0**
	Total weight	g			**9900**			920	8980	**9900**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	439	90	**529**	**459**	**99995**	64	20	**45**	**101027**
9	of which, electricity (in primary MJ)	MJ	34	52	**86**	**1**	**99942**	0	0	**0**	**100029**
10	Water (process)	ltr	8	1	**9**	**0**	**6663**	0	0	**0**	**6671**
11	Water (cooling)	ltr	110	22	**132**	**0**	**266512**	0	1	**-1**	**266643**
12	Waste, non-haz./ landfill	g	30031	406	**30437**	**248**	**116181**	607	1	**606**	**147472**
13	Waste, hazardous/ incinerated	g	10	0	**10**	**5**	**2303**	450	0	**450**	**2768**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	30	5	**35**	**29**	**4365**	5	1	**3**	**4433**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	378	22	**400**	**86**	**25743**	10	2	**8**	**26237**
17	Volatile Organic Compounds (VOC)	g	1	0	**1**	**6**	**38**	0	0	**0**	**46**
18	Persistent Organic Pollutants (POP)	ng i-Teq	173	9	**183**	**1**	**657**	4	0	**4**	**845**
19	Heavy Metals	mg Ni eq.	80	22	**102**	**13**	**1726**	18	0	**18**	**1859**
	PAHs	mg Ni eq.	22	0	**22**	**16**	**208**	0	0	**0**	**245**
20	Particulate Matter (PM, dust)	g	23	3	**26**	**1026**	**726**	84	0	**84**	**1862**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	55	0	**56**	**0**	**645**	5	0	**5**	**706**
22	Eutrophication	g PO4	1	0	**2**	**0**	**3**	0	0	**0**	**5**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

Figure 97: Life Cycle Impact of Average EU Product category 6

The importance of the use phase on the overall environmental impacts can be clearly seen, if the data is presented graphically, Figure 98.

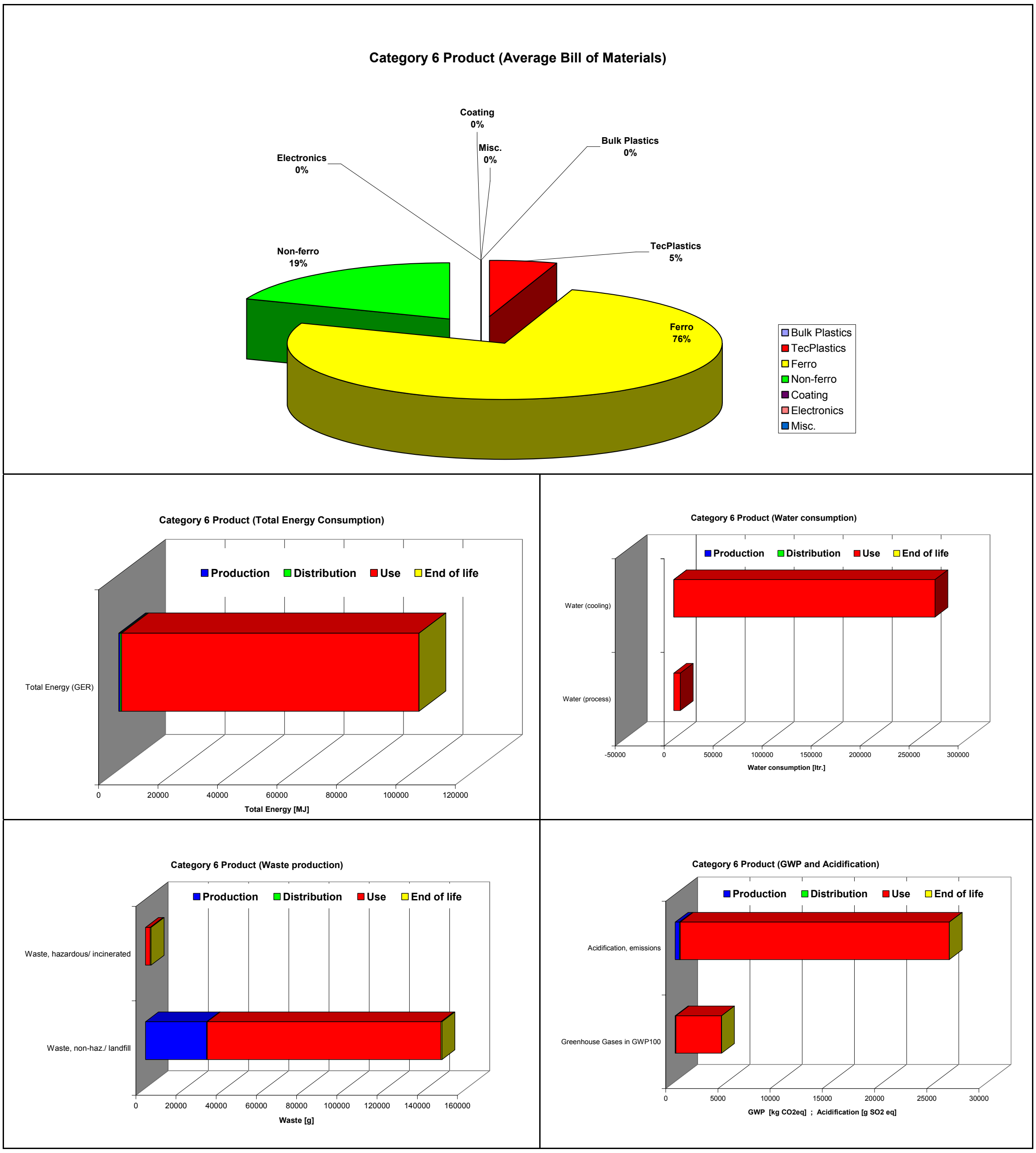


Figure 98: Results of the environmental impact assessment by phase of product life cycle (category 6)

5.1.7 Average BOM Category 7

The average product has a power of about 1.2 kW and a weight of 60.4 kg. The different parts of the fan product, chassis, stator and rotor and casing are mainly produced from copper, aluminium and steel.

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: INPUTS
Assessment of Environmental Impact

Nr	Product name	Date	Author
7	**Average EU Product Category 7 (roof fan)**	**07.09.2007**	**Peter Radgen**

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Copper Component (mainly motor)	1700,0	4-Non-ferro	**28-Cu winding wire**
2	Chasis,Stator, Rotor	8200,0	4-Non-ferro	**27-Al diecast**
3	Chasis,Stator, Rotor	7900,0	3-Ferro	**22-St tube/profile**
4	Others	600,0	2-TecPlastics	**11-PA 6**
5	mainly casing	42000,0	3-Ferro	**21-St sheet galv.**

Figure 99: Materials use for the production of average category 7 product

For the manufacturing the default values of the tool are used. The volume of the packaged product is derived from the typical impeller size which leads to 0.8 m^3.

Pos nr	MANUFACTURING Description	Weight in g	Percentage Adjust	Category index (fixed)	
201	OEM Plastics Manufacturing (fixed)	600		20	
202	Foundries Fe/Cu/Zn (fixed)	0		34	
203	Foundries Al/Mg (fixed)	8200		35	
204	Sheetmetal Manufacturing (fixed)	42000		36	
205	PWB Manufacturing (fixed)	0		53	
206	Other materials (Manufacturing already included)	9600			
207	Sheetmetal Scrap (Please adjust percentage only)	10500	25%	37	
Pos nr	**DISTRIBUTION (incl. Final Assembly) Description**		**Answer**	**Category index (fixed)**	
208	Is it an ICT or Consumer Electronics product <15 kg ?		NO	59	0
209	Is it an installed appliance (e.g. boiler)?		NO	60	1
				62	1
210	Volume of packaged final product in m^3	in m3	0,8	63	0
				64	1

Figure 100: Manufacturing and distribution of average category 7 product

The main impact which is related to the use phase of the product is based on data as derived in described model. The average power of a category 7 product has been calculated to be 1200 W and 2520 operating hours a year.

Pos nr	USE PHASE Description		unit	Subtotals
211	Product Life in years	15	years	
	Electricity			
212	On-mode: Consumption per hour, cycle, setting, etc.	1,20	kWh	3024
213	On-mode: No. Of hours, cycles, settings, etc. / year	2520	#	
214	Standby-mode: Consumption per hour	0	kWh	0
215	Standby-mode: No. Of hours / year	0	#	
216	Off-mode: Consumption per hour	0	kWh	0
217	Off-mode: No. Of hours / year	0	#	
	TOTAL over Product Life	45,36	MWh (=000 kWh)	65

Figure 101: Energy consumption during use phase of average category 7 product

Base on the model to the developed model to break down the total number of fans introduced in the market in 2005 1138048 Units of this kind of products are sold into the European market each year. At a lifetime of the product of 15 years one could assume that the European stock of this product is at maximum 15 times as larger as the yearly consumption. As the number of fans sold in Europe still continues to increase and was lower in previous years. The stock is assumed to 10 times the annual sales in Europe. Even if this might be not very precise it is sufficient to make such estimates, as even the overall number of units sold annually is highly insecure. The price is base on average list prices and would be around 1400 Euro with an additional 140 Euro for installation and acquisition. Electricity rate has been fixed at 7.5 ct/kWh as described earlier.

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	15	years
B	Annual sales	2.694325	mln. Units/year
C	EU Stock	26.94325	mln. Units
D	Product price	1400	Euro/unit
E	Installation/acquisition costs (if any)	140	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.075	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs		Euro/ unit
M	Discount rate (interest minus inflation)	5.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	10.38	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

Figure 102: Input for EU Totals and LLC calculation of category 7 products

Version 5 VHK for European Commission 28 Nov. 2005 | Document subject to a legal notice (see below))

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: RESULTS
Assessment of Environmental Impact

Table . Life Cycle Impact (per unit) of Average EU Product Category 7 (roof fan)

Nr	Life cycle Impact per product:	Date	Author
7	Average EU Product Category 7 (roof fan)	39332	Peter Radgen

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**600**			540	60	**600**	**0**
3	Ferro	g			**49900**			2495	47405	**49900**	**0**
4	Non-ferro	g			**9900**			495	9405	**9900**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**0**			0	0	**0**	**0**
	Total weight	g			**60400**			3530	56870	**60400**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	2329	839	**3168**	**1137**	**476360**	243	26	**217**	**480882**
9	of which, electricity (in primary MJ)	MJ	141	481	**622**	**2**	**476286**	0	0	**0**	**476910**
10	Water (process)	ltr	10	6	**16**	**0**	**31752**	0	0	**0**	**31768**
11	Water (cooling)	ltr	131	203	**334**	**0**	**1270083**	0	1	**-1**	**1270416**
12	Waste, non-haz./ landfill	g	118953	4127	**123080**	**575**	**553450**	3703	1	**3702**	**680807**
13	Waste, hazardous/ incinerated	g	13	1	**13**	**11**	**10975**	540	0	**540**	**11540**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	176	48	**224**	**69**	**20791**	18	2	**16**	**21100**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	1010	208	**1218**	**210**	**122658**	36	2	**33**	**124119**
17	Volatile Organic Compounds (VOC)	g	7	1	**8**	**17**	**180**	1	0	**1**	**206**
18	Persistent Organic Pollutants (POP)	ng i-Teq	1468	113	**1581**	**3**	**3138**	25	0	**25**	**4748**
19	Heavy Metals	mg Ni eq.	272	265	**537**	**29**	**8187**	70	0	**70**	**8823**
	PAHs	mg Ni eq.	158	0	**158**	**38**	**950**	0	0	**0**	**1146**
20	Particulate Matter (PM, dust)	g	163	32	**195**	**2736**	**2798**	316	0	**316**	**6044**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	255	0	**255**	**1**	**3073**	20	0	**20**	**3350**
22	Eutrophication	g PO4	4	0	**5**	**0**	**15**	1	0	**1**	**21**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

Figure 103: Life Cycle Impact of Average EU Product category 7

The importance of the use phase on the overall environmental impacts can be clearly seen, if the data is presented graphically, Figure 104.

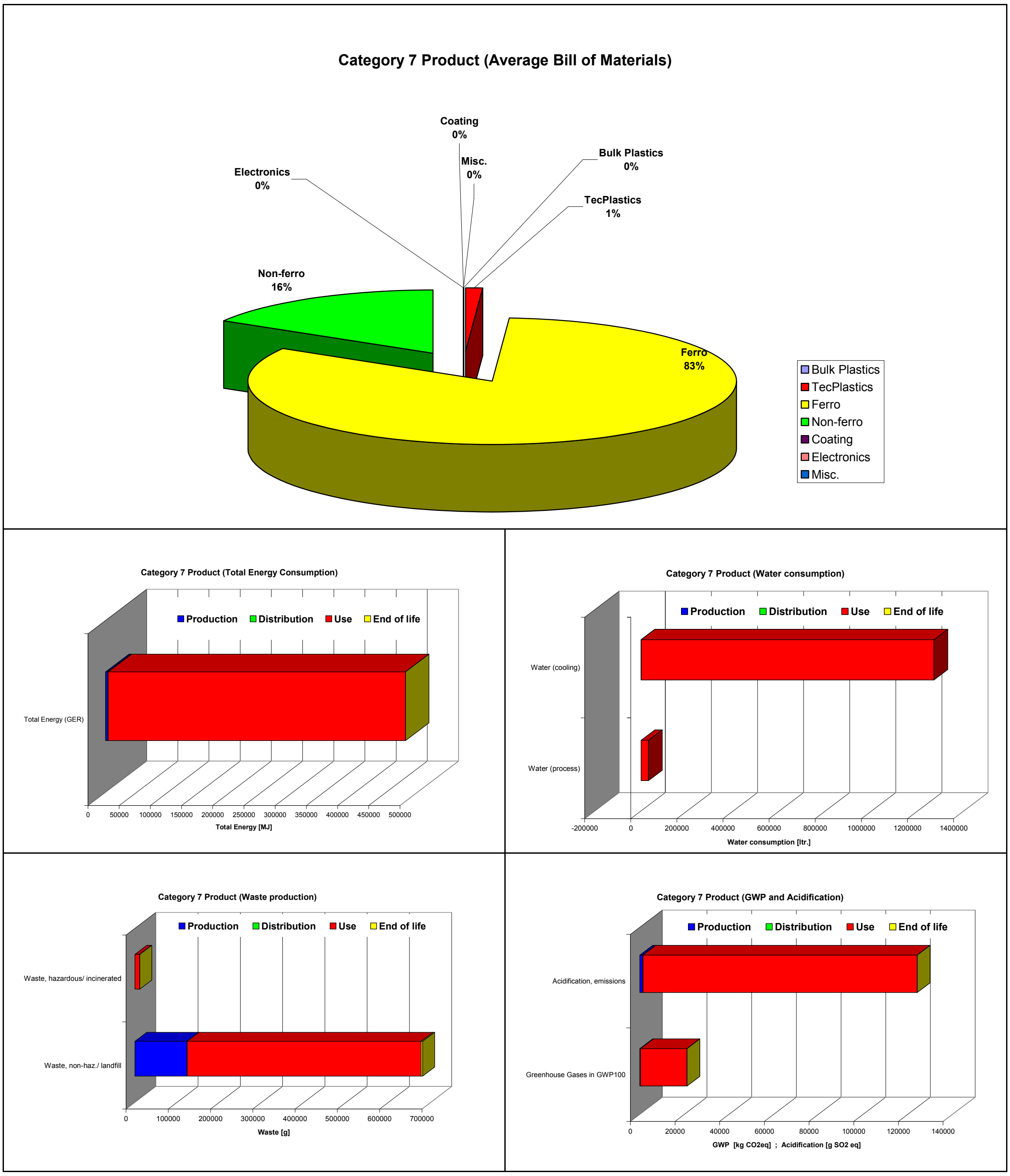


Figure 104: Results of the environmental impact assessment by phase of product life cycle (category 7)

5.1.8 Average BOM Category 8

The average product has a power of about 0.42 kW and a weight of 7.8 kg. The different parts of the fan product, chassis, stator and rotor and casing are mainly produced from copper, aluminium and steel.

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: INPUTS
Assessment of Environmental Impact

Nr	Product name	Date	Author
8	**Average EU Product Category 8 (crossflow)**	**07.09.2007**	**Peter Radgen**

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Copper Component (mainly motor)	1000,0	4-Non-ferro	**28-Cu winding wire**
2	Chasis,Stator, Rotor	890,0	4-Non-ferro	**27-Al diecast**
3	Chasis,Stator, Rotor	4980,0	3-Ferro	**22-St tube/profile**
4	Casing	500,0	3-Ferro	**21-St sheet galv.**
5	Others	400,0	2-TecPlastics	**11-PA 6**

Figure 105: Materials use for the production of average category 8 product

For the manufacturing the default values of the tool are used. The volume of the packaged product is derived from the typical impeller size which leads to 0.3 m^3.

Pos nr	MANUFACTURING Description	Weight in g	Percentage Adjust	Category index (fixed)	
201	OEM Plastics Manufacturing (fixed)	400		20	
202	Foundries Fe/Cu/Zn (fixed)	0		34	
203	Foundries Al/Mg (fixed)	890		35	
204	Sheetmetal Manufacturing (fixed)	500		36	
205	PWB Manufacturing (fixed)	0		53	
206	Other materials (Manufacturing already included)	5980			
207	Sheetmetal Scrap (Please adjust percentage only)	125	25%	37	
Pos nr	**DISTRIBUTION (incl. Final Assembly) Description**		**Answer**	**Category index (fixed)**	
208	Is it an ICT or Consumer Electronics product <15 kg ?		NO	59	0
209	Is it an installed appliance (e.g. boiler)?		NO	60	1
				62	1
210	Volume of packaged final product in m^3	in m3	0,3	63	0
				64	1

Figure 106: Manufacturing and distribution of average category 8 product

The main impact which is related to the use phase of the product is based on data as derived in described model. The average power of a category 7 product has been calculated to be 420 W and 1865 operating hours a year.

Pos nr	USE PHASE Description		unit	Subtotals	
211	Product Life in years	15	years		
	Electricity				
212	On-mode: Consumption per hour, cycle, setting, etc.	0,42	kWh	783,3	
213	On-mode: No. Of hours, cycles, settings, etc. / year	1865	#		
214	Standby-mode: Consumption per hour	0	kWh	0	
215	Standby-mode: No. Of hours / year	0	#		
216	Off-mode: Consumption per hour	0	kWh	0	
217	Off-mode: No. Of hours / year	0	#		
	TOTAL over Product Life	11,75	MWh (=000 kWh)		65

Figure 107: Energy consumption during use phase of average category 8 product

Base on the model to the developed model to break down the total number of fans introduced in the market in 2005 77055 Units of this kind of products are sold into the European market each year. At a lifetime of the product of 15 years one could assume that the European stock of this product is at maximum 15 times as larger as the yearly consumption. As the number of fans sold in Europe still continues to increase and was lower in previous years. The stock is assumed to 10 times the annual sales in Europe. Even if this might be not very precise it is sufficient to make such estimates, as even the overall number of units sold annually is highly insecure. The price is base on average list prices and would be around 600 Euro with an additional 50 Euro for installation and acquisition. Electricity rate has been fixed at 7.5 ct/kWh as described earlier.

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	15	years
B	Annual sales	0.182428	mln. Units/year
C	EU Stock	1.82428	mln. Units
D	Product price	600	Euro/unit
E	Installation/acquisition costs (if any)	50	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.075	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs		Euro/ unit
M	Discount rate (interest minus inflation)	5.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	10.38	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

Figure 108: Input for EU Totals and LLC calculation of category 8 products

Version 5 VHK for European Commission 28 Nov. 2005 | Document subject to a legal notice (see below))

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: RESULTS
Assessment of Environmental Impact

Table . Life Cycle Impact (per unit) of Average EU Product Category 8 (crossflow)

Nr	Life cycle Impact per product:	Date	Author
8	Average EU Product Category 8 (crossflow)	39332	Peter Radgen

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**400**			360	40	**400**	**0**
3	Ferro	g			**5480**			274	5206	**5480**	**0**
4	Non-ferro	g			**1890**			95	1796	**1890**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**0**			0	0	**0**	**0**
	Total weight	g			**7770**			729	7042	**7770**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	341	31	**372**	**459**	**123422**	51	15	**36**	**124288**
9	of which, electricity (in primary MJ)	MJ	30	18	**48**	**1**	**123370**	0	0	**0**	**123419**
10	Water (process)	ltr	6	0	**7**	**0**	**8225**	0	0	**0**	**8231**
11	Water (cooling)	ltr	88	8	**96**	**0**	**328987**	0	1	**-1**	**329082**
12	Waste, non-haz./ landfill	g	25626	116	**25742**	**248**	**143298**	476	1	**476**	**169763**
13	Waste, hazardous/ incinerated	g	8	0	**8**	**5**	**2843**	360	0	**360**	**3216**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	22	2	**24**	**29**	**5388**	4	1	**3**	**5443**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	355	8	**363**	**86**	**31775**	8	1	**6**	**32230**
17	Volatile Organic Compounds (VOC)	g	1	0	**1**	**6**	**47**	0	0	**0**	**54**
18	Persistent Organic Pollutants (POP)	ng i-Teq	107	1	**108**	**1**	**810**	3	0	**3**	**922**
19	Heavy Metals	mg Ni eq.	72	3	**75**	**13**	**2128**	14	0	**14**	**2230**
	PAHs	mg Ni eq.	22	0	**22**	**16**	**254**	0	0	**0**	**291**
20	Particulate Matter (PM, dust)	g	15	1	**16**	**1026**	**855**	66	0	**66**	**1964**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	41	0	**41**	**0**	**796**	4	0	**4**	**842**
22	Eutrophication	g PO4	1	0	**1**	**0**	**4**	0	0	**0**	**5**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

Figure 109: Life Cycle Impact of Average EU Product category 8

The importance of the use phase on the overall environmental impacts can be clearly seen, if the data is presented graphically, Figure 110.

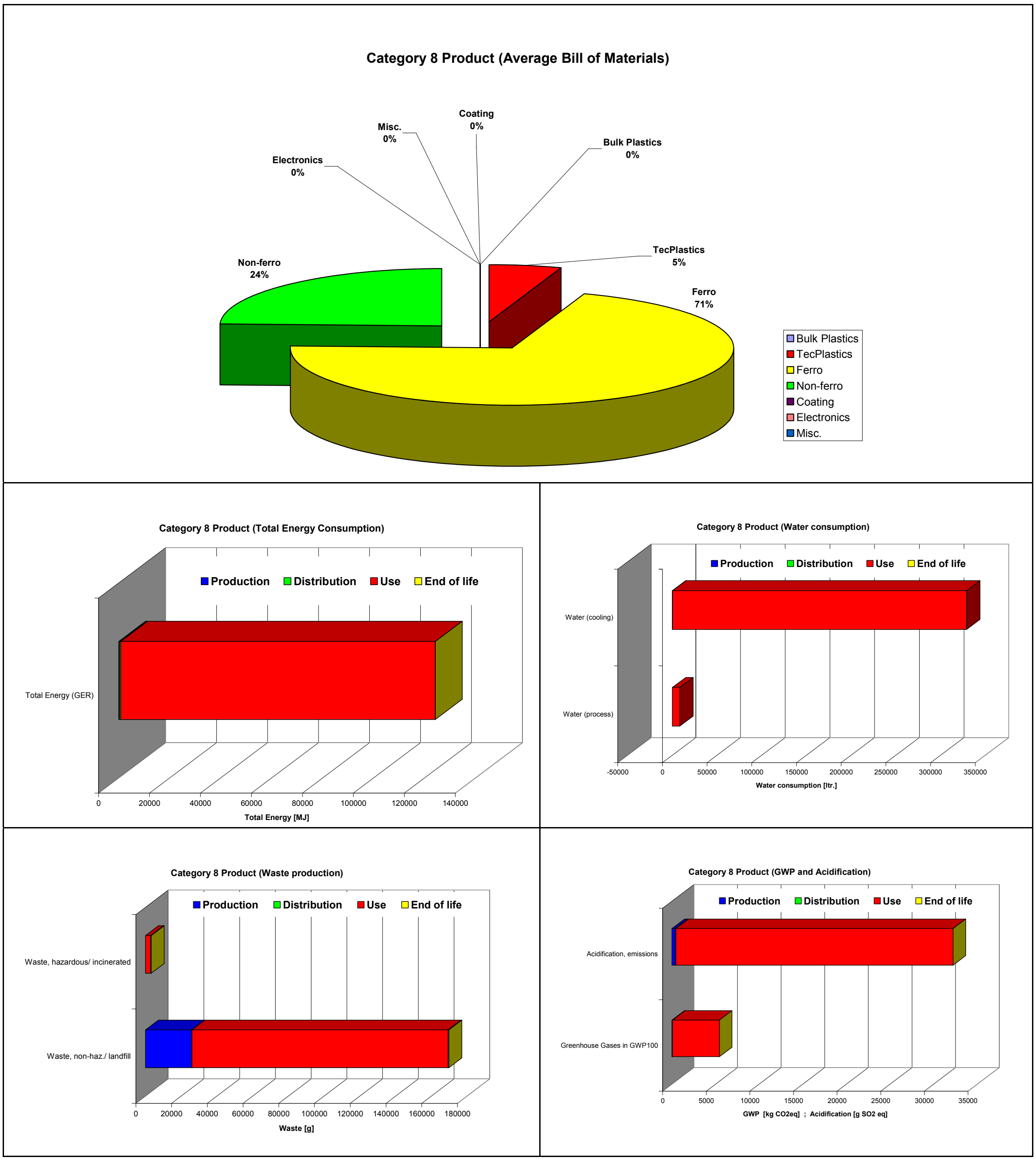


Figure 110: Results of the environmental impact assessment by phase of product life cycle (category 8)

5.2 Base-case environmental impact assessment

The total environmental impact of the installed stock of products of the different defined product categories is summarized in Figure 111. The main source for the environmental impact of the stock of products installed in EU-27 is related to the electricity consumption during the use phase.

Table . Summary Environmental Impacts EU-Stock 2005, Average EU Product Category 1 (axial < 300 Pa)

main life cycle indicators	value	unit
Total Energy (GER)	**122**	PJ
of which, electricity	11.5	TWh
Water (process)*	**8**	mln.m3
Waste, non-haz./ landfill*	**197**	kton
Waste, hazardous/ incinerated*	**3**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**5**	mt CO2eq.
Acidifying agents (AP)	**32**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**2**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**2**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

***=caution: low accuracy for production phase**

Table . Summary Environmental Impacts EU-Stock 2005, Average EU Product Category 2 (axial > 300 Pa)

main life cycle indicators	value	unit
Total Energy (GER)	**558**	PJ
of which, electricity	52.7	TWh
Water (process)*	**37**	mln.m3
Waste, non-haz./ landfill*	**839**	kton
Waste, hazardous/ incinerated*	**15**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**24**	mt CO2eq.
Acidifying agents (AP)	**145**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**5**	g i-Teq.
Heavy Metals (HM)	**10**	ton Ni eq.
PAHs	**2**	ton Ni eq.
Particulate Matter (PM, dust)	**6**	kt
Emissions (Water)		
Heavy Metals (HM)	4	ton Hg/20
Eutrophication (EP)	0	kt PO4

***=caution: low accuracy for production phase**

Figure 111: EU Total environmental impact for stock of product categories 1 and 2

Table . Summary Environmental Impacts EU-Stock 2005, Average EU Product Category 3 (centrifugal forward)

main life cycle indicators	value	unit
Total Energy (GER)	**152**	PJ
of which, electricity	14.4	TWh
Water (process)*	**10**	mln.m3
Waste, non-haz./ landfill*	**211**	kton
Waste, hazardous/ incinerated*	**4**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**7**	mt CO2eq.
Acidifying agents (AP)	**39**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**3**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**1**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

***=caution: low accuracy for production phase**

Table . Summary Environmental Impacts EU-Stock 2005, Average EU Product Category 4 (centrifugal free wheel)

main life cycle indicators	value	unit
Total Energy (GER)	**401**	PJ
of which, electricity	38.1	TWh
Water (process)*	**27**	mln.m3
Waste, non-haz./ landfill*	**494**	kton
Waste, hazardous/ incinerated*	**10**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**18**	mt CO2eq.
Acidifying agents (AP)	**103**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**3**	g i-Teq.
Heavy Metals (HM)	**7**	ton Ni eq.
PAHs	**1**	ton Ni eq.
Particulate Matter (PM, dust)	**3**	kt
Emissions (Water)		
Heavy Metals (HM)	3	ton Hg/20
Eutrophication (EP)	0	kt PO4

***=caution: low accuracy for production phase**

Figure 112: EU Total environmental impact for stock of product categories 3 and 4

Table . Summary Environmental Impacts EU-Stock 2005, Average EU Product Category 5 (centrifugal backward)

main life cycle indicators	value	unit
Total Energy (GER)	**454**	PJ
of which, electricity	43.1	TWh
Water (process)*	**30**	mln.m3
Waste, non-haz./ landfill*	**577**	kton
Waste, hazardous/ incinerated*	**11**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**20**	mt CO2eq.
Acidifying agents (AP)	**117**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**3**	g i-Teq.
Heavy Metals (HM)	**8**	ton Ni eq.
PAHs	**1**	ton Ni eq.
Particulate Matter (PM, dust)	**4**	kt
Emissions (Water)		
Heavy Metals (HM)	3	ton Hg/20
Eutrophication (EP)	0	kt PO4

***=caution: low accuracy for production phase**

Table . Summary Environmental Impacts EU-Stock 2005, Average EU Product Category 6 (box fan)

main life cycle indicators	value	unit
Total Energy (GER)	**104**	PJ
of which, electricity	9.7	TWh
Water (process)*	**7**	mln.m3
Waste, non-haz./ landfill*	**167**	kton
Waste, hazardous/ incinerated*	**3**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**5**	mt CO2eq.
Acidifying agents (AP)	**27**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**2**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**2**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

***=caution: low accuracy for production phase**

Figure 113: EU Total environmental impact for stock of product categories 5 and 6

Table . Summary Environmental Impacts EU-Stock 2005, Average EU Product Category 7 (roof fan)

main life cycle indicators	value	unit
Total Energy (GER)	**868**	PJ
of which, electricity	81.6	TWh
Water (process)*	**57**	mln.m3
Waste, non-haz./ landfill*	**1337**	kton
Waste, hazardous/ incinerated*	**21**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**38**	mt CO2eq.
Acidifying agents (AP)	**224**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**10**	g i-Teq.
Heavy Metals (HM)	**16**	ton Ni eq.
PAHs	**2**	ton Ni eq.
Particulate Matter (PM, dust)	**14**	kt
Emissions (Water)		
Heavy Metals (HM)	6	ton Hg/20
Eutrophication (EP)	0	kt PO4

***=caution: low accuracy for production phase**

Table . Summary Environmental Impacts EU-Stock 2005, Average EU Product Category 8 (crossflow)

main life cycle indicators	value	unit
Total Energy (GER)	**15**	PJ
of which, electricity	1.4	TWh
Water (process)*	**1**	mln.m3
Waste, non-haz./ landfill*	**22**	kton
Waste, hazardous/ incinerated*	**0**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**1**	mt CO2eq.
Acidifying agents (AP)	**4**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**0**	g i-Teq.
Heavy Metals (HM)	**0**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**0**	kt
Emissions (Water)		
Heavy Metals (HM)	0	ton Hg/20
Eutrophication (EP)	0	kt PO4

***=caution: low accuracy for production phase**

Figure 114: EU Total environmental impact for stock of product categories 7

5.3 Base-case life cycle costs

The life cycle cost of motor driven systems are highly dominated by the use phase as have been proven by many previous studies on motor driven systems [Radgen, 2000, Radgen 2001; Almeida, 2000; Almeida 2001, ZVEI 2006]. As motors are highly reliant machines they are requiring only very little maintenance over their lifetime and are very robust. So during the use phase, the electricity cost for operating the motor driven systems far outweighs all other cost factors. Energy costs make up typically more than 2/3 of the total life cycle cost of motor driven systems. As a rule of thumb, a motor driven systems consumes in the first one or two years of operation the same amount of money for energy than the initial purchase price of product. This is even true in cases where the annual number of operating ours is low as for the calculation of our average product, leading only to about 2000 hours of operation. However many applications exists, in which the number of operating hours is higher and therefore the energy cost on the total life cycle cost are even more important.

	Average EU Product Category 1 (axial < 300 Pa) *Item*	**LCC new product**		**total annual consumer expenditure in EU25**	
D	Product price	450	€	323	mln.€
E	Installation/ acquisition costs (if any)	50	€	36	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	1246	€	862	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	0	€	0	mln.€
	Total	**1746**	€	**1221**	mln.€

Figure 115: Life cycle cost for product category 1

	Average EU Product Category 2 (axial > 300 Pa) *Item*	**LCC new product**		**total annual consumer expenditure in EU25**	
D	Product price	600	€	1197	mln.€
E	Installation/ acquisition costs (if any)	50	€	100	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	2055	€	3949	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	0	€	0	mln.€
	Total	**2705**	€	**5246**	mln.€

Figure 116: Life cycle cost for product category 2

	Average EU Product Category 3 (centrifugal forward) *Item*	LCC new product	total annual consumer expenditure in EU25
D	Product price	750 €	819 mln.€
E	Installation/ acquisition costs (if any)	50 €	55 mln.€
F	Fuel (gas, oil, wood)	0 €	0 mln.€
F	Electricity	1028 €	1081 mln.€
G	Water	0 €	0 mln.€
H	Aux. 1: None	0 €	0 mln.€
I	Aux. 2 :None	0 €	0 mln.€
J	Aux. 3: None	0 €	0 mln.€
K	Repair & maintenance costs	0 €	0 mln.€
	Total	**1828** €	**1954** mln.€

Figure 117: Life cycle cost for product category 3

	Average EU Product Category 4 (centrifugal free wheel) *Item*	LCC new product	total annual consumer expenditure in EU25
D	Product price	1400 €	473 mln.€
E	Installation/ acquisition costs (if any)	140 €	47 mln.€
F	Fuel (gas, oil, wood)	0 €	0 mln.€
F	Electricity	8781 €	2856 mln.€
G	Water	0 €	0 mln.€
H	Aux. 1: None	0 €	0 mln.€
I	Aux. 2 :None	0 €	0 mln.€
J	Aux. 3: None	0 €	0 mln.€
K	Repair & maintenance costs	0 €	0 mln.€
	Total	**10321** €	**3376** mln.€

Figure 118: Life cycle cost for product category 4

	Average EU Product Category 5 (centrifugal backward) *Item*	LCC new product	total annual consumer expenditure in EU25
D	Product price	3000 €	1129 mln.€
E	Installation/ acquisition costs (if any)	300 €	113 mln.€
F	Fuel (gas, oil, wood)	0 €	0 mln.€
F	Electricity	8921 €	3233 mln.€
G	Water	0 €	0 mln.€
H	Aux. 1: None	0 €	0 mln.€
I	Aux. 2 :None	0 €	0 mln.€
J	Aux. 3: None	0 €	0 mln.€
K	Repair & maintenance costs	0 €	0 mln.€
	Total	**12221** €	**4475** mln.€

Figure 119: Life cycle cost for product category 5

	Average EU Product Category 6 (box fan) *Item*	LCC new product		total annual consumer expenditure in EU25	
D	Product price	800	€	1226	mln.€
E	Installation/ acquisition costs (if any)	80	€	123	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	494	€	729	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	0	€	0	mln.€
	Total	**1374**	€	**2078**	mln.€

Figure 120: Life cycle cost for product category 6

	Average EU Product Category 7 (roof fan) *Item*	LCC new product		total annual consumer expenditure in EU25	
D	Product price	1400	€	3772	mln.€
E	Installation/ acquisition costs (if any)	140	€	377	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	2354	€	6111	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	0	€	0	mln.€
	Total	**3894**	€	**10260**	mln.€

Figure 121: Life cycle cost for product category 7

	Average EU Product Category 8 (crossflow) *Item*	LCC new product		total annual consumer expenditure in EU25	
D	Product price	600	€	109	mln.€
E	Installation/ acquisition costs (if any)	50	€	9	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	610	€	107	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	0	€	0	mln.€
	Total	**1260**	€	**226**	mln.€

Figure 122: Life cycle cost for product category 8

5.4 EU Totals

As could be seen from the data in the previous chapters, energy consumption is the highly dominant impact of the fan products. Other product specific inputs than electricity can be neglected. During use phase only a few grams of grease for bearings or other material is needed for maintenance issues, many bearing have already lifetime greasing. Also the material consumption for the production of the products only plays a very minor role in the overall impact. Therefore changes in applied materials in the product will have negligible impact. As an example for the product category 2 the amount of Ferro material used can be increase by about 50 %, Figure 123.

Nr	Life cycle Impact per product:	Date	Author
2	Average EU Product Category 2 (axial > 300 Pa)	39332	Peter Radgen

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**1300**			1170	130	**1300**	**0**
3	Ferro	g			**59000**			2950	56050	**59000**	**0**
4	Non-ferro	g			**14700**			735	13965	**14700**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**0**			0	0	**0**	**0**
	Total weight	g			**75000**			4855	70145	**75000**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	2205	131	**2337**	**323**	**415872**	336	44	**292**	**418823**
9	of which, electricity (in primary MJ)	MJ	289	79	**368**	**1**	**415804**	0	0	**0**	**416172**
10	Water (process)	ltr	21	1	**22**	**0**	**27720**	0	0	**0**	**27742**
11	Water (cooling)	ltr	285	37	322	0	1108803	0	3	-3	1109122
12	Waste, non-haz./ landfill	g	110578	411	**110989**	**182**	**483206**	4598	2	**4596**	**598973**
13	Waste, hazardous/ incinerated	g	27	0	**27**	**4**	**9582**	1170	0	**1170**	**10782**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	155	7	**162**	**21**	**18151**	25	3	**22**	**18355**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	1271	31	**1302**	**61**	**107085**	49	4	**46**	**108494**
17	Volatile Organic Compounds (VOC)	g	8	0	**8**	**4**	**157**	1	0	**1**	**171**
18	Persistent Organic Pollutants (POP)	ng i-Teq	1121	0	**1121**	**1**	**2737**	32	0	**32**	**3890**
19	Heavy Metals	mg Ni eq.	315	0	**315**	**9**	**7147**	96	0	**96**	**7568**
	PAHs	mg Ni eq.	229	0	**229**	**11**	**832**	0	0	**0**	**1073**
20	Particulate Matter (PM, dust)	g	123	5	**128**	**684**	**2465**	437	0	**437**	**3713**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	251	0	**251**	**0**	**2683**	28	0	**28**	**2963**
22	Eutrophication	g PO4	5	0	**5**	**0**	**13**	2	0	**2**	**20**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Figure 123: Life cycle impact of category 2 product with doubled Ferro material use

However if the overall environmental impact on the EU level is analysed, the same results are obtained as already shown in Figure 111.

The selection of materials itself will therefore have no direct impact but could have a much more important indirect impact which is related to the energy efficiency of the product. In the motor for e.g. the addition of active material will increase the efficiency of the motor driving the fan wheel. Whereas the addition of copper will principally increase the environmental impact during the production phase, an effect which has

shown can be neglected, the increase of efficiency of the product will reduce the environmental impact of the use phase significantly.

So, all efforts to improve fan products should be directed towards high efficient products. This result is also underlined by the motor and pump part of the Lot 11 study. When summing up EU totals for fans, pumps, circulators and motors at a European level, care should be taken not to overestimate the savings due to the overlap in accountings. The motors which are part of the fan, pump or circulator products might be counted again as stand alone motor. So double counting is possible.

For fans we can however assume, that the overlap will be not so significant, even if no detailed data are available to prove this. Based on our fan market knowledge fans typically use custom designed motors, EC motors or in some cases standard AC motors. As many fan manufacturers product the motors for their products themselves to make them fit best with the characteristic of the fan wheel, the motors do not show up in the statistics of standard motors. As a very conservative approach we would assume that only 10 % of the fans are driven by a standard AC motor.

Summary Chapter 5:

- Definition of the base case products for the analysis
- Detailed data on material input for production and energy consumption during use phase
- Calculation of life cycle cost per product pinpointing that energy cost during use phase dominates clearly life cycle cost
- Discussion of life cycle eco impact for the products, showing that material inputs can be changed without any significant impact on overall result
- Calculation of environmental impact of EU stock of products
- Calculation of EU stock total life cycle cost showing that cost savings due to more efficient products far outweighs additional first cost.

6 Technical Analysis BAT

Based on the data available we have collected efficiency data for best efficiency point of a larger number of products in the 8 product categories defined. The data collected do not cover all manufacturers as the collection is highly time consuming due to the fact, that most of the fan companies have not been willing to provide the requested information in electronic format, often pointing out secrecy issues and competition issues. For the efficiency of further products no special break through in efficiency can be identified on the horizon; however with the business as usual the efficiency of new products is typically higher than the efficiency of the products of the previous year.

However the efficiency of the products sold on the market tends to be related not to the fact on what is possible in efficiency but on what can be sold on the market. So even as the product selection based on life cycle cost leads to much more efficient products there is still the dilemma that products are selected often on a first cost basis only.

This explains why there is a large spread of efficiencies for the same product category and size in the market, as efficiency is still not the key driver.

6.1 State-of-the-art in applied research for the product (prototype level)

There are three main aspects on which the applied research is focussing. The two aspects related to efficiency are the continuous improvement of the fan impeller/blade design to reduce the aerodynamic losses and the second to increase motor efficiency via more active materials or other motor concepts such as the EC-motors. Information about the state of the art in electric motors can be found in the Lot 11 report on motors. Therefore no additional information is given here. The aerodynamic losses can be significantly reduced by aerofoil bladed design (curved and twisted profiles instead of flat sheet metal blades) and additional features such as winglet as the end of the profile to reduce tip losses. Aerofoil blade designs are today designed using CFD software; however production of such complex geometries is much more expensive. The state of the art at the product level can therefore be expressed as maximum efficiencies of a product already on the market. A large number of efficiency data of the products can be found in chapter 4.3.3.4.

The third aspect is not related to energy and efficiency but noise. Ventilations systems should not only be efficient but also producing a low noise level. Compared to industrial applications the noise level of products in building ventilation applications should be as low as possible. However, there is a possible conflict of interest, as motors with a higher number of poles tend to have lower efficiencies but also lower noise levels.

6.2 State-of-the-art at component level (prototype, test, and field trial level)

The fan market is highly competitive; therefore manufacturers are not willing to disclose the kind of improvements they are working on. At a component level the development of better aerodynamic blade profiles is underway. If the aerodynamic losses can be re-

duced, the efficiency of the products can be significantly increased compared to simple not profiled blades. However it is less a question of what can be done but more a question of what will be paid by the customer. Continuous work is underway which is also reflected by the large variety of efficiencies for the same product category and size, cf. chapter 4.3.3.4. The aim of manufacturers tends actually therefore more to profiles which are cheaper to manufacture instead of improving the efficiency to a maximum. Also new design options such as winglets at the tip of the blades are tested, Figure 124. It should however be noted, that often such highly visible changes might have no impact on the efficiency but would be helpful to market products as innovative. So it is less important with which design features improvements are achieved. Simple invisible measures such as reduction of gap clearances might have higher impact on the efficiency than "innovative" measures. However new features are tested for the first products. It should also be noted, that new design features make their way into the market by one product and will then be taken up for additional sizes and product categories if applied successfully on the market. However which solution might be best for an individual product has to be determined individually. Bends instead of winglets can lead to a more efficient product. There is no special BAT design feature.

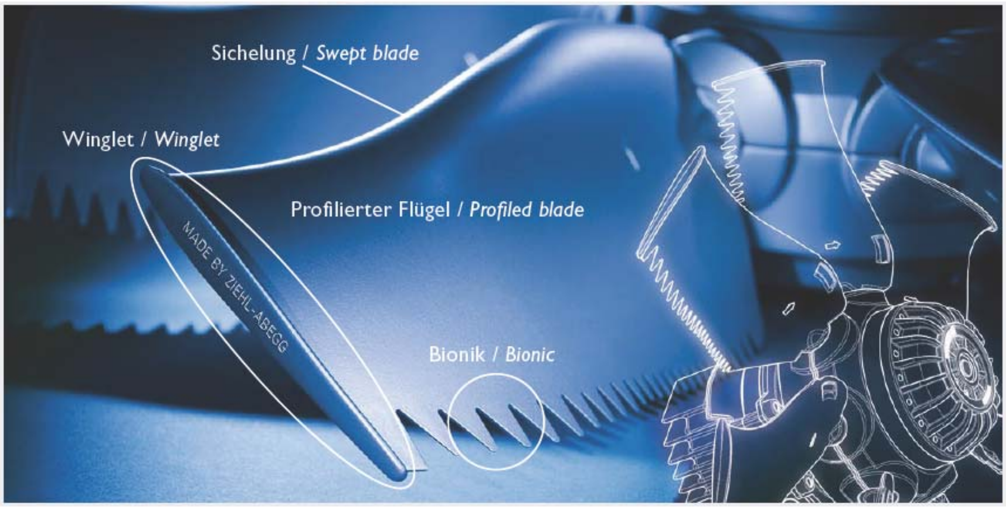


Figure 124: Possible example design features of an axial fan [FE2owlet of Ziehl-Abbegg]

Similar trends can be also identified for radial fans. Profiled impellers made from composite material with optimised rotating diffuser by using new design principles to increase efficiency. Often insides from the aerospace sector are used to improve the design. Computer modelling can be used to tweak the blade including rounding off the blade’s leading edge.

For the fan drive, direct driven fans are best, using EC motor technology below 5 kW and high efficient EFF 1 AC motors or inside out motors with efficiencies equivalent to EFF1 values. Motor issues are dealt in detail in the motor part of the report for lot 11 and are not further discussed here.

In addition manufacturers are further developing their software selection tools for the fans produced. These tools help the user to choose the most efficient product for a specified application. To limit the number of different products, fans can typically be

used within a broader band of operating points. Therefore highly efficient products which are wrongly used/selected will not work efficiently. Improvements of the selection tools will not improve the product itself but will have a positive impact on the efficiency of the products in use. Unfortunately there seems to be no interest on the part of the fan manufacturers to have a common database of products which would make the selection of the most efficient product for an application across the manufacturers possible.

As for the complete fan product, typically no information on what will come next on the market is available. As typically prototype and test are within the manufacturers and field tests are not really relevant in the fan business, the state of the art should be assumed to be the products on the market. However products having high static overall efficiencies as shown in chapter 4.3.3.4 and are at the upper bound of the range of values are typically using the state of the art technology.

6.3 State-of-the-art of best existing product technology outside the EU

The manufacturers inside the European Union are well known for the quality and efficiency of their products. They are serving not only the European but the international market. So we have not found better products outside the EU. Instead cheap but low efficient products produced in countries such as e.g. India and China which are entering the European market tend to lower the efficiency levels. Products from these low wages countries are typically not designed using CFD to optimise blades, using low efficient AC motors and often simple straight sheet metal blades. So these products can not help to increase efficiency of the products but instead are lowering the average efficiencies as they are imported and used in Europe due to their highly competitive price in first cost.

Fans for ventilation are covering a very broad range of fan sizes, types and power which makes it very difficult to specify the benchmark values for the best products on the market. To give benchmark values would mean that this is not a single value per product group but hundreds of values. Therefore it is impossible to collect the data of all fans to determine the benchmark for each individual product. A large number of efficiencies had been collected by the preparatory study and are presented in the report in a graphical form (see 4.3.3.4) which gives some good estimates for the best products on the market. However it is possible, that products with higher efficiencies are available on the market. To give a limited set of benchmark values for ventilation fans seems therefore not appropriate for guidance.

Summary Chapter 6:

- ❖ Analysis of BAT at product level which is dominated by efficiency.
- ❖ Best overall static efficiencies: Cat. 1: 40-50 %; Cat.2: 45 %; Cat.3: 40-50 %; Cat.4: 55-70 %; Cat.5: 50-70 %; Cat.6: 30-50 %; Cat.7.: 40-60; Cat.8: 15-20 %. It should be noted that the efficiency depends strongly on size
- ❖ Analysis of BAT at component level: Aerofoil design with swept and corrugated blades, including winglets or tip rings

7 Improvement Potential

7.1 Options

The major improvement potential in fans and their associated systems can be achieved by increasing the efficiency It is suggested that it would be possible to achieve a reduction of 30 % in total fan input power simply by the better selection of fans, their transmissions, their motors and their controls and the better design of systems [Cory, 2005b]. Even if the purchase price is higher, the total cost of ownership will decrease as less energy is consumed over the fan's working life.

i. The fan itself

Aerofoil bladed fans can achieve a static efficiency of up to about 88 %. By contrast, the best forward curved bladed centrifugal fans can only achieve 60 %. The smaller and cheap mass-produced sizes with ladder strip impellers often can hardly achieve 40 %. In like manner, axial flow fans, which can reduce system resistance by eliminating bends in the ductwork, are frequently of the tube-axial type (i.e., without guide vanes). The rotational energy at the outlet is lost and real efficiency on blowing systems is often moderate. Replacement by, or modification to, the vane-axial alternative should give a higher usable efficiency.

It should be noted that some axial fan manufacturers produce a 'bolted-on' upstream guide vane section, but this will require re-setting of the impeller pitch angle when added. The best efficiency could increase from about 75 % to 83 %

The designs of the backward bladed centrifugal fan and the axial flow fan have achieved high efficiencies and further progress in this direction will be modest. The recent introduction of CFD (Computational Fluid Dynamics) has been taken up by the larger companies, and refinement of their designs is taking place. Such programmes are however expensive and can only be afforded by the few. Companies that cannot afford Research and Development often copy and simplify designs without appreciating the deleterious effect they have made to its efficiency.

ii. The transmission

Many fans in the HVAC industry are driven through pulleys and V-belts. In the interests of security and reduced maintenance, a minimum of 2 belts on small drives is often specified, even if it does make the drive much less efficient. Improvements in transmission efficiency in this case can be achieved with raw edged belts. These are much more flexible and can transmit more power at greater efficiency, such that a drive efficiency of 98 % is possible. A coupling drive, or the fan impeller directly mounted on the electric motor shaft is even better. Coupling drives with speed control for centrifugal fans or fan impellers mounted directly on the motor shaft extension have not only advantages in terms of energy efficiency, but also overcome problems concerning maintenance of V-belt drives.

iii. The motor

For many years, certainly in the larger sizes, the Squirrel cage induction motor has reigned supreme. It is robust, reliable, requires little maintenance and is relatively cheap. Over the last few years there has been a gradual improvement in its efficiency both at full and partial loads, by the inclusion of greater amounts of active material and improved design and manufacture.

Following the voluntary agreement within the motor industry, which recognizes three efficiency ranges EFF1, EFF2 and EFF3, market forces have virtually eliminated the lowest efficiency EFF3. Most motors now sold are from the mid efficiency EFF2. However, less than 8 % of motors used for fan drives are from the highest grade EFF1. By contrast, in the U.S.A. even higher efficiency motors than EFF1 are available, denoted as ‘premium’ and ‘super-premium’ efficiency. A return to copper rotors is also apparent and this can improve efficiency, especially at partial loads.

There has also been considerable research conducted within Europe into other forms of electric motor. These are especially attractive in the smaller sizes where the induction motor may be only 60 % efficient. Thus permanent magnet motors; switched reluctance motors and electronically commutated motors are becoming available which can increase the efficiency of small motors above 80 %.

iv. The controls

The inverter is a relatively cheap form of speed control for the already reliable induction motor. Wherever the resistance of the system is a function of the flow rate squared, it is ideal. Care should however be taken to ensure that this is the case. There are many systems which incorporate a fixed element of pressure e.g., VAV systems. Dependent on the magnitude of this fixed element, speed control may not be so appropriate. The efficiency of this control is often in excess of 95 % at full to ¾ load. At high turndown ratios however, the corresponding powers will be low and the efficiency can be less than 50 %.

v. System effects

Large improvements can also be achieved in the duct system. The definition of target levels of Specific Fan Power for various types of system in the UK building regulations (see section 1.3.1) takes this into consideration. The Swedish regulations have even lower values.

Whilst all the component efficiencies are important, of as great or greater importance is the value of the fan pressure i.e., the system resistance. Resistance can be reduced by easier or vane bends, reduced duct velocities, circular cross sections etc. However, due to restricted space availability ducting is sometimes reduced in size. Furthermore additional cooling coil capacity has become necessary to match the increased solar heat gains from glass buildings, increased noise attenuation and filtration has been added such that the system resistance pressure has almost doubled. However energy efficiency improvements related to the ventilation system are not relevant for the analysis in this EuP-study.

vi. Materials used

Fan wheels are typically produced from sheet metal, plastics and die cast aluminium (only the larger ones). Metal and aluminium parts can very easily be recycled as well as single material plastics. The amount of material used today depends mainly on two factors, material strength and material required to shape the blade. The efforts to reduce material consumption has already reached a very high standard, especially in the integrated units, where the motor and the fan wheel have some parts in common to reduce the overall weight and material use in the fan. However higher efficiency motors in the fan will require more active material (mainly copper or aluminium) which can be seen also in the motors part of the study. However as can be seen from the first results presented in chapter 4, the environmental impact of the production phase is rather limited compared to the use phase. So the reduction of material use will only be reasonable, if it will not impact efficiency. As the impact of the production phase (materials) is small, replacements of materials will typically not make sense if standard materials are replaced. It might however be worthwhile to replace highly hazardous materials. However these are typically not used in fans.

vii. Preliminary Conclusions

The forward curved bladed centrifugal fan is in most need of improvement. Whilst many of the units are small, there are considerable numbers of them. Their reduced size for a given duty makes it almost impossible to simply replace them with a backward bladed fan. A fan efficiency of 70 % should be achievable which with a motor efficiency of 80 % would give an overall direct drive unit efficiency of 56 %. To improve the blade passages would be difficult with the present ladder strip construction. Variable thickness to the blades or complex curvature would be necessary and outlet angles would need to be reduced to virtually zero from their present 20° approx. The intention would be to give a constantly accelerating flow velocity within the blade cell and a high actual velocity into the casing volute. Table 53 summarizes possible measures for improvement of fan performance.

Table 53: Possible improvement measures

	base case	**measure for improvement**
fan	Forward curved centrifugal (η=60 %)	Aerofoil bladed centrifugal (η=80 %)
	tube axial	vane axial
	Axial (η=75 %)	Axial with guide vanes (η=83 %)
trans-mission	V-belt	Raw-edged belt (drive efficiency up to 98 %)
	V-/raw-edged belt	coupling drive (with speed control)
	V-/raw-edged belt	fan directly mounted on motor shaft
motor	induction motor (squirrel cage)	inclusion of more active material
	induction motor (squirrel cage)	permanent magnet motor
	induction motor (squirrel cage)	switch reluctance motor
	induction motor (squirrel cage)	electronically commutated (EC) motor (efficiency up to 80 % for smaller motors)

7.2 Impacts

Significant improvements can only be achieved by improved efficiencies of the product. The possibilities to improve the products are becoming obvious when analysing the efficiency charts of state of the art products as shown in chapter 4.3.3.4. To make good assumption on possible achievements, Table 54 is summarising the results obtained form the efficiency charts. By assuming that the average product might have efficiency in between the minimum and the maximum values, an average product could therefore be probably improved by 5 to 10 % points. However for the different products this implies that the efficiency can be increased by different rates, the higher efficient products having lower improvement potential than the very inefficient products.

Table 54: Summary of average efficiency differences of state of the art products by category (note that the absolute values depend strongly on size)

Product Category	**Direction of flow**	**Type**	**Typical efficiency of the product**	**Achievable improvement of the product**	**$\Delta\eta_{(max;min)}$ of existing product[*)]**
			[%]	**[%]**	**[%-points]**
1	Axial	<= 300 Pa (static pressure)	30,0%	33,3%	20,0%
2	Axial	> 300 Pa (static pressure)	38,0%	19,7%	15,0%
3	Centrifugal	forward curved (with housing)	30,0%	25,0%	15,0%
4	Centrifugal	backward curved (free-wheel)	50,0%	13,0%	13,0%
5	Centrifugal	backward curved (with scroll housing)	60,0%	8,3%	10,0%
6	Other	Box fans	30,0%	33,3%	20,0%
7	Other	Roof fans	40,0%	31,3%	25,0%
8	Other	Cross-flow fans	8,0%	62,5%	10,0%

[*)] $\Delta\eta_{(max;min)}$ is the approximate efficiency difference between the best and the worse efficiencies of the products based on the collected data

If the improvement potentials are integrated into the EuP spreadsheet model, the environmental impact of the efficiency improvement can be calculated. This is realised by the reduction of the electrical power for the same average product. As an example the calculation is explained. The average power of the category 1 product is 0.8 kW. Together with an improvement potential of 33.3 %, the new calculation of the environmental impact will be made with a power of 0.8 kW* 0.667 =0.533 kW. As the use phase dominates the impact, an increase in efficiency will also lead to a reduction of the environmental impact by the same rate, e.g. by 33.3 % for the category 1 product.

If all category 1 products in place would be replaced by the improved products, the Greenhouse gas Emissions (in GWP100) would be therefore also be reduced by one third from 3 to 2 Mt CO_{2eq}.

7.3 Costs

The increase in cost for high efficiency products is mainly related to the more complex production technologies of the fan components. Better aerodynamic designed blades for example are more expensive as they have typically to be cast whereas simple blade geometries can be made from sheet metal. Unfortunately no detailed information on the specific cost of different design options is available. However some rule of thumb could be used as for the motors, where the change from EFF2 to EFF1 motors leads to a cost increase of about 25 %. It should be noted, that improvement measures related to the improvement of the motor efficiency will have much higher costs than improvements on the geometry but the latter will require more internal knowledge about the fan whereas the motor knowledge might be bought in more easily into the fan company. As a generalisation it could be assumed, that 1 % of improvement would increase the product cost by about 1 to 2 %.

7.4 Analysis LLCC and BAT

Improved blade design (scimitar, corrugated, winglets), improved motor efficiency (EC, copper rotor, more active material), reduced tip clearance, surface smoothing (e.g. by coating), or improved transmission (e.g. belt drive) that can be used to increase the efficiency of the product. However which measure would be the most cost effective for the fan manufacturer will depend on his individual product and his strategy for the further development of the products and the product range. It is therefore not useful to rank different design options in terms of their life cycle cost. Based on the analysis of the life cycle cost, a significant improvement of the efficiency of the products would pay of.

As an example it is assumed, that the efficiency of the average category 1 product can increase by 30 %. This would increase the price of the product by 30 to 50 %. So even if we would assume a price increase of 50 %, the life cycle cost for the product will be reduced, Figure 125.

	Average EU Product Category 1 (axial < 300 Pa) *Item*	LCC new product
D	Product price	450 €
E	Installation/ acquisition costs (if any)	50 €
F	Fuel (gas, oil, wood)	0 €
F	Electricity	1246 €
G	Water	0 €
H	Aux. 1: None	0 €
I	Aux. 2 :None	0 €
J	Aux. 3: None	0 €
K	Repair & maintenance costs	0 €
	Total	1746 €

	Average EU Product Category 1 (axial < 300 Pa) *Item*	LCC new product
D	Product price	675 €
E	Installation/ acquisition costs (if any)	50 €
F	Fuel (gas, oil, wood)	0 €
F	Electricity	958 €
G	Water	0 €
H	Aux. 1: None	0 €
I	Aux. 2 :None	0 €
J	Aux. 3: None	0 €
K	Repair & maintenance costs	0 €
	Total	1683 €

Figure 125: Life cycle cost of standard category 1 product (left) and life cycle cost of the improved category 1 product (right)

What has been shown for the products of category 1 can be confirmed also for all other product categories, as energy consumption by far dominates. However as the fan mar-

ket is highly competitive, a significant higher first cost of a product will require much more efforts to sell the product.

As the technology to improve the efficiency of the fan products is available in general, not all manufacturers would have the knowledge to do so. Especially small and medium sized fan manufacturers might not be able to cope with high minimum efficiency standards and will have not the financial resources to invest in better technology.

7.5 Long-term targets (BNAT) and systems analysis

In this chapter a more detailed discussion about the possibilities to exchange materials fans are built of and possible future improvement potentials are discussed. Whereas the sub chapter on materials can be generalised to all product classes the ways and potentials how efficiencies can be improved can be quite different in the approach to be used.

7.5.1 Trends in materials used for the construction of fans

Fans have been characterized for many years as a 'mature' product. It is inevitable therefore that the materials of construction have 'mirrored' what was going on in the engineering industry at large. Thus about 50 years ago centrifugal impeller hubs were sand castings riveted to steel back plates with blades riveted to the back plates and shrouds. The early axial fans again had cast iron hubs with single plate steel blades riveted on. Casings in all cases were either manufactured in riveted steel or, for a significant number, cast in iron. This was followed by welding which quickly became popular so that riveting for casing construction rapidly became obsolete, whilst cast iron casings were being replaced by welded steel fabrications. Impellers also became welded constructions. Overall, fans were subjected to a paint finish, which could be quite complex in its specification and was labour intensive. There was a demand for a more robust finish and competitive pressure dictated that this should be cheaper. Galvanising, a term used for the coating of iron and steel components with zinc, was seen by many as an ideal solution. Initially the galvanising was carried out after manufacture by dipping in a bath of molten zinc. This continues to be a widely used method for axial flow fan casings, which incorporate a longitudinal welded joint, to this day.

For centrifugal fans, distortion of the large flat areas of casing during the galvanising process, had led to the belief that pre-galvanised sheet was the answer for many of the lighter duty fans used for applications such as air conditioning and general ventilation. This necessitated a joining method other than welding which would have destroyed the zinc at this junction between the side plates and the scroll. Pittsburgh lock forming and other similar methods were introduced at this time and have been widely used.

Many of the materials used in the aircraft industry have been 'handed-down' to the fan industry and this has certainly applied to the aluminium alloys. These materials became available in the late 1940s and have been widely used for axial flow fan impeller blades and hubs. Their high strength and low density are the desirable attributes for an impeller material. Stresses due to centrifugal force effects can then be minimised and this has led to axial flow fans securing an ever-increasing share of the fan market. In the larger fan duties it has almost replaced the forward curved bladed centrifugal fan, which has been restricted to the smaller sizes.

The casting process (sand, gravity die or pressure die) for aerofoil section blades is still an expensive process and has led to the introduction of engineering grades of plastic. The use of these for impeller parts has increased enormously over the last two decades especially in small fans of all types. There has also been an increase in their use for the blades of axial flow fans of the very largest sizes. The plastics used may be divided into three generic types:

- thermoplastics
- thermo sets
- Composites.

Thermoplastic polymers can be re-softened by heating, in contradistinction to thermo sets, which cannot. Many practical applications of plastics for fans however required the use of composites to achieve the necessary strength and durability. Thermoplastic materials for fans are the most wide used at the moment, and their use is expected to become ever more popular in the future. They include the following:

- PVC (poly vinyl chloride)
- ABS (acrylonitrile butadiene styrene
- polyethylene
- polypropylene
- Polyamides (nylons).

They may be used for many components, apart from axial fan blades. Indeed, complete fans are manufactured in PVC. Because of their anti-corrosion properties and ability to be welded, quite large fans are manufactured in this material despite a current price penalty.

The group of materials with the most exciting future is seen to be the composites. Until now the most common strengthening agent has been glass fibre and the grades currently most popular are:

- GRP (glass reinforced plastic)
- SMC (sheet moulding compound).

Again mirroring the aircraft industry, we may envisage the increasing use of carbon fibre reinforced plastics. These will have the advantage of added strength when compared with both aluminium and steel, whilst their density will be very much less. In consequence centrifugal stresses will be greatly reduced leading to the ability to run very much faster, and develop greater pressure at greater flow rates, despite their reduced weight. Out of balance forces will also be reduced, leading to decreased weight of supporting steelwork or concrete foundations. This coupled with better anticorrosion (essential in humid atmospheres) properties, an absence of painting – but any colour available, and the ability to form any are all positive selling points. There are already companies in Europe manufacturing shafts in the material whilst certain North American fan companies are investigating the manufacture of fans completely made from carbon reinforced plastic. There are of course problems to be over come – carbon fibres are enormously strong in tension, but weak in shear such that the alignment of the fibres becomes of importance.

In the interest of fan efficiency, it would be preferable for all fans to be arranged for direct drive, but this would inevitably lead to manufacturers having to increase their prod-

uct ranges by additional sizes, widths, hub ratios, pitch angles etc., etc. For this reason an indirect drive through pulleys and belts is often incorporated. A degree of flexibility is introduced which can cater for a system resistance imprecisely calculated or 'guessed' in the first instance, and which may in any case alter through the life of the fan.

It has been noted that V-rope drives are probably the most popular of these transmission in use. Both the older 'classical' and the more modern 'wedge' belts consist of a tension member contained within a rubber base and surrounded by a fabric cover. Of recent years it has come to be recognised that the fabric at the sides of the V-rope can be deleted without affecting the strength, particularly with the improved wear properties of modern synthetic rubbers. This gives a so-called raw edge and leads to greater flexibility in the rope. Reduced pulley sizes are possible and better wrap is achieved. Greater drive efficiencies can be achieved, especially where the ropes are better matched to the duty and the wish by maintenance engineers to have an easy life is curbed. Over provision of the number of ropes in a drive can easily reduce its efficiency by more than 10 %

Driving electric motors were until recently manufactured to grade EFF3. However, the motor industry, without any undue pressure from government(s) was able to increase their efficiency to grade EFF2 by the inclusion of increased amounts of active materials. A further increase in efficiency to grade EFF1 should be possible with only a small increase in first cost. It should be noted that motors produced more than 30 years ago may well have been more efficient. Competitive pressure (first cost) had however reduced the amounts of active material used, but had increased the resultant temperature rise, made acceptable by the inclusion of improved grades of insulation. It is simply a matter of reversing that process.

Further improvements in motor efficiency are possible as surprisingly demonstrated in the USA by the specification of premium and Super Premium efficiency grades. The latter inevitably require the use of copper rotors as advocated by the Copper Development Association. It may well come down to deciding what materials are available in the market place where companies are competing for all the primary materials – steel, aluminium or copper. Steel, for instance, has increased rapidly in price, due to the Chinese 'mopping up' available supplies.

In the smaller fan sizes electronically commutated motors should increase their popularity as the price differential reduces. Certainly the efficiency of such motors can increase considerably over present designs.

Soft starts are a desirable addition to many fan systems. Certain fan components have to be designed for initial conditions experienced only in a direct on-line start. V-ropes are a prime example where the drive has to be over designed by as much as 40 % with resultant reduction in transmission efficiency.

It is also desirable that more fan systems incorporate an inverter in their controls to give the ability to reduce their speed. This is preferable to the partial closure of dampers to control the flow rate, thus simply throwing energy away. Few fans need to deliver their maximum duty all the time.

7.5.2 Trends in efficiency of fans and how they can further improved

7.5.2.1 Low pressure Axial Flow fans

Many of these fans are used in multiple with coolers. Their design is influenced very much by the manufacturers of these coolers such as Carrier, York and Trane. A major requirement is for minimum noise levels. However, a reduction in noise almost inevitably means an increase in its energy efficiency. A fan is not then wasting energy in creating noise.

The first company noted – Carrier – has indeed entered fan design itself with an appropriate research programme. It reported its conclusions at the first conference on Fan Noise. The major source of noise was due to leakage at the blade tips interacting with the irregular gap produced with the casing. Carrier's solution was to add a rotating ring (overlapping the casing) to the impeller thus preventing this tip leakage. By this means an 800mm fan normally operating at 6-pole speed could achieve the required duty with its speed reduced to an 8-pole figure of 720 rev/min.

Winglets, as used on recent jetliners, have a similar function, minimising leakage at the tips. Increasing use of these in fans may be anticipated. Rubbing strips on the tips of the blades may also be a solution, but will require a higher degree of casing circularity.

Such solutions are not however the only ones available to fan manufacturers. Fläkt Woods have introduced fans with the tail of the blade surface corrugated to break up the trailing vortex shed from the backs of these blades. This is known to be a major dipole source of noise.

Many early fans used the Göttingen series of aerofoil. Such sections were also used in the early aircraft, but were replaced by more efficient and less noisy sections. This was mirrored by the fan industry, which has adopted firstly the RAF and then the NACA series. Now aerofoils developed by the ARA for the Airbus programme e.g., ARA-D have been taken up. The nose section however needs modification to meet the lower Mach numbers experienced but also to meet the varying velocities and angles of incidence found across the fans characteristics.

It may also be anticipated that there will be an increasing use of scimitar shaped blades. Noise is a pressure wave, which fluctuates between positive and negative values. By curving the blades parts may be identified as 'sources' whilst others will be 'sinks'. The sources will feed the sinks leading to a degree of self-cancellation of the generated nose.

7.5.2.2 Higher pressure Axial Flow fans

Many of the improvements suggested for low pressure axial flow fans may also be applicable to higher-pressure units. The scimitar shaped blades will not however be possible due to the higher peripheral speeds and consequent high bending stresses. There may however be an increasing use of forced vortex blades, which have a greater chord length at the tips and therefore maximise pressure development where peripheral

speed is greatest. It will however require tip gaps to be minimized (or closed by rubbing strips) and a high degree of casing circularity.

There may also be an increasing use of anti-stall rings to give a stable characteristic from free air to zero flow.

7.5.2.3 Forward curved Centrifugal Fans

It may be anticipated that the use of forward curved bladed centrifugal fans will decrease with time, certainly in the larger sizes. The use of these fans in sizes above about 800mm diameter is virtually zero in the USA and a similar situation is apparent in the UK. They have been replaced by larger backward bladed fans or by small axial flow fans (often fitted with outlet diffusers to enable a higher static pressure to be developed).

In the small sizes there may always be a demand, subject to the legislative environment allowing their use. It may be anticipated that electronically commutated motors will become ever more popular, helping to offset the poor impeller efficiency with a higher motor efficiency.

This should not however deter us from seeking to improve such impellers. At the moment many impellers are of 'ladder strip' construction with the blades of simple circular arc form. Inlet angles to the blades are too shallow whilst outlet angles are too high. The blade passage areas are also greater in the median diameters and certainly greater than those at either the inlet or periphery. Thus air velocities are firstly high, then decelerate, then accelerate again. This inevitably leads to losses.

Pollrich was the first to point out that if the outlet angle of the blades was virtually zero (parallel to the periphery) then the absolute air velocity would theoretically be infinite. Careful design of the blade passages would be required to ensure a continually increasing velocity. This will require multiple radii of blade curvature, but will not be impossible with blade press tools. It should certainly be possible to achieve a peak total fan efficiency of 70 % compared with present designs, often less than 55 %.

For the direct driven units, incorporation of electronically commutated motors will no doubt increase where the size and power make these possible.

7.5.2.4 Centrifugal backward bladed 'plug' fans

Present designs are used in air handling units. It is a fact that most have simply been the impellers of cased designs used in an open fashion. They have not been specifically designed for the application. Aerofoil blades are often incorporated, but these are not essential. It appears that a logarithmic spiral blade form and a non-stalling characteristic would be advantageous. It also appears that computational fluid mechanics (CFD) should be used to optimise the design. It may well be that the shroud diameter should be greater than the back plate and that the blades should be 'triangulated'.

7.5.2.5 Centrifugal backward bladed cased fans

It may be anticipated that the aerofoil bladed variant will increase in popularity due to its high efficiency, both static and total, over much of its characteristic. It might be thought that this design has reached its optimum performance, but the use of CFD and improved aerofoil sections may lead to small improvements in efficiency. There may also be increases in flow rate for a given size and speed.

7.5.2.6 Box fans

These fans incorporate forward curved, backward curved bladed axial or mixed flow impellers and typically conventional electric motors. They are less efficient than normal cased fans, but have the advantage that they are more easily installed in duct runs. It might be thought that their use should be restricted, but if not, the improvements foreseen should be similar to forward curved cased fans.

7.5.2.7 Roof Extract units

The use of these fans was widely incorporated in the architecture of supermarkets. Roof extract units can use different types of fans such as axial, mixed flow or centrifugal one with forward or backward curved blades. More recently it has been recognised that this was throwing away large quantities of low-grade heat. Many supermarkets have abandoned their use whilst others have incorporated heat exchangers to recover the low-grade heat before discharge to atmosphere. This feature should be incorporated in more units in the future.

7.5.2.8 Cross-flow fans

The number of these fans has reduced over recent years. Perhaps their most popular usage has been in unit heaters for greenhouses and other similar applications. They have the ability to 'throw' the heated air a long way, but are restricted in size and power. It is not anticipated that there will be any incentive to devote much effort to improvement. Electronically commutated motors may be viable.

Summary Chapter 7:

- Improvement potentials at the fan level and the system level
- Analysis of the impacts of different improvement options based on model runs.
- Increases in products costs based on the implementation of design options
- Impact of improvement options on life cycle costs of the product
- Long term trends and NBAT for fan products

8 Scenario, Policy, Impact, and Sensitivity Analysis

In the previous chapters we have analysed all the relevant environmental impacts which has shown that energy consumption in use represent the main environmental impact (more than 90 %) and that efficiency improvements of the fan product are possible with the same or reduced life cycle costs. Therefore the introduction of minimum efficiency performance standards (MEPS) could reduce the environmental impact of fans for non residential ventilation at negative costs for the society. However the necessary control and enforcement of MEPS will cause additional costs which have to be taken into account.

8.1 Policy and scenario analysis

As energy consumption in use phase is the only significant environmental impact related to fan products covered by this study and as the market is moving only very slowly towards higher efficient products due to a high competition regarding first cost it seems to be appropriate to set minimum efficiency levels for products to be sold in Europe. If minimum efficiency standards would be introduced, the efficiency of the products could be significantly improved, helping to achieve the environmental targets set out by the EC. Minimum efficiency values would speed up the application of higher efficient products. Besides minimum efficiency performance values, labelling is often used to achieve market pull to more efficient products. Both options will be analysed in the following.

8.1.1 Generic eco design requirements for the products

Even if energy consumption during the use phase is of highest importance, some general requirements could be set for fan products. The most important point will be that the product can be easily dismantled at the end of life and that the materials used can be recycled. The reduction of the materials used for the production and for packaging is typically considered by the manufacturers to the cost.

Due to the highly divers types of systems in which the products are going to be installed, the formulation of installation requirements or application notes should not be considered. Only a request for general statements in the form that the efficiency of the product will not be reached if it is wrongly installed might be helpful to make the buyers of the products aware that the efficiency of the system and therefore the overall costs depend not only the components used but on the way they are fitted into the system.

A problem which has been encountered during the study has been the fact, that manufacturers are sometimes unaware which quantities of which materials are use in the products. One reason behind this fact is that the fan manufacturers are buying in the motor and therefore do not have and can not get the data of the materials used in the motor. So a requirement to provide the material composition from which the products are made would be helpful information.

Another eco design factor that could be considered is the noise level of the product. However due to it´s importance in some cases the noise levels are often already included in the catalogues.

In summary, the study proposes to set generic ecodesign requirements on the provision of information in the product documentation as follows:

- Product can be easily dismantled at the end of life and that the materials used can be recycled. Plastic materials should be marked with the relevant logos

- Efficiency of the system and therefore the overall costs depend not only the components used but on the way they are fitted into the system.

- Requirement to prepare the material input into the products as defined in the eco design spread sheet model as presented in chapter 5.

- Noise level of the product to be indicated based on test standard ISO 13347.

- Requirement to give the value of the overall static efficiency of their products in the catalogues (Print, Internet, CD) together with the information who and how the values have been produced (based on ISO 5801)

- Requirement to deliver the information in a standardised form to the commission which collects the data from all manufacturers and make them available via an internet based data base.

8.1.2 Specific ecodesign requirements

Besides the more general generic ecodesign requirements, specific design requirements should be set for the 8 product categories as defined in chapter 1. A specific design requirement would be also the labelling of products.

8.1.2.1 Labelling of Fan Products

Consumers are using labels as one decision variable in their purchase procedure, where energy labels could in principle help them to easily identify products with better efficiencies. A labelling of fan products, which was successful for the white goods market, would however be of limited value or might have even opposite effects on the market for non-residential building ventilation.

Fan products are often not purchased by the final user but by OEM customers, who normally won't have an interest in efficient products, as they will typically have no responsibility for the energy bill of the products later on. Additionally for the 8 EuP fan categories the typical efficiencies are quite different (e.g. for 1 kW a category 4 fan (centrifugal, backward curved free wheel) has an average efficiency of 50 % and a category 6 (box fan) has an efficiency of 30 %). Thus, if a labelling scheme would be introduced for fans for non-residential building ventilation in general, it would be necessary to set a minimum value for class A above 50 %. This would however mean that none of the category 4 products would be able to achieve the required value for class A.

In addition it would be difficult to communicate why labelling should be based on a globally defined scale for all fans whereas the minimum energy efficiency standards would depend on product category. On the other hand, in the case of labelling differen-

tiated per product category some confusion could occur on the market, in particular in those cases, where the user has the choice between products from different categories to fulfil the same duty. This is because an axial fan of efficiency class B could have a lower efficiency than a centrifugal fan which might be rated only class C.

Another problem arises from the fact that there is a large number of product sizes (and therefore P_{el}) and a strong correlation between efficiency and power consumption. This would require a rather complex labelling scheme, taking into account not only the product category but also the power input.

Therefore, the authors of the study are not proposing any labelling scheme as an alternative or in addition to the MEPS values proposed below, because labelling is regarded to be inadequate for fans.

Instead an Eco-Labelling could be added, giving marketing support to the products achieving efficiencies above MEPS levels. The study proposes to set the minimum efficiency level to achieve the Eco-label 25 percent higher than the MEPS levels as defined in the following chapter. To define the Eco-label requirements based on the MEPS lines also ensures, that at later revisions of the MEPS values the requirements for the Eco-Label are changed accordingly and therefore it will be avoided that most of the products would qualify for the Eco-label when the MEPS values are increased.

A better solution would be to **require from all manufacturers to give the real value of the overall static efficiency of their products in their catalogues** (Print, Internet, CD) together with the information who and how the values had been produced. In addition **manufacturers should be requested to deliver this information in a standardised form to the commission** which collects the data from all manufacturers and make them available via an internet based data base. It is recommended to include such an obligation in the implementing measures. The Commission shall prepare the necessary procedures to deal with the data adequately. The collection of data over time will also be very useful when the MEPS levels should be revised at a later time.

8.1.2.2 Proposed Minimum Efficiency Values by Product Category

While the above proposal on the possible labelling of the best of the product groups offers an incentive for manufacturers and consumers to mover towards the best efficiency products, minimum efficiency performance standards (MEPS) for fan products are aimed at cutting off the poorest products out of each product category from the European market. As already discussed in the previous section, efficiency levels not only depend on the product category but also on power range. As this study is dealing with fans for ventilation in non residential buildings, in principal the MEPS proposed in this chapter are related to these types of products. However as the product could be used also in other applications it seems to be the best solution to generalise the MEPS for the fan categories as specified in general, not taking into account where they might be applied. However this would then require excluding some products which are used for special purposes.

We recommend excluding the following products from the MEPS:

- Smoke extraction fans not to be used for general ventilation

- Fans for solid material transport
- Fans for transport of other gases than air
- Fans which are falling under the ATEX 95 equipment directive 94/9/EC
- Fans for emergency smoke extraction purposes, having less than 25 operating hours per year.
- Fans with an electrical input power above 500 kW[20]

Thus, the proposed power range for possible implementing is 125 W - 500 kW. As fans below 125 W have been outside the scope of this study as these are considered to be residential products based on the NACE/Prodcom classification we could not make recommendation for these fans. Therefore no MEPS are proposed for these fans in the study. Reference is made to the Lot 10 study dealing with residential ventilation. All other fans should fulfil the MEPS levels.

This Fan products can be generally described as followed:

> Rotary bladed machines that are used to maintain a flow of a gas, typically air and which are driven by an electric motor.

These fans can be further divided in eight categories (see also chapter 1.1.5) which can be defined as followed[21]:

Product Category 1

Axial flow fan having a static pressure development less than 300Pa comprising an impeller with low hub to tip ratio having in line entry and exit for the air. The blades may be cast to an aerofoil section or of single sheet construction profiled to suit the duty requirements. The complete impeller is usually overhung on the shaft extension of an electric motor which in turn is supported by arms attached to the fan casing. The latter may take many forms, but is usually either a short flanged duct, a rectangular diaphragm plate or a circular mounting ring.

Product Category 2

Axial flow fan having a static pressure development greater than 300 Pa comprising an impeller with a high hub to tip ratio having in line entry and exit for the air. The blades are invariably of aerofoil section and may be of adjustable or fixed pitch angle. The complete impeller is usually overhung on the shaft extension of an airstream rated electric motor which in turn is supported by radial arms or mounting feet attached to the

---

20 This value is very high and typically fans have much lower power ratings. However this ensures that manufacturers producing fans above the 10 kW rating can not choose a larger motor just to bypass the possible MEPS.

21 It should be noted that this study is of technical nature; therefore it is out of scope to judge if these definitions would be sufficient to exactly define the products in legislation.

fan casing. The latter is usually a long flanged duct encompassing the impeller and motor permitting easy removal from a duct run. The terminal box is often externally fitted to permit easy electrical connection.

Product Category 3

A centrifugal (or radial flow) fan comprising an impeller with a large number of forward curved to rotation blades attached to a shroud and backplate. The air entry to the impeller is axial but the air exit is radial i.e. at a right angle. This impeller may be directly driven by an electric motor (either of the inside-out type contained within the impeller or a normal type flanged or foot mounted supported by a pedestal. Alternatively the impeller may be mounted on a shaft extended for belt or coupling drive. This format has the bearings supported by mounting arms or bearer bars attached to the casing which is of a volute (or snail shaped) form and may have either a single or double inlet.

Product Category 4

A centrifugal (or radial flow) impeller with backward inclined blades (aerofoil, curved or straight section) running open i.e. without a volute housing. Usually supplied with a low loss entry cone. May be arranged for direct or indirect drive. Often called a plug fan, the absence of a fan casing permits easy installation into box structures where multiple and/or awkwardly positioned outlets may be accommodated without the need for additional duct bends or fittings.

Product Category 5

A centrifugal (or radial flow) fan comprising an impeller with backward inclined to rotation blades of aerofoil, curved or straight section attached to a shroud and back plate. The air entry to the impeller is axial but the air exit is radial i.e. at a right angle. This impeller may be directly driven by an electric motor either of the inside-out type contained within the impeller or a normal type flanged or foot mounted supported by a pedestal. Alternatively the impeller may be mounted on a shaft extended for belt or coupling drive. This format has the bearings supported by mounting arms or bearer bars attached to the casing which is of volute (or snail shaped) form and may have either a single or double inlet.

Product Category 6

Box fans are designed to permit easy installation in a duct run. They comprise often a centrifugal fan contained within a box having inlet and outlet connections, usually circular but sometimes rectangular. However other types such as mixed flow fans could be used. The fan is supplied with a volute casing and usually has a forward curved bladed impeller. The majority are direct driven, but there are examples of belt drive. Twin units with running and standby fans are available. However other types of fans could be used in a similar way such as axial or mixed flow fans. They will also fall in this category of products. A typical indication for such a product is the fact, that it is installed decentralised and inline and connected to an inlet and outlet duct.

Product Category 7

These fans are designed to be easily mounted on the roof of building by the provision of a curb for a flat roof or a purlin for a sloping roof. They may de designed for supply or extract use. All types of impeller may be incorporated according to duty e.g. propeller, axial flow, mixed flow or backward bladed centrifugal. There are many types of cowl fitted to give a low contour, whilst bird guards, soaker sheets, acoustic linings, back draught shutters and other features are frequently included.

Product Category 8

Cross flow fans may be compared with forward curved centrifugal fans. The impeller however is of a greatly increased axial length to enable a smaller diameter to be used for a given flow rate. The air entry to the casing is however positioned on the scroll such that the air traverses the impeller. Drive is invariably direct.

In the following a possible set of MEPS values for the eight defined fan categories is proposed. Figure 126 shows Minimum Efficiency Lines (MEL) for each product, indicating overall static efficiency over electrical power input. The proposed MEPS lines are seen as a compromise between the accurateness of addressing each product and product size on a very detailed level and the easiness of the MEPS approach. In the following the arguments for the different lines are given.

Category 4 (free wheel) and Category 5 (centrifugal backward curved) products have in general the highest efficiency with the free wheel some efficiency points above due to the more complete conversion of the energy into static pressure. Above a power of 100 kW we have had only a limited number of data available for the products and there is typically a higher perception of energy consumption anyways. Therefore the MEPS are proposed to remain constant from 10 kW and above, which would have in any case no negative impact on the market. The same arguments apply for all other product categories above an electrical power input of 10 kW and above. This approach is supported by the results of the calculations made (cf. Appendix 4), showing that about 40 % of the overall electricity consumption in product categories 1+2 and the product categories 3+4+5 are related to fan products with a power of less than 10 kW, for product categories 6+7+8 products under 10 kW are even responsible for about 90 % of the total electricity consumption.

Thus, most attention should be paid to the products with a power below 10 kW. On the longer run it could be recommended, that some lines might be merged, such as the MEPS for products category 1+2. All proposed MEPS lines can be easily described as formulas which are shown in Table 55.

Table 55: Proposed MEPS levels for the 8 fan categories (2010)

MEPS in % to be introduced in **2010**	**Power Range**		
	0.125-1 kW	**1-10 kW**	**10 -500 kW**
MEL1 - Axial <=300Pa	3.42*ln(P_{el}) + 27.12		=35
MEL2 - Axial > 300Pa	2.28*ln(P_{el}) + 29.75		=35
MEL3 - Cetrifugal forw w housing	2.74*ln(P_{el}) + 28.69		=35
MEL4 - Centrifugal backw free wheel	4.68*ln(P_{el}) + 47.23		=58
MEL5 - Centrifugal backw w housing	4.56*ln(P_{el}) + 44.49		=55
MEL6 - Box fans	7.53*ln(P_{el}) + 25.66		=43
MEL7 - Roof fans	3.42*ln(P_{el}) + 37.12		=45
MEL8 - Cross-flow fans	=8	11.73*ln(P_{el}) + 8	=35
Results should be rounded to one digit, P_{el} to be entered in kW			

Product category 8 shows MEPS levels far below all other categories. This category of products is typically only used below 1 kW and significant efficiency improvements are mainly achievable by using better motors such as EC motors to drive the fans. Only at small sizes they have advantages compared to other types in terms of higher air delivery with the same wheel sizes. At higher power they compete with forward curved centrifugal fans (category 3) and should therefore achieve the same MEPS level as these products.

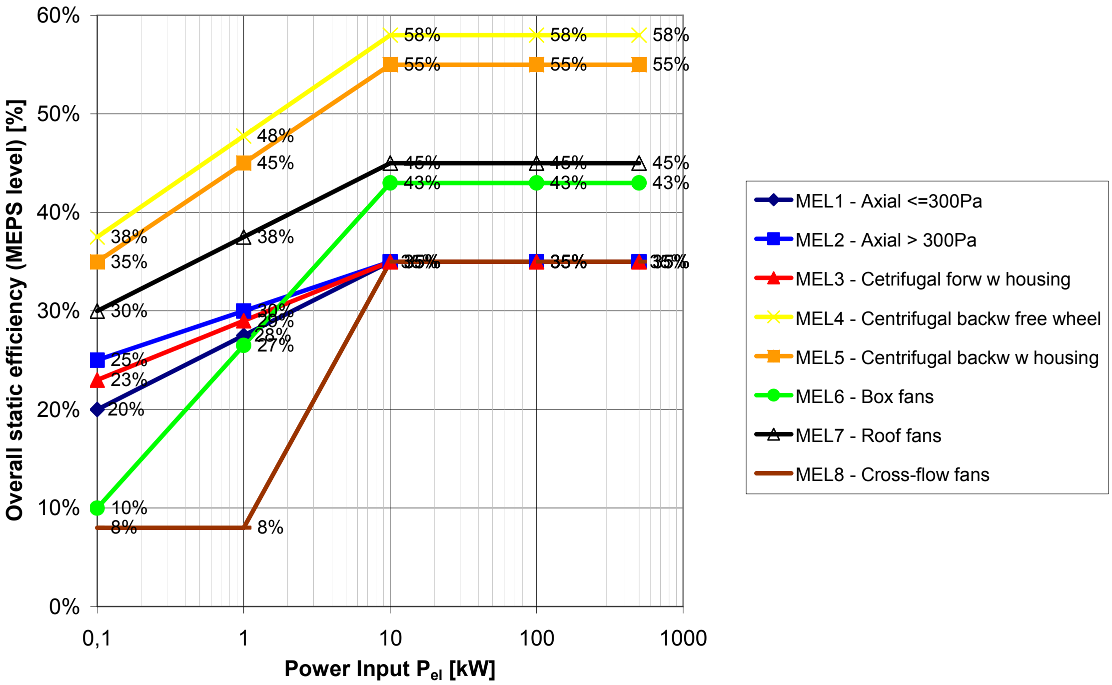


Figure 126: Proposed Minimum Efficiency Performance Standards (2010)

As no other information is available we can assume that the efficiencies of the products in each category will have a normal distribution as shown in Figure 127.

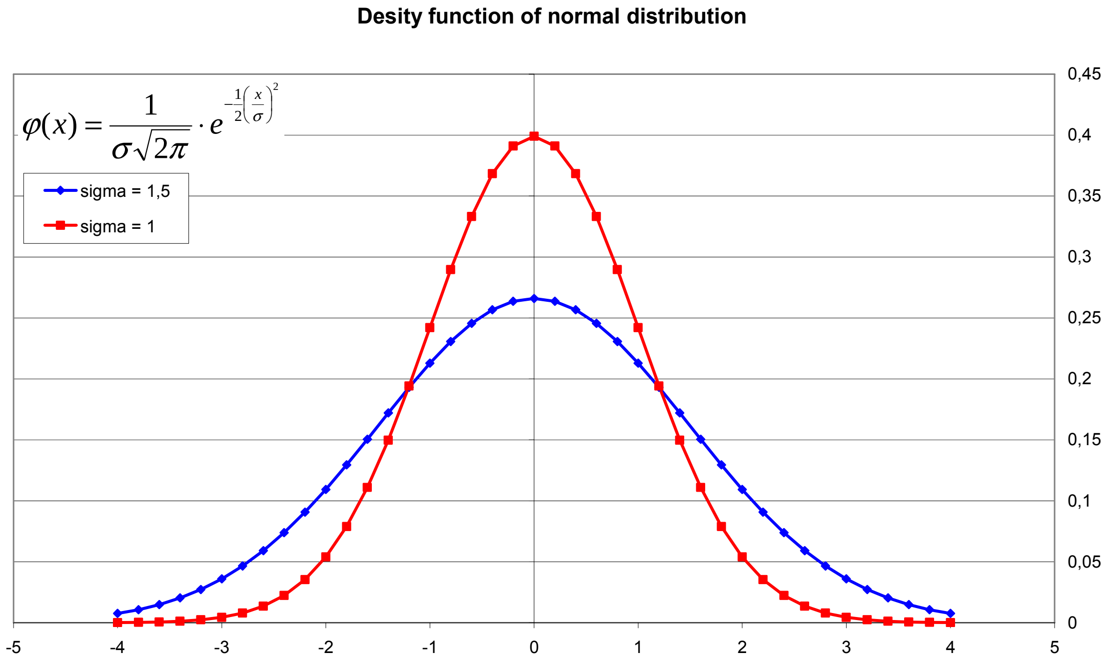


Figure 127: Normal distribution of product efficiencies

Depending on the selection of the variance σ the shape of the normal distribution changes but is always symmetric to the average value. Base on the experience made with the efficiency data collected we can however assume that it is more likely that the variance tends to be small. Therefore we have based our work on a variance of σ=1. For a variance σ=1 the number of products with a small deviation in efficiency compared to the mean value will be much larger compared to the value for a low variance. Figure 128 shows the cumulative distribution function for the normal distribution. If the variance is assumed to be σ=1, the amount of fan products which may be cut of from the market for the category can be estimated.

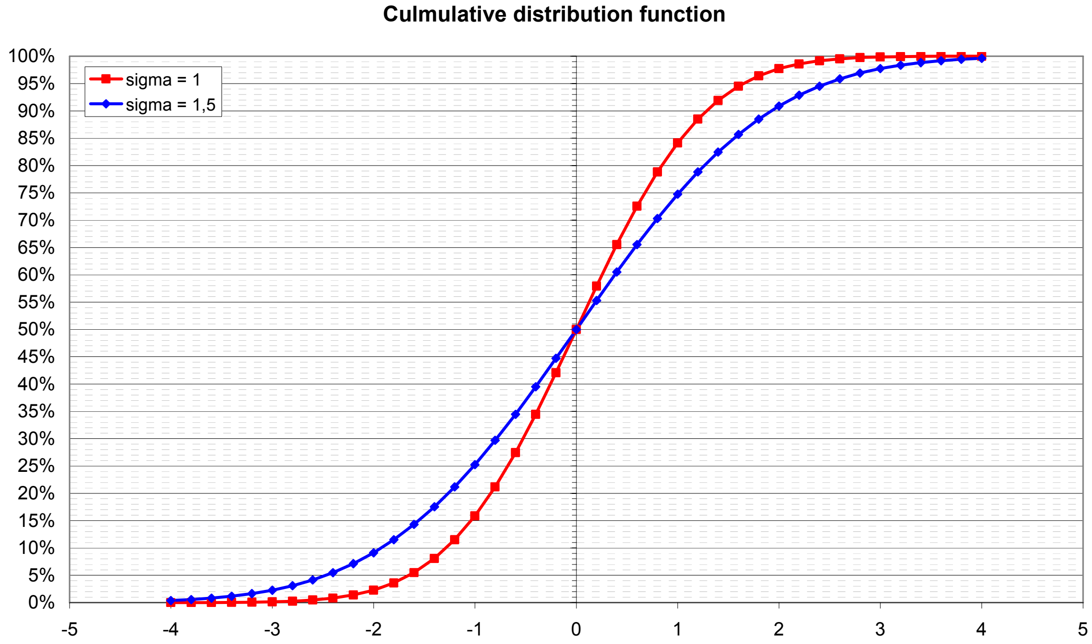


Figure 128: Cumulative distribution function for normal distribution and different variance

Based on the fact, that the efficiency of category 1 products (axial; < 300 Pa) of 1 kW deviate between 20 and 50 % with a mean value of 30 %, the shares of products shown in Table 56 might be banned from the market.

Table 56: Share of products eliminated from the market depending on minimum efficiency level defined for a 1.0 kW category 1 (axial fan < 300 Pa).

Minimum efficiency level [%]	26	27.5	29	30.5	32	33.5	35
share of category 1 products banned from the market [%]	0.82	2.28	5.48	11.51	21.19	34.46	50

If at least the worst 10 % of the fans on the market should be eliminated, this would require to set a minimum efficiency level for a category 1 product of 1 kW to around 30% overall static efficiency. For each category of product such an analysis can be performed. The lower the total variance in efficiencies, the smaller would be the difference in efficiencies between the mean value and the minimum efficiency level to be fixed.

As a general guideline it could be said, that for product categories with small differences in efficiencies (<20 %) on the market the minimum level should be set about 3 %-point below the average efficiency and for products with a large difference in efficiency for the same size (> 20 %) the minimum level could be set 6 %-point below the average efficiency of the product of this size. It should however be noted that the results are rather sensitive in terms of shares and efficiencies. So in the above case e.g.

if the MEPS would be raised to 32 % overall static efficiency, the number of product banned from the market might be doubled.

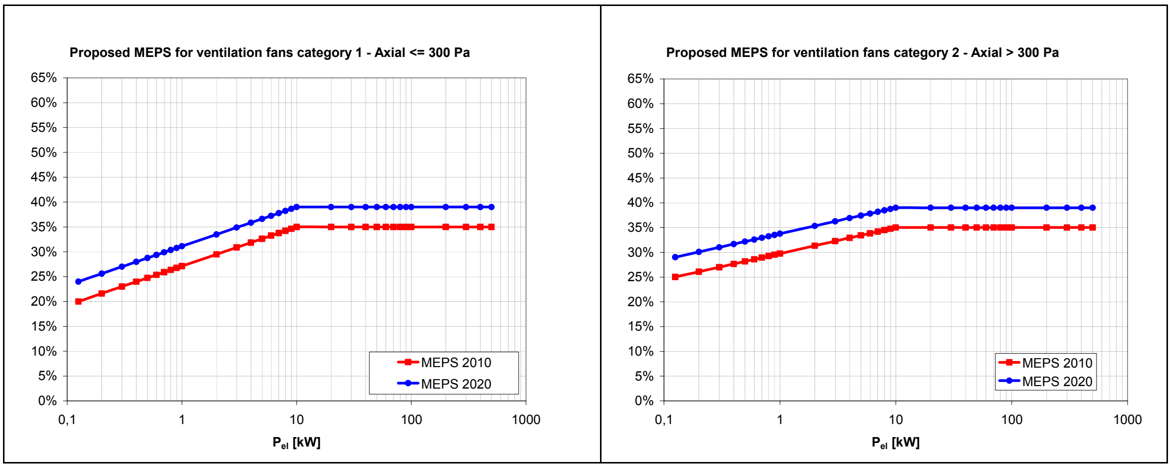
The adoption of MEPS should therefore be introduced carefully. MEPS will force manufacturers with low efficient products to improve their products to comply with the MEPS levels. Therefore sufficient time should be given before the MEPS will come into force. In the following we propose a MEPS implementation plan which could be used.

Table 57: Proposed MEPS implementation plan for Fans

MEPS Levels published	MEPS Levels come into force	MEPS Levels of Cat.8 equalised to the levels for Cat.3	MEPS Levels for all categories of all sizes at least 20 %	MEPS Levels for all categories and sizes increased by 4 %-points
01.01.2009	01.01.2010	01.01.2011	01.01.2012	01.01.2020

To avoid that a new study might be necessary shortly after the MEPS have been entering into force, the proposed implementation plan for MEPS is given for the next 10 years. This will also enable the stakeholders and administrations involved the necessary time to adapt to the changing conditions and provide a sound basis for further planning.

Figure 129 shows for the eight product categories how the MEPS will develop over time. For nearly all product categories the main change occurs in 2020, when efficiencies are increased by 4%-points. Only for product categories 6 and 8 their will be an additional step in the MEPS values.



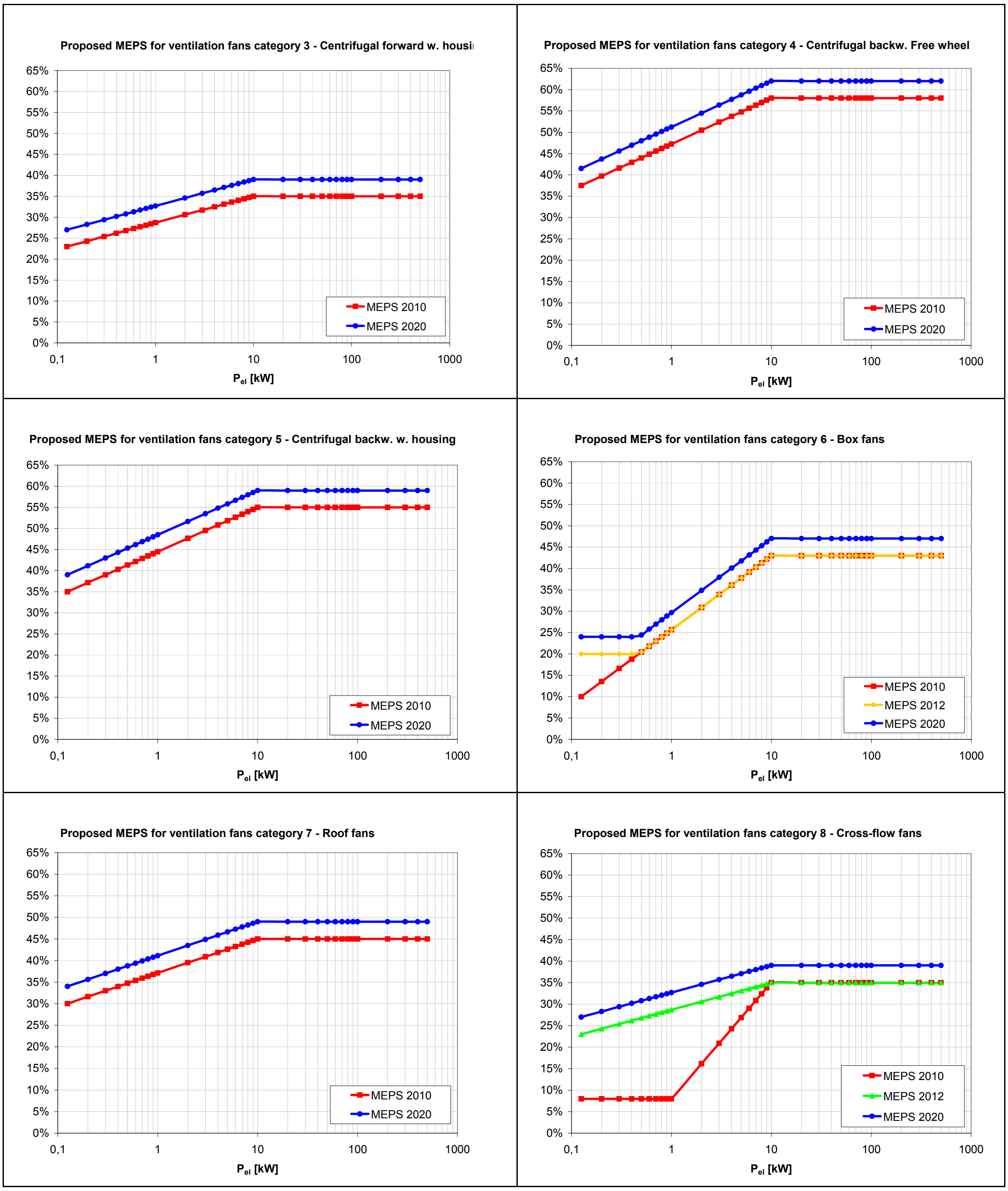


Figure 129: Proposed changes of MEPS levels over time by category

To estimate the possible savings related to the introduction of MEPS, two cases have been considered compared to a Business as usual case giving scenarios as follows:

1. BAU: No further improvement of fan efficiencies

2. MEPS+10: Cutting of the worst appliances with corresponding efficiency levels for each of the 8 fan categories form 1.10.2010 and therefore improving the average efficiency of the products entering the market by 10 %.

3. MEPS+15: Cutting of the worst appliances with corresponding efficiency levels for each of the 8 fan categories from 1.10.2010 and therefore improving the average efficiency of the products entering the market by 15 %.

In the business as usual case we have assumed that no efficiency improvement of the newly installed fans takes place in the future, due to the high price pressure in the market and the existing split-incentives problem often found in the building ventilation market. The introduction of MEPS will however cut off the poorest products from the market and will thus lead to an increase of the average efficiency of the products on the market. By assuming that about 10 % of the products with the lowest efficiency on the market will be banned, the average efficiency of the products sold in the market might increase by 10 or 15 %. Table 58 and Table 59 show the possible savings due to the introduction of MEPS for these two cases compared to the business as usual case. Based on the LCC calculations made it seem to be reasonable to cut much larger into the market with the MEPS in the first step or some years later. However as MEPS will bring market distortion in Europe (the manufacturers with high efficient and low efficient products are not distributed equally across Europe) we recommend to increase the MEPS requirements in 2020 significantly as in this case manufacturers will have sufficient time to adapt to the new market situation.

The values in the tables are given on an annual basis for each specified product category and in addition for the cumulative time between the proposed introduction of the MEPS on January 1st, 2010 and the target year 2020. The cumulative savings related to the introduction of MEPS was calculated to be between 29.6 TWh for MEPS+10 and and 44.4 TWh for the MEPS+15 scenario.

Table 58: Possible energy savings in TWh due to the implementation of MEPS – case 10 % improvement

Additional energy saving per year [TWh], Assumed average efficiency improvement due to MEPS 10%																	
Prod. Cat.	**Type**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Total savings in 2020**
1	Axial <= 300 Pa (static pressure)	0,104	0,105	0,106	0,107	0,108	0,109	0,110	0,111	0,113	0,114	0,115	0,116	0,117	0,118	0,119	1,251
2	Axial > 300 Pa (static pressure)	0,487	0,492	0,497	0,502	0,507	0,512	0,517	0,523	0,528	0,533	0,538	0,544	0,549	0,555	0,560	5,867
3	Centrifugal forward curved blades (with casing)	0,146	0,148	0,149	0,151	0,152	0,154	0,155	0,157	0,158	0,160	0,162	0,163	0,165	0,166	0,168	1,761
4	Centrifugal backward curved blades (no casing)	0,384	0,388	0,392	0,396	0,400	0,404	0,408	0,412	0,416	0,420	0,425	0,429	0,433	0,437	0,442	4,626
5	Centrifugal backward curved blades (with scroll housing)	0,436	0,440	0,444	0,449	0,453	0,458	0,462	0,467	0,472	0,476	0,481	0,486	0,491	0,496	0,501	5,242
6	Other Box fans	0,097	0,098	0,099	0,100	0,101	0,102	0,103	0,104	0,105	0,106	0,107	0,109	0,110	0,111	0,112	1,171
7	Other Roof fans	0,792	0,800	0,808	0,816	0,825	0,833	0,841	0,850	0,858	0,867	0,875	0,884	0,893	0,902	0,911	9,538
8	Other Cross-flow fans	0,014	0,015	0,015	0,015	0,015	0,015	0,015	0,016	0,016	0,016	0,016	0,016	0,016	0,016	0,017	0,174
																Total anticipated Savings	**29,629**
																	12,2%

Table 59: Possible energy savings in TWh due to the implementation of MEPS – case 15 % improvement.

Additional energy saving per year [TWh], Assumed average efficiency improvement due to MEPS 15%																	
Prod. Cat.	**Type**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Total savings in 2020**
1	Axial <= 300 Pa (static pressure)	0,156	0,157	0,159	0,161	0,162	0,164	0,165	0,167	0,169	0,170	0,172	0,174	0,176	0,177	0,179	1,876
2	Axial > 300 Pa (static pressure)	0,731	0,738	0,746	0,753	0,761	0,768	0,776	0,784	0,792	0,800	0,808	0,816	0,824	0,832	0,840	8,800
3	Centrifugal forward curved blades (with casing)	0,219	0,222	0,224	0,226	0,228	0,231	0,233	0,235	0,238	0,240	0,242	0,245	0,247	0,250	0,252	2,641
4	Centrifugal backward curved blades (no casing)	0,576	0,582	0,588	0,594	0,600	0,606	0,612	0,618	0,624	0,630	0,637	0,643	0,650	0,656	0,663	6,939
5	Centrifugal backward curved blades (with scroll housing)	0,653	0,660	0,666	0,673	0,680	0,687	0,693	0,700	0,707	0,714	0,722	0,729	0,736	0,744	0,751	7,863
6	Other Box fans	0,146	0,147	0,149	0,150	0,152	0,153	0,155	0,156	0,158	0,160	0,161	0,163	0,164	0,166	0,168	1,756
7	Other Roof fans	1,189	1,200	1,212	1,225	1,237	1,249	1,262	1,274	1,287	1,300	1,313	1,326	1,339	1,353	1,366	14,306
8	Other Cross-flow fans	0,022	0,022	0,022	0,022	0,023	0,023	0,023	0,023	0,024	0,024	0,024	0,024	0,024	0,025	0,025	0,262
																Total anticipated Savings	**44,444**
																	18,2%

If the MEPS standards would be introduced not on the 1.1.2010, the possible savings of this year would be lost which are equivalent to 2.6 and 3.8 TWh. For each additional year the MEPS levels would be introduced later, about the same amount of energy savings due to MEPS would be lost.

Based on the data the electricity consumption for fans in non residential buildings can be compared between the BAU and the MEPS cases. Figure 130 shows the development of the electricity consumption in the BAU case without MEPS and to MEPS cases in which the MEPS will bring an average efficiency increase of 10% or 15 % for all products. If MEPS are come into force January 1st, 2010, the consumption starts to be divergent for the MEPS cases. It should however be noted, that the overall electricity consumption for fans will continue to rise, due to a much faster grows of number of units compared to improvements in energy efficiency.

Figure 130: Development of electricity consumption for the BAU and MEPS cases.

If the proposed implementation plan would be adopted, the MEPS lines would be changed as given in the following tables. In 2011 and 2012 only minor changes are made, mainly to ban the fans with the worst efficiency which are belonging to the product category 6 and 8. There could be also some interest to merge these two steps into one single change to reduce the administrative burden associated with the changes. In the tables the relevant changes are highlighted in blue.

Table 60: Revised MEPS lines in 2011 (cat 8 MEPS lines increased to cat. 3 levels)

MEPS in % to be introduced in **2011**	**Power Range**		
	0.125-1 kW	**1-10 kW**	**10 -500 kW**
MEL1 - Axial <=300Pa	3.42*ln(P_{el}) + 27.12		=35
MEL2 - Axial > 300Pa	2.28*ln(P_{el}) + 29.75		=35
MEL3 - Cetrifugal forw w housing	2.74*ln(P_{el}) + 28.69		=35
MEL4 - Centrifugal backw free wheel	4.68*ln(P_{el}) + 47.23		=58
MEL5 - Centrifugal backw w housing	4.56*ln(P_{el}) + 44.49		=55
MEL6 - Box fans	7.53*ln(P_{el}) + 25.66		=43
MEL7 - Roof fans	3.42*ln(P_{el}) + 37.12		=45
MEL8 - Cross-flow fans	2.74*ln(P_{el}) + 28.69		=35
Results should be rounded to one digit, P_{el} to be entered in kW			

Table 61: Revised MEPS lines in 2012 (Minimum efficiency of all categories and sizes above 20 %)

MEPS in % to be introduced in **2012**	**Power Range**		
	0.125-1 kW	**1-10 kW**	**10 -500 kW**
MEL1 - Axial <=300Pa	3.42*ln(P_{el}) + 27.12		=35
MEL2 - Axial > 300Pa	2.28*ln(P_{el}) + 29.75		=35
MEL3 - Cetrifugal forw w housing	2.74*ln(P_{el}) + 28.69		=35
MEL4 - Centrifugal backw free wheel	4.68*ln(P_{el}) + 47.23		=58
MEL5 - Centrifugal backw w housing	4.56*ln(P_{el}) + 44.49		=55
MEL6 - Box fans	if (7.53*ln(P_{el}) + 25.66) < 20 then MEPS =20; if (7.53*ln(P_{el}) + 25.66) ≥ 20 then MEPS = (7.53*ln(P_{el}) + 25.66)		=43
MEL7 - Roof fans	3.26*ln(P_{el}) + 37.5		=45
MEL8 - Cross-flow fans	2.74*ln(P_{el}) + 28.69		=35
Results should be rounded to one digit, P_{el} to be entered in kW			

Table 62: Revised MEPS lines in 2020 (Minimum efficiency of all categories and sizes increased by 4 percentage points)

MEPS in % to be introduced in **2020**	**Power Range**		
	0.125-1 kW	**1-10 kW**	**10 -500 kW**
MEL1 - Axial <=300Pa	$3.42*\ln(P_{el}) + 31.12$		=39
MEL2 - Axial > 300Pa	$2.28*\ln(P_{el}) + 33.75$		=39
MEL3 - Cetrifugal forw w housing	$2.74*\ln(P_{el}) + 32.69$		=39
MEL4 - Centrifugal backw free wheel	$4.68*\ln(P_{el}) + 51.23$		=62
MEL5 - Centrifugal backw w housing	$4.56*\ln(P_{el}) + 49.49$		=59
MEL6 - Box fans	if $(7.53*\ln(P_{el}) + 29.66) < 24$ then MEPS =24; if $(7.53*\ln(P_{el}) + 29.66) \geq 24$ then MEPS = $(7.53*\ln(P_{el}) + 29.66)$		=47
MEL7 - Roof fans	$3.26*\ln(P_{el}) + 41.5$		=49
MEL8 - Cross-flow fans	$2.74*\ln(P_{el}) + 32.69$		=39
Results should be rounded to one digit, P_{el} to be entered in kW			

8.2 Overlap between Motors and Fans Study Savings

The fan study has defined the fan product as including the fan wheel, the transmission, and the motor due to the fact that in some products can not be analysed as separate components and because the fan product sold on the market is typically including the motor. Therefore the study team decided to set the product boundary including the motor. As lot 11 comprises motors, pumps and fans questions could arise if the savings potentials calculated in the different parts of lot 11 are independent form each other and can therefore be simply added or if there is some overlap and therefore double counting of potentials. Table 63 summarises the coverage of the studies and gives some remarks to the possible overlap.

Table 63: Product coverage of lot 11

Study part	**Coverage**	**Remarks**
Motors	Standard AC motors between 0.75 and 250 kW	Savings only related to the motors traded on the market
Pumps	Clean water pumps without motor. For submersible water pumps the motor is included.	Calculation of total electricity consumption based on an assumed motor efficiency. Savings are based on improvements on the pump using the same fixed motor efficiency. This means that total energy savings depend on assumed motor efficiency
Circulators	Circulators including the motor	No overlap due to motor size and most motors produced by circulator manufacturers themselves (not traded on the market).
Fans	Fans for ventilation above 125 W including motor and transmission	For small fans between 125 and 750 W no overlap. For Fans between 750 W and about 5 KW no overlap as typically special motors are used and fan manufacturers produce their own motors. For Fans above 5 kW overlap with motor savings.

Unfortunately there is no data available about the possible overlap between the studies. In addition it should be noted that the overlap in terms of number of units might be small but in terms of energy consumption it could be significant. For the fans we have estimated with the fan stock model developed that about 50 % of the energy consumption is related to the larger fans above 5 kW and therefore the maximum overlap could be about 50 % of the savings. However in reality the value will be lower due to the following reasons:

- Fans above 5 kW are driven also by motors produced by the fan manufacturer themselves which are therefore not included in the motor study

- The saving for the fan product is based on savings achieved by improving any component of the product, i.e. motor, transmission and/or the fan wheel; therefore only about 30 % of the total fans savings are related to the motor.

- Some fans might be driven by special motors not covered in the motor study.

Based on these facts a possible overlap of 10 to 15 % in terms of energy consumption and energy savings between the motors and the fans study seems possible. However this in the range of uncertainty for the stock of products and have therefore only little impact on the overall result.

8.3 Impact analysis industry and consumers

The fan consumers will face higher first cost for ventilation if minimum efficiency levels for fans are introduced. However for the companies who have to pay the energy costs of the products the additional first cost will pay off. As the standards will apply for products produced in or imported to Europe, no significant problems are expected for European manufacturers in terms of international competition.

Problems might occur from the fact that a larger number of fans is sold to OEMs. However no specific information about the share of fans sold to OEMs is available. Neither statistical nor information from other sources could be used. Based on the application of the different product groups it might be realistic that more than 70% of the fans for ventilation are sold to OEMs. If these are located within the EC they would only be able to buy products which comply with the minimum efficiency standard. However if the OEM (e.g. producing fan coils or air handling units) would be located outside the EC he could also include non-compliant products which are bought outside the EC. If the OEM is selling his product including fans to the European market, the fans would be in use in Europe without having been hindered to enter the market as not the fan has been sold across the border.

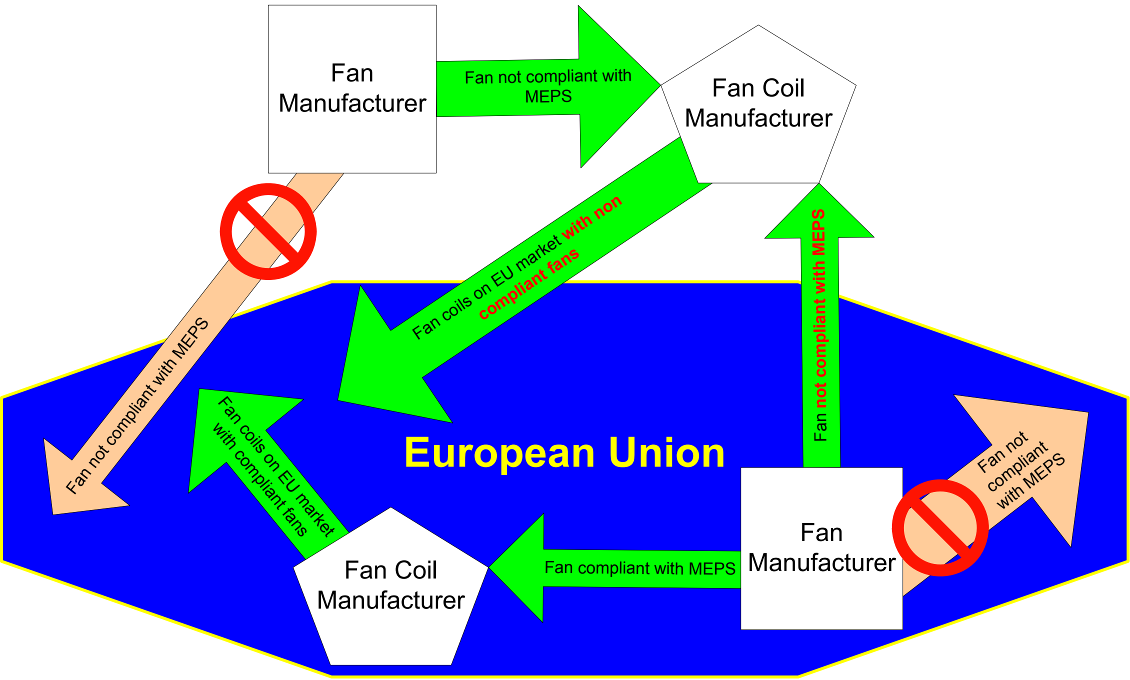


Figure 131: The leak for non compliant products entering Europe, the example of fan coils

This problem is based on the fact, that the fan products under consideration are either end user products or products to be incorporated into end user products. These products are used for non residential building ventilation, either entering directly or indirectly the European market. The best way to solve this issue would be to request that for all energy using products also the parts and components for which individual MEPS exist must be compliant with the corresponding implementing measures. Otherwise separate implementing measure should be developed for those products for which the energy consumption of the fan has a high share on the overall consumption. In this case the following products should be considered as quickly as possible for implementing measures. However it should be noted that the number of products could be below the threshold of 200,000 units per year set out in the EuP Directive.

- Air handling units
- Fan coils
- Fan heaters

The introduction of minimum efficiency levels for fans will also have an impact on the fan manufacturers. Those having put more focus on the efficiency of their products will profit, those who have tried to supply the lowest cost sector could have problems as not all of their products might be compliant with the minimum efficiency values set in the EuP implementing measures. In this case the existing market structure could be changed significantly, if the values to be achieved are set to high. It therefore seems to be more appropriate to introduce the minimum efficiency values a little bit below the average efficiency but to set clear targets how the minimum requirements will be in-

creased in the following years. This would give a clear signal about the framework conditions in which the manufacturers can develop their individual strategy how to take highest advantage out of the new regulation and at the same time give them the time to improve their products to such an extend that they will fulfil the minimum efficiency levels. As the efficiency is significantly affected by the power rating of the fan it is also recommended not only to set minimum efficiency levels individually per product category but also to make them dependent on power rating.

An important question to decide is how compliance with the required minimum efficiency levels is confirmed. To make sure that all fans sold in Europe will comply with such standards, it has to be assured that the data specified by the manufacturers is measured and calculated correctly. **Third party certification or self declaration** by manufacturers could be envisaged. In addition it has to be decided, which measurement standard should be used or might be the most appropriate in Europe.

Often manufacturers use ISO 5801 but also national standards such as VDI 2044, DIN 24163, BS 848 Part 1 or AMCA 210 are widely used. However more and more European Countries such as the UK, France and Italy are using ISO 5801. In some countries such as Germany some doubts exist regarding ISO 5801 but these problems might to be solved with the revision of ISO 5801 coming up in the end of 2008.

The revised version will probably be in place by the time when implementing measures for fans will take effect and **therefore the use of ISO 5801 would be widely accepted as a test standard for MEPS**. Some uncertainty could remain, as ISO 5801 describes different test stands for fans, which might lead to different results for the same product. ISO 5801 also do not sets the level of uncertainty for the motor which will be part of the product to be analysed. Therefore ISO 5801 should be extended with an uncertainty for the motor. As long as this is not implemented in the standard, an uncertainty level of 4 % proposed which should be used.

Care should be taken also with regard to allowable tolerances. As measurement tolerances are a fact, the acceptable tolerances should be as small as possible. ISO 13348 defines 4 manufacturing tolerances classes AN1 to AN4 (Table 64) that can be used as a basis for contractual agreements but which should not be misinterpreted as measuring tolerances. However ISO 13348 deals only with the fan wheel and does not include transmission and motor. The smaller the fan size the more difficult it gets to achieve a small tolerance. To date, most manufacturers are not specifying the tolerance classes in their catalogues at all. If MEPS or a fan labelling scheme are considered, these tolerances have to be taken into account. Together with MEPS tolerance classes to be used have to be fixed. To assure a sufficient accuracy it is proposed to require at least tolerance class AN2 for the ratings of smaller fans and AN1 for fans above or equal a power rating of 1.1 kW. This value could be set also to the lower value of 0.75 kW, where the use of standard motors starts, or a higher value such as 5 kW, where above there is no market competition between EC and AC motors so far. However there is a conflict in the sence low tolerances to specify the efficiency of the product are necessary, as otherwise manufacturers may use the largest allowable tolerances to comply with MEPS and the values specified in ISO 13348. However the study finally haven taken up the power ranges as specified in ISO 13348 to be consistent with this standard. However these large tolerances should be taken into consideration when fixing MEPS levels.

Table 64: Tolerances classes as specified in ISO 13348:2006

	AN1	AN2	AN3	AN4
Power range	>500 kW	> 50 kW	> 10 kW	≤ 10 KW
Efficiency	-1 %	-2 %	-5 %	-12 %

If a standard for the fan test procedure is agreed, one might ask if manufacturers themselves are trustful sources for the measurements and publication of efficiency and other data. In general manufacturers should have an own interest to declare correct values as the market forces will work against wrong data from manufacturers. However it is assumed that is more likely to come from the other manufacturers than from the system operators, as it is not easy to identify faulty installations or installations which do not achieve the expected efficiencies due to wrong data given by a manufacturer. On the other hand a third party certification might be more acceptable by customers. Third party certification is adding costs to the products for the manufacturers which might be not covered by the market and may force speciality products out of the market. The certification cost and the transaction cost for the manufacturers related to third party certification would in particular concern manufacturers with a broad product range, and even more if an annual or biannual control would be required. It would also take a significant time before all products might have passed third party testing, as it seems that actually there are not enough accredited laboratories available.

The cost of third party certification will also depend on the certification approach chosen. The two general approaches are "Test all“ or "Certify all“. In the first approach cost will be very high, as every product has to be tested. In the second approach there is the risk, that it is a question of chance, if wrong declared products are identified and the necessary amount of testing is difficult to fix. It would be required that the risk for manufacturers to be blamed for false declaration is high enough, which might lead to a rate of 20 % of the products that require testing. An important point to take into consideration is also the fact that not the stated efficiency value has to be checked for the EuP approach but only that the efficiency value of the product is above the MEPS Level which is required to obtain the CE mark. The third party certification for the proof of catalogue data is much more detailed and is not subject of the EuP directive.

Instead of adding cost for third party certification it seems to be sufficient to have the controls to check whether the juridical requirements are fulfilled by the products. In addition painful fines for non compliant products should be fixed and to leave it to the market to remove the faulty products from the market. However, to make sure that the laboratories of the manufacturers show comparable results, a system of accreditation for the test stands to be used should be set up. Thereby, intercomparison programmes or round robin tests could further increase reliability of manufacturers' laboratories. These measures should ensure that the tests are performed with up to date equipment by skilled and trained personal. Experience from laboratory accreditation programs for fans in the US [AMCA, 1999] should be evaluated when setting up such a program. There is also an international standard (ISO 17025) for the certification of laboratories which could be used. Table 65 summarizes the arguments for self declaration by manufacturers and third party certification.

Table 65: Third party certification or self declaration

	Third party certification	Self declaration
Advantage	☺ reliable data of performance ☺ ISO 17025 standard on certification of laboratories available.	☺ cost effective as tests are performed anyway at the companies ☺ Self regulation of the market ☺ Quick implementation possible ☺ Inline with actual CE mark conditions ☺ Similar to machinery directive
Disadvantage	☹ cost involved for testing and transactions due to high number of different products ☹ not enough accredited laboratories to perform testing ☹ Will required regularly testing of the same product	☹ No independent check of data ☹ May not hinder poor products to enter the European market without effective control

In any case there should be some enforcement and control about the compliance of products with the EuP directive as it is which every directive.

8.4 Sensitivity analysis of the main parameters

To get better understanding of the relationships of the different factors, influencing the economic and ecologic of the fan products, a sensitivity analysis is carried out. However due to the fact that the production phase of the product has only minor impact on the environmental impact we are focussing in the sensitivity analysis on the product life cycle cost. Environmental impacts are strongly related to the energy consumption during the use phase of the product and will therefore correspond to the overall static efficiency. If the efficiency of the product increases the environmental impact will be reduced accordingly. The following parameters have been studied in a sensitivity analysis with regard to life cycle costs:

Table 66: Sensitivity analysis for life cycle cost for category 1 fan product

	Discount rate	Overall static efficiency	Electricity price Number of operating hours[22]
Product cost	YES	YES	YES
Discount rate			YES
Overall static efficiency			YES

22 It should be noted that an increase of the electricity price has the same effect than an increase of the number of operating hours.

For the sensitivity analysis, as the main impact is energy consumption and as the fan function is the same, it is not important which of the 8 fan categories we use in the sensitivity analysis. We have focussed on product category 1 which is the fan type most broadly known as most of the other fans are typically invisible after installation. The conclusions are therefore for all categories the same, with only differences in the absolute values but the same relationships between the different inputs and results. We have however kept the absolute values in the sensitivity analysis to facilitate the understanding of the graphs and to provide some insights into the life cycle cost of the product. Therefore there is no need to perform a sensitivity analysis for each product category separately.

Figure 132 show that the electricity rate to be paid is of much high importance than the product costs. An increase of the electricity price from 5 ct/kWh to 10 ct/kWh is equivalent to an increase of operating hours from 2000 to 4000 hours/a.

This can be generalised to the point, that higher electricity prices makes the efficiency improvements even more important.

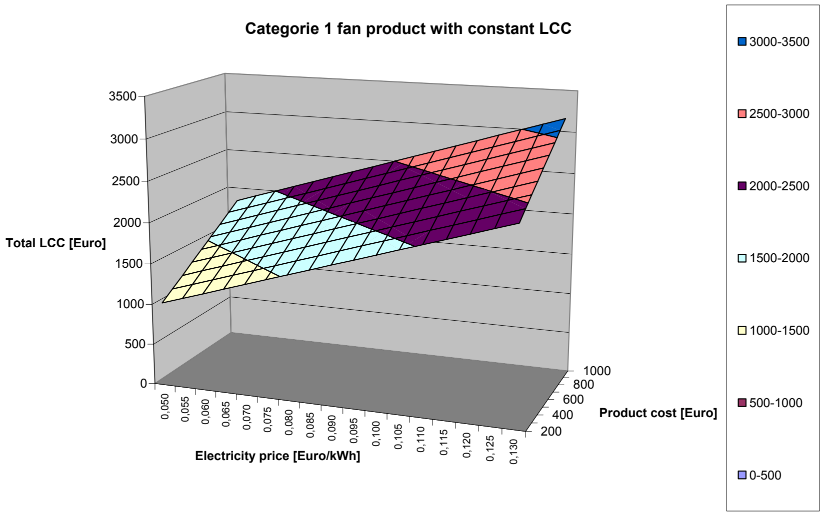


Figure 132: LCC as a function of electricity price and product cost for product category 1

If high electricity rates and high number of operating hours are coming together, the total life cycle cost of the product can increase dramatically, . Again this makes clear the high relevance of the electricity consumption during operation on the life cycle cost.

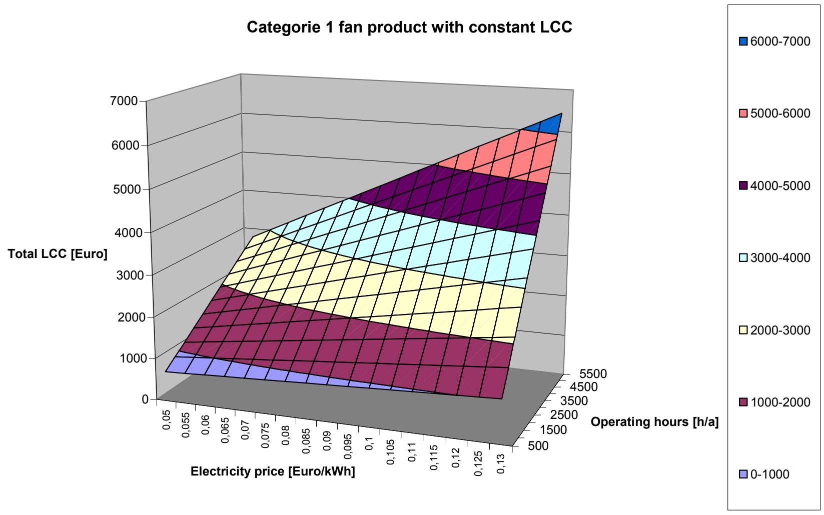


Figure 133: LCC as a function of electricity price and number of operating hours for product category 1

The dependence of the life cycle cost on electricity price and discount rate is shown in Figure 134. As the discount rate do not influence in the model the product cost but only the energy cost to be payer in later years, higher discount rates reduces the net present value of the future energy costs and therefore higher discount rates will lower life cycle cost.

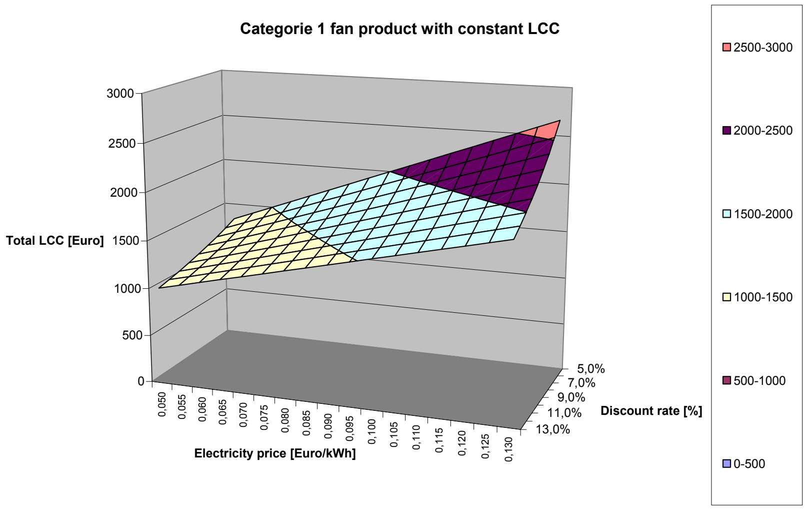


Figure 134: LCC as a function of electricity price and discount rate for product category 1

The strongest impact on the life cycle costs can be observed for the overall static efficiency of the product. The efficiency is the dominating factor in regards to life cycle cost, Figure 135.

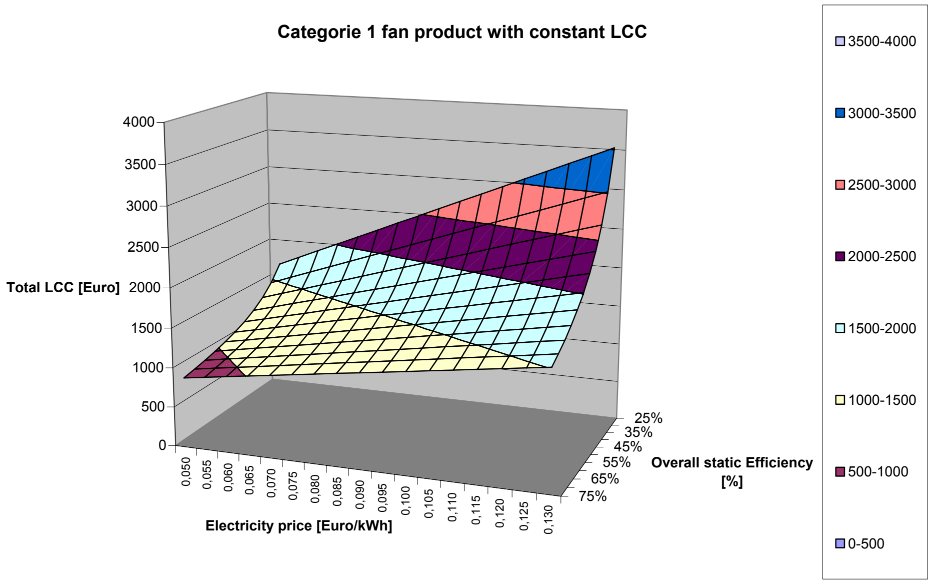


Figure 135: LCC as a function of electricity price and overall static efficiency for product category 1

Neither electricity price nor product cost (Figure 136) play the major role in the total life cycle cost for fans.

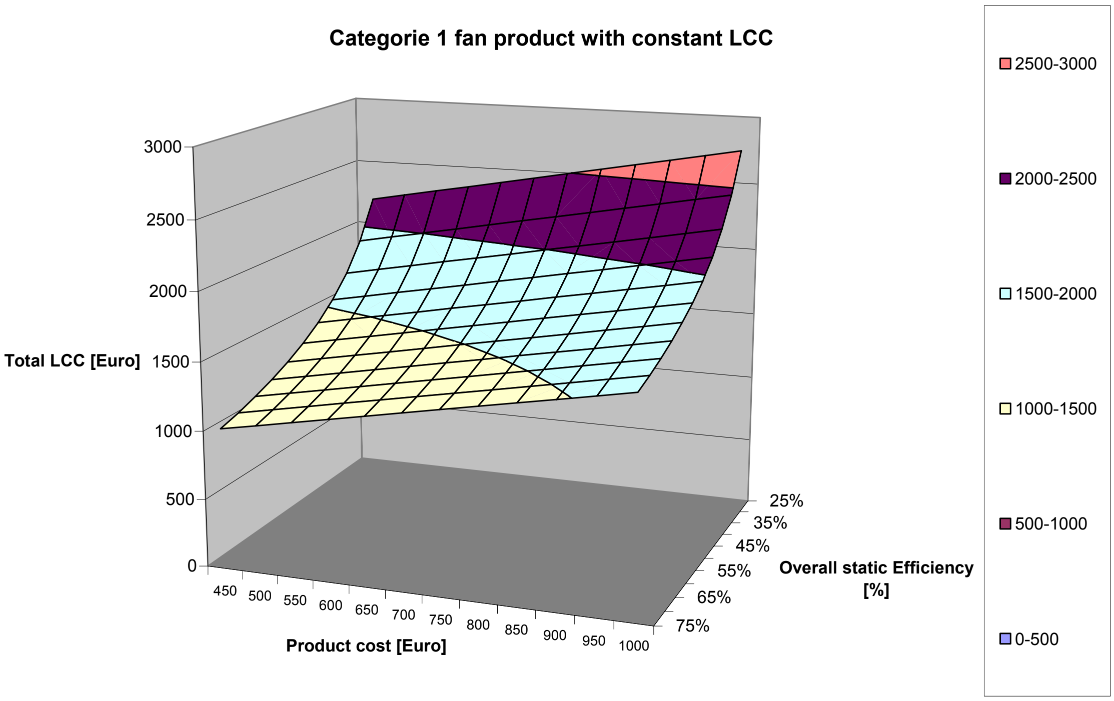


Figure 136: LCC as a function of product cost and overall static efficiency for product category 1

Figure 137 finally shows the relationship between product costs, discount rate und life cycle cost. As has already identified, both factors are not so important in terms of life cycle cost.

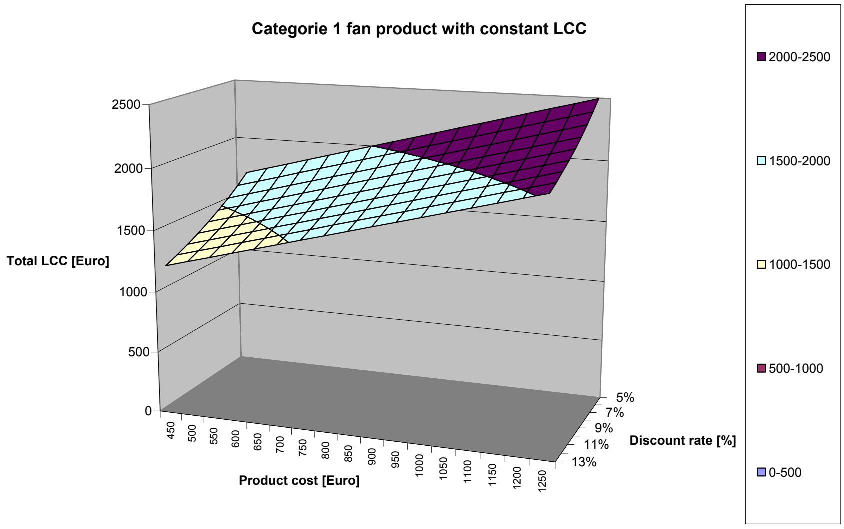


Figure 137: LCC as a function of product cost and discount rate for product category 1

So if the efficiency is the main driver for the life cycle cost the question should be answered, who much additional money can be spend in the beginning if this would lead to the use of higher efficient products. For a category 1 product of 0.8 kW[23] the average overall static efficiency is in the range of 35 %. If we want to keep the total life cycle cost constant this lead to possible additional product costs if the efficiency of the product could be increased. Figure 138 shows the result of the analysis, showing on the left side the base case for the product. For an increase of the product efficiency of 5 %-points the cost of the product can increase by about 30 % without increasing the life cycle costs.

23 Please note that a specific product is used here to give absolute values fort he cost. All product categories show similar behaviour but have higher first cost, higher efficiencies or higher power, leading to different total cost.

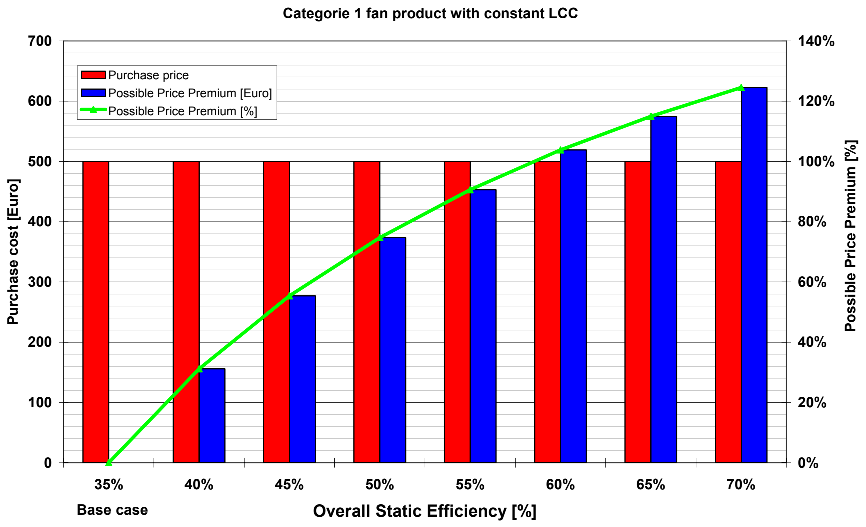


Figure 138: Possible price premium for constant LCC for average category 1 product

The problem to sell higher efficiency on the market will therefore not come from increased cost for the user or increased life cycle costs for the better product but from the fact that the costumers still tend to evaluate products on the basis of their first costs, not taking into account the later energy costs.

So very high minimum efficiency levels will reduce the life cycle cost but may have very strong impacts on the market players and their market shares. Therefore minimum efficiency levels should start not to low but their further increase in the future should be fixed to enable the companies to adapt themselves to the changing market conditions.

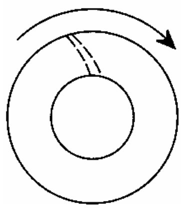
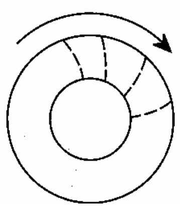
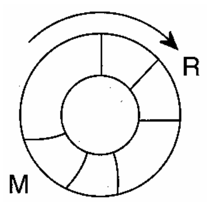
Summary Chapter 8:

- ❖ Implementation of labelling for fans is difficult to handle and might have even negative impact. Labelling is therefore not recommended.
- ❖ If Eco-labelling for the best products should be introduced, minimum qualifying efficiencies should be 25 % above MEPS levels.
- ❖ Manufacturers should be requested to indicate the maximum overall static efficiency of their products in their catalogues (print and electronic).
- ❖ Manufacturers should be requested to submit the data for their products to be included in a database.
- ❖ Request that products can be easily dismantled at the end of life and that the materials used can be recycled. Plastic materials should be marked with the relevant logos
- ❖ Noise level of the product to be indicated based on test standard ISO 13347.

- ❖ The introduction of minimum efficiency values will have high impact on the market actors and should therefore start not with very high values but with a clear increased target in the years to come so that manufacturers can adopt.
- ❖ Risk of having non compliant fans in products which are for them self compliant to their product regulation.
- ❖ Efficiency of the fan is not only dependent on fan category but also on power range. Minimum efficiency values should therefore be dependent of power rating and fan category
- ❖ Fans to comply with the ATEX directive and emergency fans operating less than 25 h/a should be excluded from the minimum efficiency standards
- ❖ 01.01.2010: MEPS should come into force for fans between 125 W and 500 kW with the exclusion of some special purpose fans (see chapter 8.1.2.2)
- ❖ 01.01.2011 MEPS for Category 8 (cross flow) products should be equalised to category 3 (forward curved centrifugal) products
- ❖ 01.01.2012 Lowest allowable MEPS level for all product categories and sizes should be set to 20%
- ❖ 01.01.2020 MEPS levels for all product categories should be increased by 4 %-points
- ❖ Third party certification will produce high additional costs for the manufacturers but will guarantee accurate results. For the minimum efficiency levels self declaration combined with law enforcement on the level of member states seems to be sufficient. Therefore self declaration for compliance is recommended
- ❖ Minimum efficiency standards should be based on overall static efficiency and should be measured according to ISO 5801.
- ❖ ISO 5801 should be extended with an uncertainty level for the electric motor as part of the fan. Until this extension is made, the maximum allowable uncertainty level for the motor should be fixed at 4%.
- ❖ MEPS are proposed for all 8 product categories (see Figure 126)
- ❖ The following Tolerance classes (according to ISO 13348:2006) should be required: AN1 P> 500 kW, AN 2 P>50 kW, AN 3 P>10 kW, AN 4 P≤ 10 kW.
- ❖ Life cycle cost are dominated by the efficiency of the product
- ❖ Efficiency improvements of the product are typically paid of by reduced energy costs and will therefore lead to lower life cycle cost.

Appendix 1 – Fan Types

Table 67: Characteristics of fans used for ventilation in non residential buildings [AMCA, 1990]

Type	Impeller design	Performance characteristics	Applications
Airfoil 	Highest efficiency of all centrifugal fan designs. 10 to16 blades of airfoil contour curved away from the direction of rotation. Air leaves the impeller at a velocity less than its tip speed and relatively deep blades provide for efficient expansion within the blades passage. For given duty this will be the highest speed of the centrifugal-fan designs.	Highest efficiencies occur at 50 to 65 % of wide open volume. This is also the area of the good pressure characteristics. The horsepower curve reaches a maximum near the peak efficiency area and becomes lower towards free delivery. A self-limiting power characteristic as shows.	General heating, ventilation and air-conditioning systems. Usually applying only to large systems where the savings in power are significant. Can be used on low-, medium- and high-pressure systems. Used in large sizes for clean air industrial applications where power savings are significant.
Backward-inclined Backward-curved 	Efficiency is only slightly less than that of airfoil fans. Backward-inclined or backward-curved blades are single thickness. 10 to 16 blades curved or inclined away from the direction of rotation. Efficient for the same reasons given for the airfoil fan above.	Operating characteristics of this fan are similar to the airfoil fan mentioned above. Peak efficiency for this fan is slightly lower than the airfoil fan.	Same heating, ventilation and air-conditioning applications as the airfoil fan. Also used in some industrial applications where the airfoil blade is not acceptable because of corrosive and/or erosion environment.
Radial 	Simplest of all centrifugal fans and least efficient. Has high mechanical strength and the wheel is easily repaired. For a given point of rating this fan requires medium speed. This classification includes radial blades (R) and modified radial blades (M). Usually 6 to 10 in number.	Higher pressure characteristics than the above mentioned fans. Curve may have a break left of peak pressure but this usually is not sufficient to cause difficulty. Power rises continually to free delivery.	Used primarily for material-handling applications in industrial plants. Wheel can be rugged construction, and is simple to repair in the field. Wheel is sometimes coated with special material. This design also used for high-pressure industrial requirements. Not commonly found in HVAC applications.

Continuation …

Table 67 (continuation)

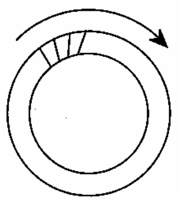
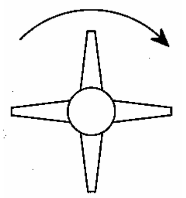
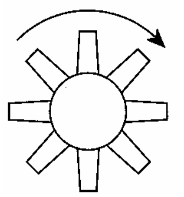
Type	**Impeller design**	**Performance characteristics**	**Applications**
Forward-curved 	Efficiency is somewhat less than airfoil and backwards-curved bladed fans. Usually fabricated of lightweight and low cost construction. Has 24 to 64 shallow blades with both the heel and tip curved forward. Primary energy transferred to the air is by use of high velocity in the wheel for given duty. Wheel is smallest of all centrifugal types and operates at lowest speed. Primary energy transferred to the air is by use of high velocity in the wheel for given duty.	Pressure curve is less steep than that of backward-curved bladed fans. There is a dip in the pressure curve left of the peak pressure point and highest efficiency occurs to the right of peak pressure, 40 to 50 % of wide open volume. Fan should be rated to the right of peak pressure. Power curve rises continually toward free delivery and must be taken into account when motor is selected.	Used primarily in low-pressure heating, ventilation and air-conditioning applications such as domestic furnaces, central station units and packaged air-conditioning equipment from room air-conditioning units to roof top units.
Propeller 	Efficiency is low. Impellers are usually of inexpensive construction and limited to low-pressure applications. Impeller is of 2 or more blades, usually of single thickness attached to relatively small hub. Energy transfer is primarily in form of velocity pressure.	High flow rate but very low pressure capabilities and maximum efficiency is reached near free delivery. The discharge pattern of the air is circular in shape and the air stream swirls because of the action of the blades and the lack of straightening facilities.	For low-pressure and high-volume air moving applications such as circulation within a space or ventilation through a wall without attached ductwork. Used for makeup air applications.
Tube axial 	Somewhat more efficient than propeller fan design and is capable of developing a more useful static pressure. Number of blades usually from 4 to 8 and hub is usually less than 50 % of fan tip diameter. Blades can be of airfoil or single thickness cross section.	High flow rate characteristics with medium pressure capabilities. Performance curve includes a dip to the left of peak pressure which should be avoided. The discharge air pattern is circular and is rotating and whirling because of the propeller rotation and lack of guide vanes.	Low- and medium-pressure heating, ventilating and air-conditioning applications where air distribution on the downstream side is not critical. Also used in some industrial applications such as drying ovens, paint spray booths and fume exhaust systems.

Table 67 (continuation)

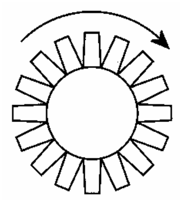
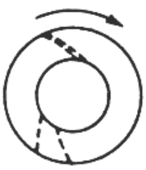
Type	**Impeller design**	**Performance characteristics**	**Applications**
Vane-axial 	Good design of blades permits medium- to high-pressure capability at good efficiency. The most efficient fans of this type have airfoil blades. Blades are fixed, adjustable or controllable pitch types and hub is usually greater than 50 % of fan tip diameter.	High-pressure characteristics with medium volume flow-rate capabilities. Performance curve includes a dip, caused by aerodynamic stall, to the left of peak pressure which should be avoided. Guide vanes correct the circular motions imparted to the air by the wheel and improve pressure characteristics and efficiency of the fan.	General heating, ventilating and air-conditioning systems in low-, medium- and high-pressure applications is of advantage where straight-through flow and compact installations are required. Air distribution on downstream side is good. Also used in industrial application similar to the tube-axial fan. Relatively more compact than comparable centrifugal-type fans for same.
Tubular 	This fan usually has a wheel similar to the airfoil backward-inclined or backward-curved blade as described above. (However, this fan wheel type is of lower efficiency when used in fan of this type). Mixed flow impellers are sometimes used	Performance is similar to backward-curve fan, except lower capacity and pressure because of the 90 degree change in direction of the air flow in the housing. The efficiency will be lower than the backward-curved fan. Some designs may have a dip in the curve similar to the axial-flow fan.	Used primarily for low-pressure return air systems in heating, ventilating, and air conditioning applications. Has straight-through flow configuration.
Power roof centrifugal ventilators 	Many models use airfoil or backward-inclined impeller designs. These have been modified from those mentioned above to produce a low-pressure-high-volume flow rate characteristic. In addition, many special centrifugal impeller designs are used, including mixed-flow design.	Usually intended to operate without attached ductwork and therefore to operate against very low-pressure head. It is usually intended to have a rather high volume-flow rate characteristic. Only static pressure and static efficiency are shown for this type of product.	For low pressure exhaust systems such as general factory, kitchen, warehouse, and commercial installations where the low pressure rise limitation can be tolerated. Unit has low initial cost and low operating cost and provides positive exhaust ventilation in the space which is a decided advantage over gravity type exhaust units. The centrifugal unit is somewhat quieter than the axial unit described below.

Table 67 (continuation)

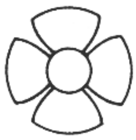
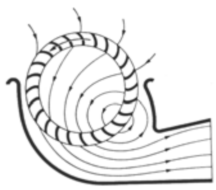
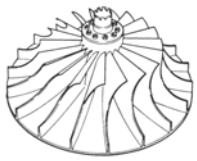
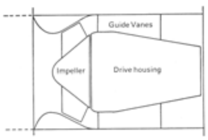
Type	Impeller design	Performance characteristics	Applications
Power roof axial ventilators 	A great variety of propeller designs are employed with the objective of high-volume flow rates at low pressure.	Usually intended to operate without attached ductwork and therefore to operate against very low pressure head. It is usually intended to have a rather high volume-flow rate characteristic. Only static pressure and static efficiency are shown for this type of product.	For low pressure exhaust systems such as general factory, kitchen, warehouse, and commercial installations where the low pressure rise limitation can be tolerated. Unit is low in first cost and low in operating cost and provides positive exhaust ventilation in the space which is a decided advantage over gravity type exhaust units.
Tangential flow 	Impellers similar to those of multi-vane forward curved centrifugal fans are used. The action for this type of fan is radically different. A vortex is formed and maintained by the blade forces and has its axis parallel to the shaft and near to a point on the impeller circumference.	Efficiency is low but the fans are fairly quiet for their duty. To obtain a reasonable efficiency an adequate outlet diffuser is necessary since most of the pressure comes from the conversion of the high velocity pressure leaving the impeller.	Improvements in casing design have brought this type into prominence for use in certain small domestic appliances. They present long, narrow rectangular shape of inlets and outlets which opens up new possibilities for functional and appearance design for table fans and electric fan heaters.

Table 68: Characteristics of other fans (not relevant for ventilation in non residential buildings) [AMCA, 1990]

Type	**Impeller design**	**Performance characteristics**	**Applications**
Mixed Flow Centrifugal exit  Axial entry mixed flow blades can be extended into a radial flow centrifugal formation leading to a volute outer casing.	High pressure development can be combined with high efficiency given careful design.	Extension into the fan field of the high-strength, high tip-speed designs used for turbo-compressors and superchargers, finds a place in the high power applications of heavy industry.	
Mixed Flow axial discharge 	Similar to axial fan impeller, the blades rotate in a conic channel that widens progressively. The discharge happens in a duct with the aid of stationary blades.	A significant part of the pressure is developed by centrifugal action and static pressure is higher than that produced by an axial fan rotating at the same rotational speed.	Although it is possible to reach efficiency and noise levels comparable to those of a backward-curved centrifugal fan with a more compact in-line casing these fans are not very popular due to the relatively high costs for quantity production and to the limited flexibility in duty

Appendix 2 – Fan Parameters

Table 69: Parameters and variables for mechanical and aerodynamic performance of fans [Radgen, 2002]

Mechanical parameters and aerodynamic performance	
Volume of air flow	Size and diameter
Pressure developed	Hub / impeller ratio
Efficiency	Blade angle / adjustment
Sound levels	Blade shape
Rotation speed	Impeller solidity / no. of blades
Reversible	Acoustic cladding
Balance	Belt drives
Standards	AMCA, LPCB, BS, CEN, ISO
Temperature	Std, HT, Bifurcated

Table 70: Parameters and variables for electrical supply and motors [Radgen, 2002]

Electrical supply and motors	
Absorbed power	Motor size / heat loss
Maximum power	Electrical capacity
Starting current	Starters / inverters
Power factor	Single / 2 speed
Speed / variable	Single / 3 speed
Efficiency	Bearings / insulation
Life	

Table 71: Parameters and variables for reliability and life of fans [Radgen, 2002]

Reliability and life	
Clean / contaminated air	Materials
Ambient / high temperature	Finishes
Smoke / fire duty	Tolerances
Water / dust protection	Sealing
Explosion protection	Bearing selection
High shock protection	Motor selection
Normal life / hours	Lubricants
Reversible	Fasteners

Appendix 3 – Information on Motors used in the Fans Report

Appendix 3.1 – Efficiencies of small motors

The efficiency of fan products especially at smaller power ratings depends heavily on the efficiency of the drive motor Today, typically single phase asynchronous motors with capacitor are used for fans Universal motors or shaded pole motors which are even cheaper than the previous mentioned have efficiencies even lower that the single phase motors with capacitors and are typically used in household appliances

Highest efficiencies for fractional horsepower motors can be achieved with DC permanent magnet motors, which have started to make their way into the application as fan drives

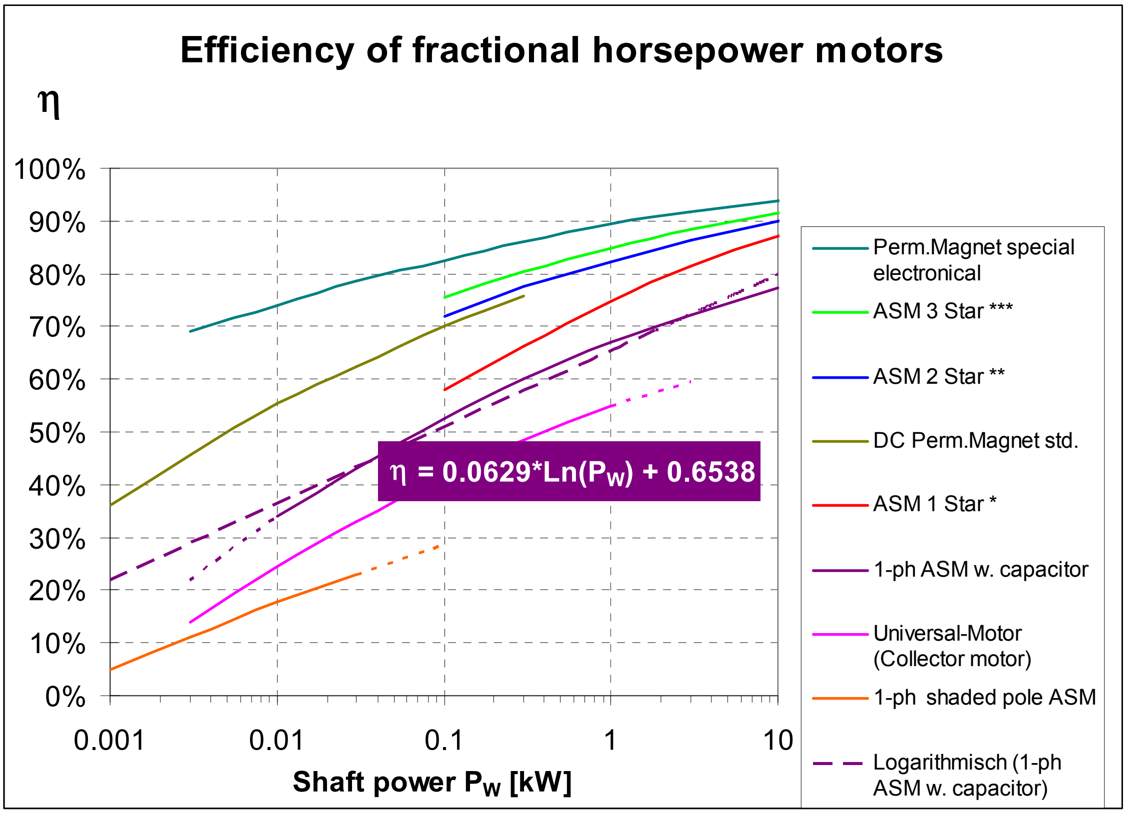


Figure 139: Efficiency of fractional horsepower motors [Nipkow, 2007]

Appendix 3.2 – Calculation of BOM data for AC motors

The calculation of the motor BOM data used in the fans study is based on motor data from the motor part of the study The data have been fitted into a model to calculated motor BOMs for non standard sizes and powers which are often specifically designed for fans To calculate the fitting curves, BOM data of standard AC motors for 075, 11,

75, 11 and 110 kW has been used We obtained the following relationships for the BOM data of the motors Table 72 shows the formulas for EFF1 and Table 73 the formulas for EFF2 motors

Table 72

: Calculation BOM data for fan motors based on class EFF1

EFF 1	
21-St sheet galvanised	$y = -11{,}154x^2 + 4776{,}9x + 5491{,}9$
24-Ferrite	$y = -2{,}92x^2 + 1011{,}5x + 1069{,}7$
23-Cast iron	$y = 19{,}256x^2 + 843{,}7x + 4180{,}7$
27-Al die cast	$y = -6{,}9696x^2 + 955{,}24x + 1256{,}7$
28-Cu winding wire	$y = -1{,}9362x^2 + 802{,}84x + 1116{,}4$
19-Aramid fibre	$y = -0{,}0502x^2 + 15{,}349x + 19{,}333$
56-Cardboard	$y = -3{,}2277x^2 + 859{,}72x – 509{,}56$
14-Epoxy	$y = -0{,}1957x^2 + 70{,}121x + 154{,}98$
39-powder coating	$y = -0{,}2784x^2 + 40{,}672x – 4{,}3055$
Note: y = Amount of material in gram; x=nominal required power of the motor	

Table 73: Calculation BOM data for fan motors based on class EFF2

EFF 2	
21-St sheet galvanised	y = -4,2955x2 + 3547,8x + 2716,8
24-Ferrite	y = -3,1705x2 + 1014,7x + 442,7
23-Cast iron	y = 19,256x2 + 843,7x + 4180,7
27-Al die cast	y = -5,6878x2 + 794,65x + 1211,7
28-Cu winding wire	y = -0,3832x2 + 576,26x + 648,88
19-Aramid fibre	y = -0,0426x2 + 14,442x + 27,153
56-Cardboard	y = -2,8972x2 + 820,28x – 169,6
14-Epoxy	y = -0,2265x2 + 73,797x + 123,3
39-powder coating	y = -0,2683x2 + 39,459x + 6,1475
Note: y = Amount of material in gram; x=nominal required power of the motor	

Appendix 4 – Apparent Consumption of Fans by Product Category

Unfortunately the statistical and other data available on the number of fans produced by type and country are imprecise and incomplete. However we have developed an Excel model to break down the total number of units to the different product categories. I should however be noted, the preciseness of the calculation is limited due to the high uncertainty of data. However the model allows describing transparently how the numbers have been obtained. Changes in base data can be easily incorporated and the updated number of units can be calculated automatically.

Table 74: Break down of apparent consumption to product categories

Legend: Number of Units / Share from previous category / Share of total number / Input value Number of Units / Input value share

apparent consumption	
Base Year	2005
Axial Fans (29.23.20.30)	53,190,746
Centrifugal Fans (29.23.20.50)	13,502,530
Other Fans (29.23.20.70)	37,421,183
Total Number	104,114,459

Fan Apparent Consumption in Non residental Buildings

2,712,728	Axial Fans (29.23.20.30) Base Year 2005
1,805,423	Centrifugal Fans (29.23.20.50) Base Year 2005
4,409,151	Other Fans (29.23.20.70) Base Year 2005

Axial Fans (29.23.20.30)

Category	Number of Units	Share from previous category	Share of total number
Axial Fans (29.23.20.30) Base Year 2005	53,190,746	100.0%	100.0%
Pressure > 300 Pa	10,638,149	20.0%	20.0%
Pressure < 300 Pa	23,935,836	45.0%	45.0%
Power < 125 such as PC, Printer, Cars	18,616,761	35.0%	35.0%
Industrial > 300 Pa	6,914,797	65.0%	13.0%
Industrial < 300 Pa	7,180,751	30.0%	13.5%
Transport > 300 Pa	1,063,815	10.0%	2.0%
Transport < 300 Pa	2,393,584	10.0%	4.5%
Electronics > 300 Pa	0	0.0%	0.0%
Electronics < 300 Pa	11,967,918	50.0%	22.5%
Buildings > 300 Pa	2,659,537	25.0%	5.0%
Buildings < 300 Pa	2,393,584	10.0%	4.5%
Residential Buildings > 300 Pa	664,884	25.0%	1.3%
Residential Buildings < 300 Pa	1,675,508	70.0%	3.2%
Non Residential Buildings > 300 Pa	1,994,653	75.0%	3.8%
Non Residential Buildings < 300 Pa	718,075	30.0%	1.4%

Power class	Non Residental Buildings> 300 Pa			Non Residental Buildings < 300 Pa			Non Residental Buildings			Average Power [kW]	Average Number of Operating hours [h/a]
Power 0,125<x<=0,750 kW	1,495,990	75.0%	2.8%	574,460	80.0%	1.1%	2,070,450	76.3%	3.9%	0.25	1500.00
Power 0,750<x<=1,1 kW	139,626	7.0%	0.3%	57,446	8.0%	0.1%	197,072	7.3%	0.4%	0.80	3000.00
Power 1,1<x<=7,5 kW	259,305	13.0%	0.5%	71,808	10.0%	0.1%	331,112	12.2%	0.6%	2.50	2500.00
Power > 7,5 kW	99,733	5.0%	0.2%	14,362	2.0%	0.0%	114,094	4.2%	0.2%	15.00	3500.00

Axial Fans (29.23.20.30) Base Year 2005	Anual Energy Consumption [kWh]	Anual Energy Consumption [TWh]	Share on Consumption [%]
Power 0,125<x<=0,750 kW	776,418,670	0.8	8.3%
Power 0,750<x<=1,1 kW	472,972,113	0.5	5.1%
Power 1,1<x<=7,5 kW	2,069,452,461	2.1	22.2%
Power > 7,5 kW	5,989,942,883	6.0	64.3%
Total	**9,308,786,128**	**9.3**	**100.0%**

Newly installed fans in Non residental buildings

Centrifugal Fans (29.23.20.50)

Category	Number of Units	Share from previous category	Share of total number
Centrifugal Fans (29.23.20.50) Base Year 2005	13,502,530	100.0%	100.0%
Forward curved with housing	7,426,391	55.0%	55.0%
backward curved free wheel	1,350,253	10.0%	10.0%
backward curved with scroll housing	4,725,885	35.0%	35.0%

Application	Forward curved with housing			backward curved free wheel			backward curved with scroll housing		
Industrial	2,599,237	35.0%	19.3%	472,589	35.0%	3.5%	2,599,237	55.0%	19.3%
Transport	2,227,917	30.0%	16.5%	405,076	30.0%	3.0%	1,654,060	35.0%	12.3%
Electronics	1,485,278	20.0%	11.0%	135,025	10.0%	1.0%	94,518	2.0%	0.7%
Buildings	1,113,959	15.0%	8.3%	337,563	25.0%	2.5%	378,071	8.0%	2.8%
Residential Buildings	22,279	2.0%	0.2%	0	0.0%	0.0%	1,890	0.5%	0.0%
Non Residential Buildings	1,091,680	98.0%	8.1%	337,563	100.0%	2.5%	376,180	99.5%	2.8%

Power class	Non Residental Buildings (forward curved)			Non Residental Buildings (free wheel)			Non Residental Buildings (backward curved with housing)			Non Residental Buildings			Average Power [kW]	Average Number of Operating hours [h/a]
Power 0,125<x<=0,750 kW	944,303	86.5%	7.0%	50,634	15.0%	0.4%	225,708	60.0%	1.7%	1,220,646	67.6%	9.0%	0.25	3000.00
Power 0,750<x<=1,1 kW	131,002	12.0%	1.0%	50,634	15.0%	0.4%	63,951	17.0%	0.5%	245,587	13.6%	1.8%	0.80	3000.00
Power 1,1<x<=7,5 kW	10,917	1.0%	0.1%	202,538	60.0%	1.5%	26,333	7.0%	0.2%	239,787	13.3%	1.8%	2.50	3000.00
Power > 7,5 kW	5,458	0.5%	0.0%	33,756	10.0%	0.3%	60,189	16.0%	0.4%	99,404	5.5%	0.7%	21.00	3000.00

Centrifugal Fans (29.23.20.50) Base Year 2005	Anual Energy Consumption [kWh]	Anual Energy Consumption [TWh]	Share on Consumption [%]
Power 0,125<x<=0,750 kW	915,484,171	0.9	9.6%
Power 0,750<x<=1,1 kW	589,408,105	0.6	6.2%
Power 1,1<x<=7,5 kW	1,798,405,304	1.8	18.8%
Power > 7,5 kW	6,262,426,683	6.3	65.5%
Total	**9,565,724,264**	**9.6**	**100.0%**

Newly installed fans in Non residental buildings

Other Fans (29.23.20.70)

Category	Number of Units	Share from previous category	Share of total number
Other Fans (29.23.20.70) Base Year 2005	37,421,183	100.0%	100.0%
Box Fans	3,742,118	10.0%	10.0%
Roof Fans	4,490,542	12.0%	12.0%
Cross Flow Fans	4,864,754	13.0%	13.0%
Other types below 125 W	24,323,769	65.0%	65.0%

Application	Box Fans			Roof Fans			Cross Flow Fans		
Industrial	1,309,741	35.0%	3.5%	1,122,635	25.0%	3.0%	1,216,188	25.0%	3.3%
Transport	74,842	2.0%	0.2%	0	0.0%	0.0%	1,702,664	35.0%	4.6%
Electronics	0	0.0%	0.0%	0	0.0%	0.0%	1,702,664	35.0%	4.6%
Buildings	2,357,535	63.0%	6.3%	3,367,906	75.0%	9.0%	243,238	5.0%	0.7%
Residential Buildings	825,137	35.0%	2.2%	673,581	20.0%	1.8%	60,809	25.0%	0.2%
Non Residential Buildings	1,532,397	65.0%	4.1%	2,694,325	80.0%	7.2%	182,428	75.0%	0.5%

Power class	Non Residental Buildings (Box Fans)			Non Residental Buildings (Roof Fans)			Non Residental Buildings (Cross Flow Fans)			Non Residental Buildings			Average Power [kW]	Average Number of Operating hours [h/a]
Power 0,125<x<=0,750 kW	1,302,538	85.0%	3.5%	673,581	25.0%	1.8%	136,821	75.0%	0.4%	2,112,940	47.9%	5.6%	0.25	1500.00
Power 0,750<x<=1,1 kW	199,212	13.0%	0.5%	1,374,106	51.0%	3.7%	41,959	23.0%	0.1%	1,615,276	36.6%	4.3%	0.80	3000.00
Power 1,1<x<=7,5 kW	30,648	2.0%	0.1%	619,695	23.0%	1.7%	3,649	2.0%	0.0%	653,991	14.8%	1.7%	2.50	2500.00
Power > 7,5 kW	0	0.0%	0.0%	26,943	1.0%	0.1%	0	0.0%	0.0%	26,943	0.6%	0.1%	11.00	4000.00

Other Fans (29.23.20.70) Base Year 2005	Anual Energy Consumption [kWh]	Anual Energy Consumption [TWh]	Share on Consumption [%]
Power 0,125<x<=0,750 kW	792,352,625	0.8	8.0%
Power 0,750<x<=1,1 kW	3,876,662,444	3.9	39.0%
Power 1,1<x<=7,5 kW	4,087,445,679	4.1	41.1%
Power > 7,5 kW	1,185,503,085	1.2	11.9%
Total	**9,941,963,833**	**9.9**	**100.0%**

Newly installed fans in Non residental buildings

Appendix 5 – Fan Efficiencies over Fan Size by Product Category and Impeller Size

In addition to the data presented in chapter 4.3.3 (fan efficiency over electrical power input), the efficiency data collected has also been analysed with regard to the size of the fan, i.e. impeller diameter (spigot size for category 6, box fans, and inlet diameter for category 7, roof fans). The results of this analysis can be seen in Figure 140 to Figure 147. For all EuP fan categories a similar distribution of the efficiency points depending on fan size can be observed when compared to the efficiency points over power input (Figure 51 to Figure 58).

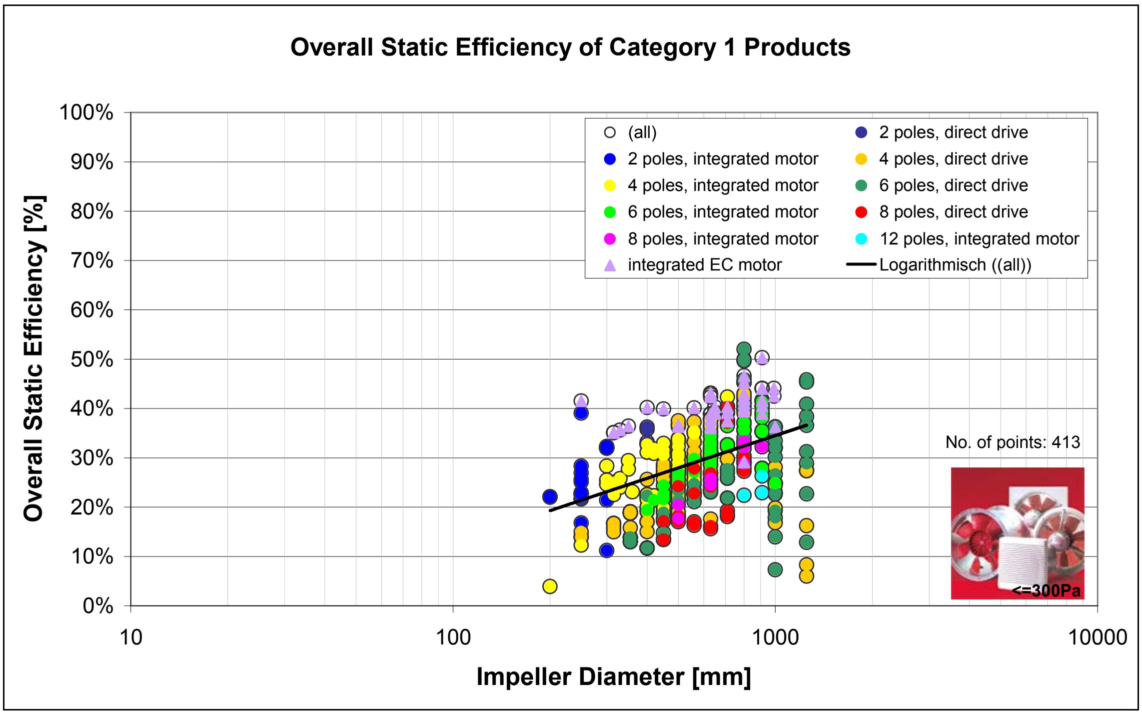


Figure 140: Overall static efficiency over fan size of existing category 1 fan products (axial fans, static pressure <= 300Pa)

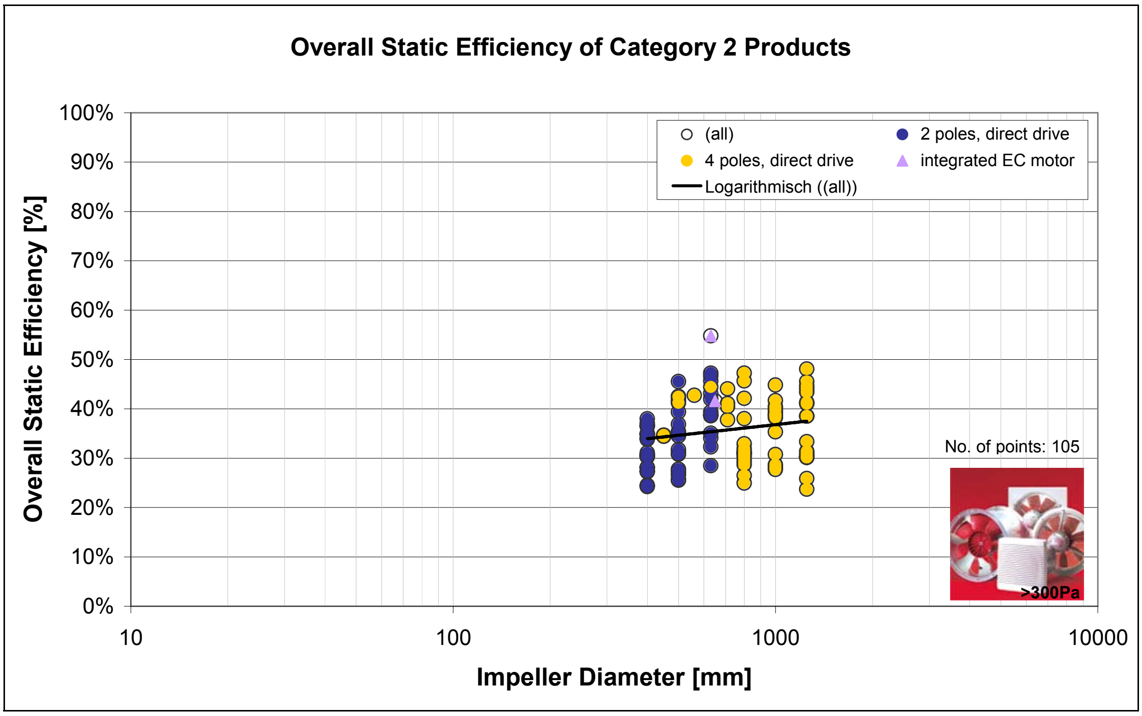


Figure 141: Overall static efficiency over fan size of existing category 2 fan products (axial fans, static pressure> 300Pa)

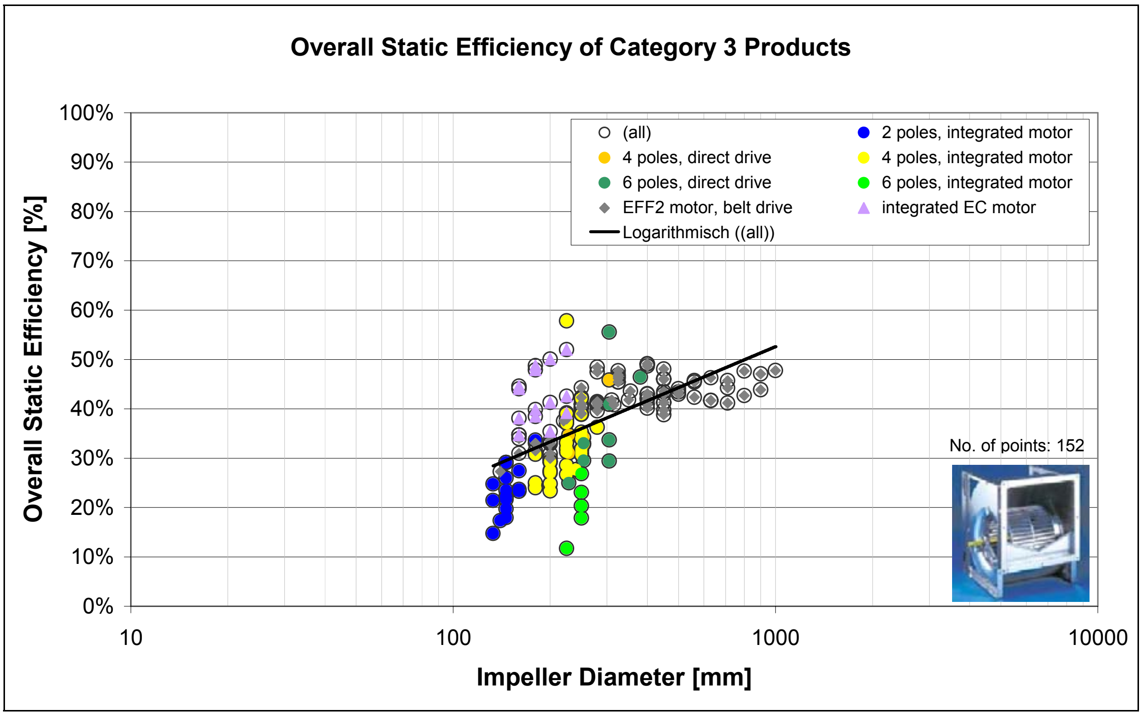


Figure 142: Overall static efficiency over fan size of existing category 3 fan products (centrifugal fans, forward curved blades, with housing)

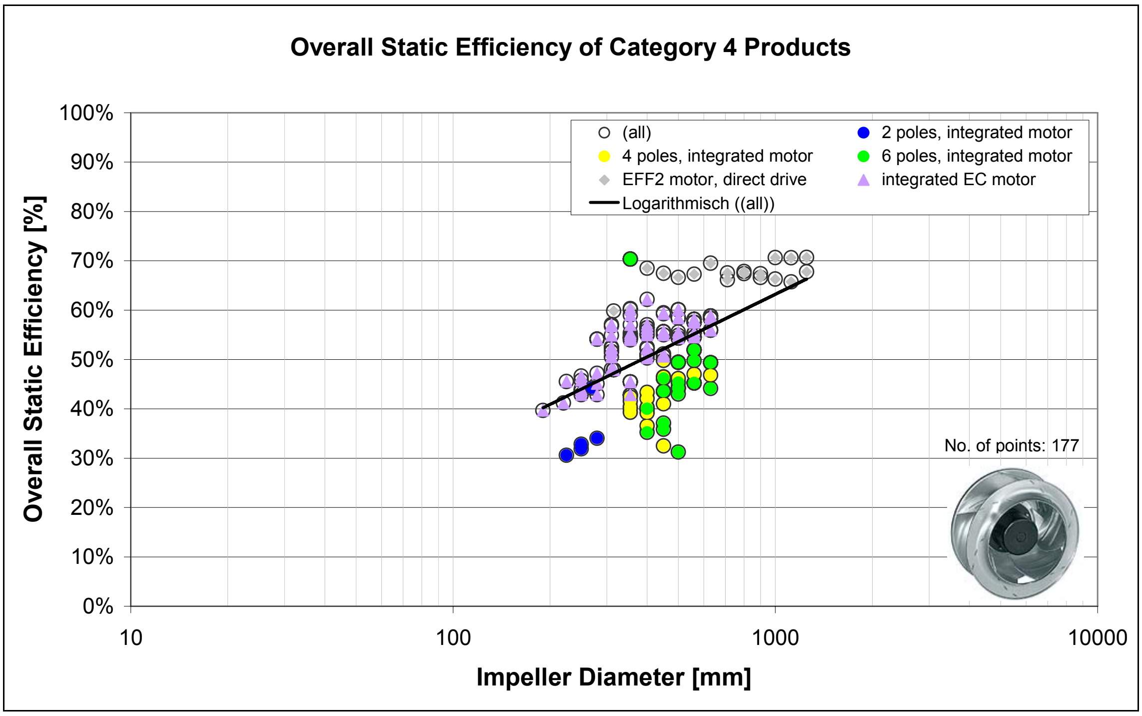


Figure 143: Overall static efficiency over fan size of existing category 4 fan products (centrifugal fans, backward curved blades, free wheel)

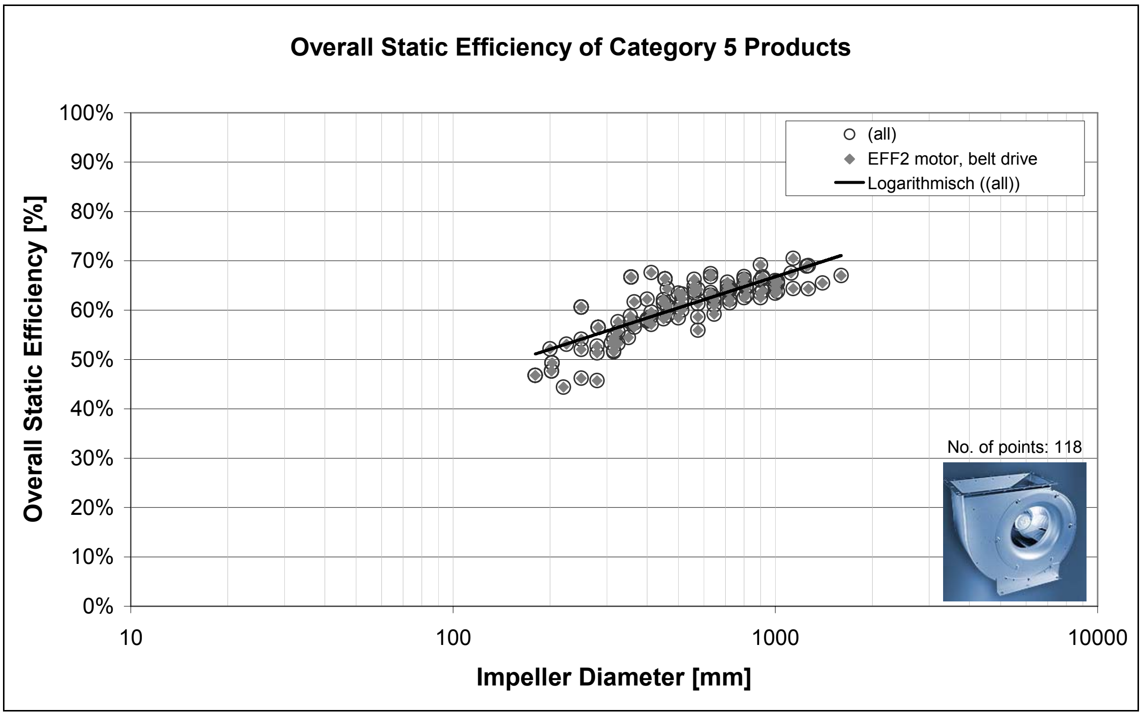


Figure 144: Overall static efficiency over fan size of existing category 5 fan products (centrifugal fans, backward curved blades, with scroll housing)

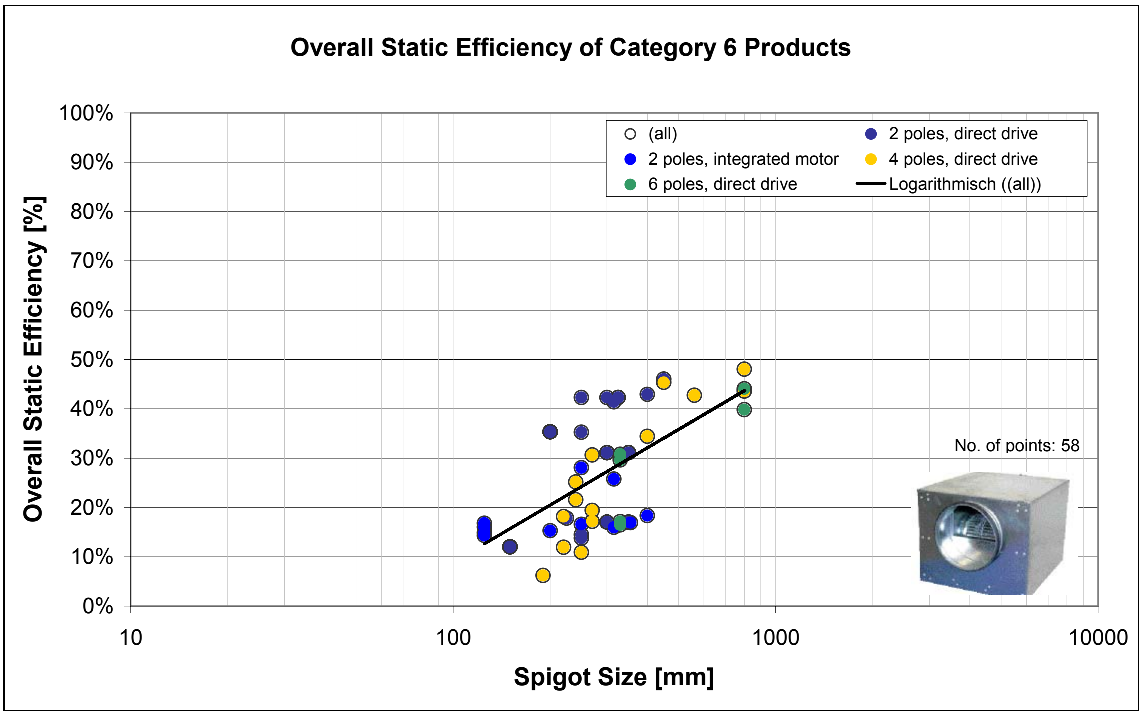


Figure 145: Overall static efficiency over fan size of existing category 6 fan products (box fans)

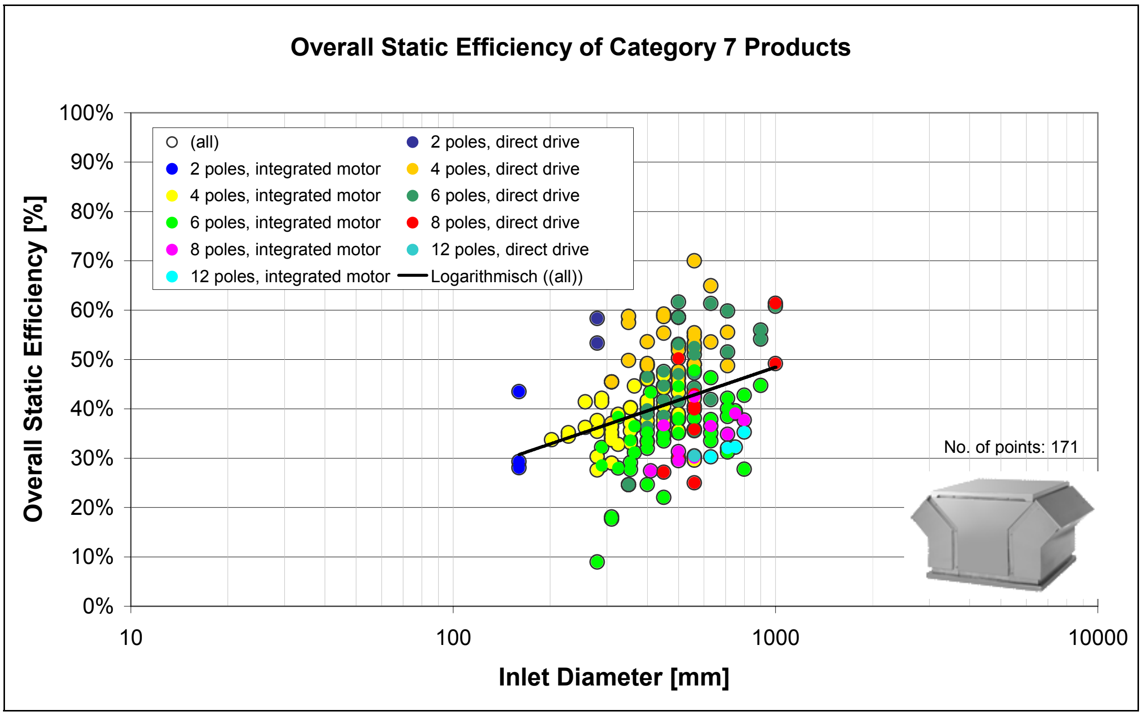


Figure 146: Overall static efficiency over fan size of existing category 7 fan products (roof fans)

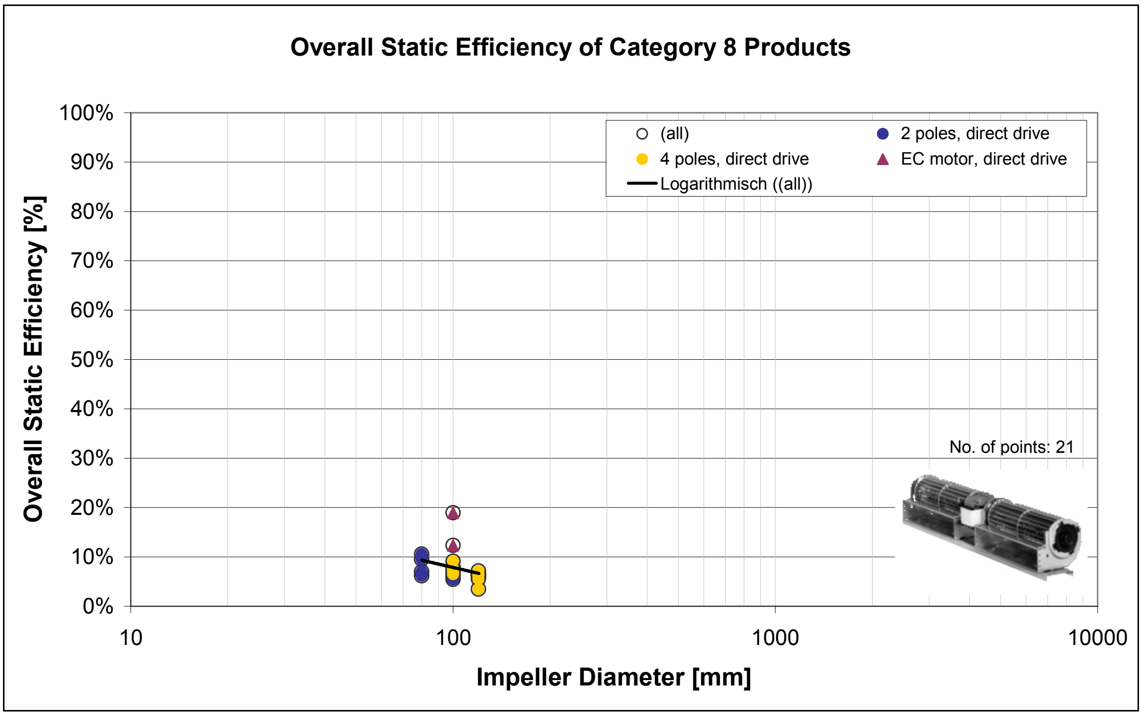


Figure 147: Overall static efficiency over fan size of existing category 8 fan products (cross-flow fans)

9 References

Almeida, A; Chretien, B.; Falkner, H., et.al., 2001: VSD for electric motor systems. Final Report to the EC. SAVE Program Final Report.

Almeida, A.; Guisse, F., Reichert, J.et.al., 2000: Improving the Penetration of Energy-Efficient Motors and Drives. Final Report to the EC. SAVE Program Final Report.

AMCA, 1990: Fans and System. Air Movement and Control Association International, Inc. (AMCA International): s. Publication 201-90.

AMCA, 2003: AMCA directory of agriculture products with certified ratings. AMCA Publication 262; 15th edition, Air Movement and Control Association, Arlington Heights, US; available online at: www.amca.org.

AMCA, 2005: Certified ratings programme – Product rating manual for fan air performance. AMCA Publication 211-05, Air Movement and Control Association, Arlington Heights, US; available online at: www.amca.org.

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), 1988: Handbook – HVAC Systems and Equipment; Principles of Heating, Ventilation and Air-Conditioning.

BMWA – Bundesministerium für Wirtschaft und Arbeit, 2005: Zahlen und Fakten – Energiedaten – Nationale und Internationale Entwicklung. BMWA, Referat IX A 2; http://www.bmwa.bund.de/Navigation/Technologie-und-Energie/Energiepolitik/energiedaten.html.

CCI, 2007a: Neue Materialien für bessere Ventilatoren CCi, Nr 7, 1 Juni

CCI, 2007b: Bionisch entwickelter Radialventilator CCi, Nr 3, 23 Februar

China, 2005：通风机能效限定值及节能评价值 (Limited values of energy efficiency and evaluating values of energy conservation for fan), GB19761—2005, Republic of China.

Cory, W.T.W., 1992: Short History of Mechanical Fans and the Measurement of their Noise. CETIM Publication „FAN NOISE Bruit des Ventilateurs“, International INCE Symposium, Senlis, France.

Cory, W.T.W., 2005: Fans & Ventilation – A Practical Guide. Elsevier, Amsterdam.

Cory, W.T.W.; 2005b: The role of the fan industry in the field of energy efficiency in motor driven systems. EEMODS Conference Proceedings, Part I, pp. 33-36, Fraunhofer IRB, Stuttgart.

De Keulenaer, H.; Belmans, R.; Blaustein, E.; Chapman, D.; De Almeida, A.; De Wachter, B.; Radgen, P., 2004: Efficient Motor Driven Systems. European Copper Institute, Brussels, Belgium

Department for Communities and Local Government, 2006: Non-domestic Heating, Cooling and Ventilation Compliance Guide, Compliance with approved Documents L2A: New Buildings other than Dwellings and L2B: Existing Buildings other than Dwellings, London.

DESTATIS – Statistisches Bundesamt 2005b: Produzierendes Gewerbe – Produktion im Produzierenden Gewerbe 2004. Fachserie 4, Reihe 3.1, Statistisches Bundesamt, Wiesbaden.

DESTATIS – Statistisches Bundesamt, 2005a: Außenhandel nach Waren und Ländern Dezember und Jahr 2004 (CD-ROM). Statistisches Bundesamt, Wiesbaden.

DLG, n.d.: Vermeidung von Wärmebelastung für Milchkühe. DLG Merkblatt 336. DLG, Frankfurt.

EnEv, 2006: Referentenentwurf zur Novellierung der Energieeinsparverordnung vom 7. April 2006, §15 Anlagen der Kühl- und Raumlufttechnik, BMBau, BMWi, Berlin, 2006.

Energy Star, 2006a: Energy Star Program Requirements for Residential Ceiling Fans. Version 2.1, www.energystar.gov/index.cfm?c=ceiling_fans.pr_ceiling_fans; visited September 2006.

Energy Star, 2006b: Energy Star Program Requirements for Residential Ventilating Fans 2.0. www.energystar.gov/index.cfm?c=vent_fans.pr_vent_fans. Visited September 2006.

EU, 1998: Directive 98/37/EC of the European Parliament and of the Council of 22 June 1998 on the approximation of the laws of the Member States relating to machinery, published in the Official Journal of the European Communities on July 23 1998.

EU, 2001: Directive 2001/95/EC of the European Parliament and of the Council of 3 December 2001 on general product safety, published in the Official Journal of the European Communities on February 15 2002.

EU, 2002: EU Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings, published in the Official Journal of the European Communities on January 4 2003.

EU, 2003a: Directive 2002/96/EC of the European Parliament and the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE), published in the Official Journal of the European Communities on February 13 2003.

EU, 2003b: Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, published in the Official Journal of the European Communities on February 13 2003.

EU, 2006: Directive 2006/95/EC of the European Parliament and of the Council of 12 December 2006 on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits, published in the Official Journal of the European Communities on December 12 2006.

European Commission, 2002: Frequently Asked Questions on Directive 2002/95/EC on the Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE), http://ec.europa.eu/environment/waste/pdf/faq_weee.pdf.

European Commission, 2005: Directive 2005/32/EC of the European Parliament and the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for Energy-Using Products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council, Brussels.

Eurostat – Statistical Office of the European Communities, 2003: Europroms PRODCOM Data, Eurostat Data Shop Handbook Part 6.4.2 Europroms. http://fd.comext.eurostat.cec.eu.int/xtweb/setuplistmeta.do.

Eurostat – Statistical Office of the European Communities, 2006: EU Trade since 1995 by SITC. http://fd.comext.eurostat.cec.eu.int/xtweb/mainxtnet.do.

Eurostat – Statistical Office of the European Communities, 2006b: PRODCOM ANNUAL. http://fd.comext.eurostat.cec.eu.int/xtweb/mainxtnet.do.

Eurovent, 2005: Review, Eurovent CECOMAF, No.86, June, Paris

Eurovent, 2006: Review, Eurovent CECOMAF, No.75, May, Paris.

Falkner, H., Reeves, D., 2001: Study on improving the energy efficiency of pumps. ETSU, AEAT PLC, (United Kingdom). SAVE Study

FläktWoods, 2003: Centrimaster GX Technical Data, FIFLO 4437 GB 03.02, http://www.flaktwoods.com/c5d0f9d8-989f-41e6-907d-6b95e9d93e98 (31.08.2007).

Franke, G., 2005: Entwicklungstendenzen in der Stallklimatechnik, EURO-Tier 2005, Landesbetrieb Landwirtschaft Hessen (LLH), Kassel, http://www.llh-hessen.de/landwirtschaft/bw_vtec/vtec/s06_8_franke_landbau_2_04.pdf.

Heidenreich, T.; n.d.: Stallklimatisierung für steigende Leistungen. Sächsische Landesanstalt für Landwirtschaft, Freistaat Sachsen.

HLH, 2007: Lüftungstechnik – Unsere Verbündeten sind die Planer HLH, Nr 2, S18-22

Hogeling, J., 2006: The set of CEN standards developed to support the implementation of the EPBD in the EU Member States, EPBD Buildings Platform, Newsletter No. 001, May 2006, European Commission, Brussels, http://www.buildingsplatform.org/cms/index.php?id=41.

Hönmann, W.; Recknagel, H.; Sprenger, E. (Eds), 1990: Taschenbuch für Heizung und Klimatechnik, einschließlich Brauchwassererwärmung und Kältetechnik; Oldenbourg; München, Wien.

Hydor, 2006: Heating and Ventilation for Pigs. www.hydor.co.uk

IPTS/ESTO – Institute for Prospective Technological Studies/ European Science Technology Observatory, 2006: Environmental Impact of Products (EIPRO), Analysis of the life cycle environmental impacts related to the final consumption of the EU-25, European Commission, Joint Research Centre (DG JRC), http://ec.europa.eu/environment/ipp/pdf/eipro_report.pdf.

ISO/CEN, 2001: ISO Council resolution 35/2001 and CEN Administrative Board resolution 2/2001, confirmation of agreement on technical co-operation between ISO and CEN, approved by ISO Council resolution 18/1990 and CEN General Assembly resolution 3/1990 (Vienna Agreement).

ISO/DIS 5801, 2005: Performance testing using standardized airways, Revision of first edition (ISO 5801:1997), Secretariat of ISO/TC 117 – Industrial Fans.

Lelkes, A., 2005: Energy Efficiency Improvement in Brushless Fan Drives, EEMODS (Energy Efficiency in Motor Driven Systems) Conference 2005.

LGA – Landesgewerbeamt Baden-Württemberg, 2002: Energieeffiziente Lüftungsanlagen in Betrieben.

Mekikdjan, C., Sévila, F., 1990: Optimal static ventilation in greenhouses, Acta Hort. (ISHS) 263:335-342, http://www.actahort.org/books/263/263_34.htm.

Nipkow, Jürg, 2007: Enorme Effizienzpotentiale bei Kleinmotoren Motor Summit, Zürich, Schweiz

Office for National Statistics (UK), *different years*:
2005: Product Sales and Trade PRA 29230 – Non-Domestic Cooling & Ventilation Equipment 2004.
2004: Product Sales and Trade PRA 29230 – Non-Domestic Cooling & Ventilation Equipment 2003.
2003: Product Sales and Trade PRA 29230 – Non-Domestic Cooling & Ventilation Equipment 2002.
2002: Product Sales and Trade PRA 29230 – Non-Domestic Cooling & Ventilation Equipment 2001.
2001b: Product Sales and Trade PRA 29230 – Non-Domestic Cooling & Ventilation Equipment 2000.
2001a: Product Sales and Trade PRA 51 – Non-Domestic Cooling & Ventilation Equipment 1999.
1999: Product Sales and Trade PRA 51 – Non-Domestic Cooling & Ventilation Equipment 1998.
1998: Product Sales and Trade PRA 51 – Non-Domestic Cooling & Ventilation Equipment 1996.

Radgen, P. (Ed.), 2002: Market Study for Improving Energy Efficiency for Fans. Fraunhofer IRB, Stuttgart.

Radgen, P.; Baustein, E., 2001: Compressed Air System in the European Union. Energy, Emssions, Savings Potential and Policy Actions. LOG_X Publishing, Stuttgart, Germany.

Recknagel, Sprenger; 2005: Taschenbuch für Heizung und Lüftungstechnik. 72 Edition, Oldenburg Publishing, Oldenburg.

REHVA – Federation of European Heating and air-conditioning associations, 2004: Matrix of existing, national Guidelines in REHVA. 3. Draft September 2004.

Riviere, P. et.al., 2007: Preparatory study on the environmental performance of residential room conditioning appliances (airco and ventilation), Draft study on residential ventilation, Situation on September 10 2007.

Sanford, S., 2004: Ventilation and Cooling Systems for Animal Housing. Paper A3784-6, University of Wisconsin, http://s142412519.onlinehome.us/uw/pdfs/A3784-6.PDF.

VDI 6014 Entwurf, 2006: Energieeinsparung durch Einsatz drehzahlsteuerbarer Antriebe in der Technischen Gebäudeausrüstung. VDI Richtlinie, Entwurf, VDI Gesellschaft Technische Gebäudeausrüstung, Düsseldorf, 2006

VDMA – Verband Deutscher Maschinen- und Anlagenbau e.V., 2003: Statistisches Handbuch für den Maschinenbau, Ed. 2003.

VDMA – Verband Deutscher Maschinen- und Anlagenbau e.V., 2004: Statistisches Handbuch für den Maschinenbau, Ed. 2004.

VHK – Van Holsteijn en Kemna BV, 2005: Methodology Study Eco-design of Energy-using Products (MEEUP), final report, Delft, http://www.vhknet.com/download/MEEUP_Methodology_fin.pdf.

Wilcke, W. F., Morey, R. V., 1999: Selecting Fans and Determining Airflow for Crop Drying, Cooling, and Storage, College of Agricultural, Food, and Environmental Sciences, Biosystems and Agricultural Engineering Department, University of Minnesota, http://www.extension.umn.edu/distribution/cropsystems/DC5716.html

Wouters, P.; van Orshoven, D.; Loncour, X., 2006: HVAC and The Energy Performance of Buildings Directive: Challenges and Opportunities. In: REHVA Journal March 2006 1st Quarter, S. 12-18.

ZVEI, 2006: Energiesparen mit elektrischen Antrieben. ZVEI, Frankfurt.