

Improving Energy Efficiency - Potential of Power Electronics

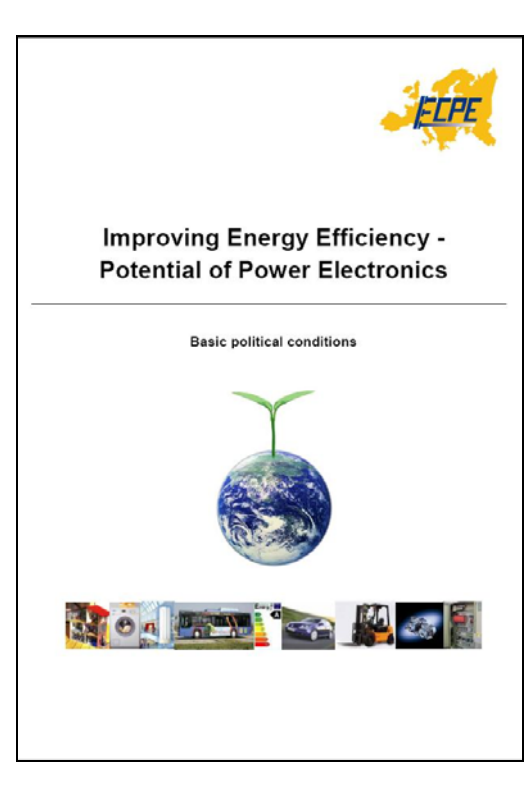
(Summary)

Basic political conditions



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Excerpt of the full-length-study:

 <p>The cover of the study 'Improving Energy Efficiency - Potential of Power Electronics' features the ELPE logo in the top right corner. The title is centered in bold black text. Below the title, the subtitle 'Basic political conditions' is centered. The main visual is a globe with a green sprout growing from the top, symbolizing environmental growth. At the bottom, there is a row of small icons representing various energy-related technologies and applications, including a washing machine, a car, a house, a factory, and a power plug.</p>	<p>The study presents examples for employing power electronics to improve energy efficiency for various typical application fields:</p> <p>electric drives, transport, lighting, domestic appliances, consumer electronics, building services, information and communication technology devices, standby.</p> <p>Besides technical descriptions the study provides data of specific energy consumption and saving potential assessments.</p> <p>In addition market strategic measures or basic political conditions to enforce application of energy efficient technologies are carried out : information, consulting and qualifying, financial aid, competitions/prizes, pioneer role of public authorities, research and development, model and demonstration facilities, benchmark indices, product markings, imperatives/bans, voluntary commitments, and energy services, energy pricing,. This is followed by a section where relevant ongoing political initiatives of the European Union as well as specifically in Germany are presented.</p>
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Summary

1 Introduction Purpose, Definition, Motivation

The **Member States** of the **European Union** are obliged to **reduce** their energy consumption by 20 to 40 percent compared to the reference year 1990 in order to safeguard non-renewable resources for future generations, to limit climatic change, to obviate political dependencies through import of fossil fuels and also to stabilise energy costs. During the past years, the European Union has laid a corresponding **legal foundation** for this reduction with appropriate resolutions and directives. The “Energy Efficiency Green Paper”, the EU Directives concerning “Energy End-use Efficiency and Energy Services” and “Ecodesign Requirements for Energy-using Products”, and not least, the EU “Action Plan for Energy Efficiency” of 19-10-2006 may be mentioned at this point.

A significant part of **primary energy consumption** is allocated to generation, distributing, and applying electric energy. In 2004 **consumption of electric energy in EU-countries** (EU-15) reached 2.403.600GWh. Electric motors in industrial applications (drives powering mechanical processes) are the most important consumers of electric energy. Second is heating for chemical or physical processes (welding, soldering, heating, radiation, induction heaters). Third is lighting, especially for crafts, distribution and commerce (included is lighting of public streets).

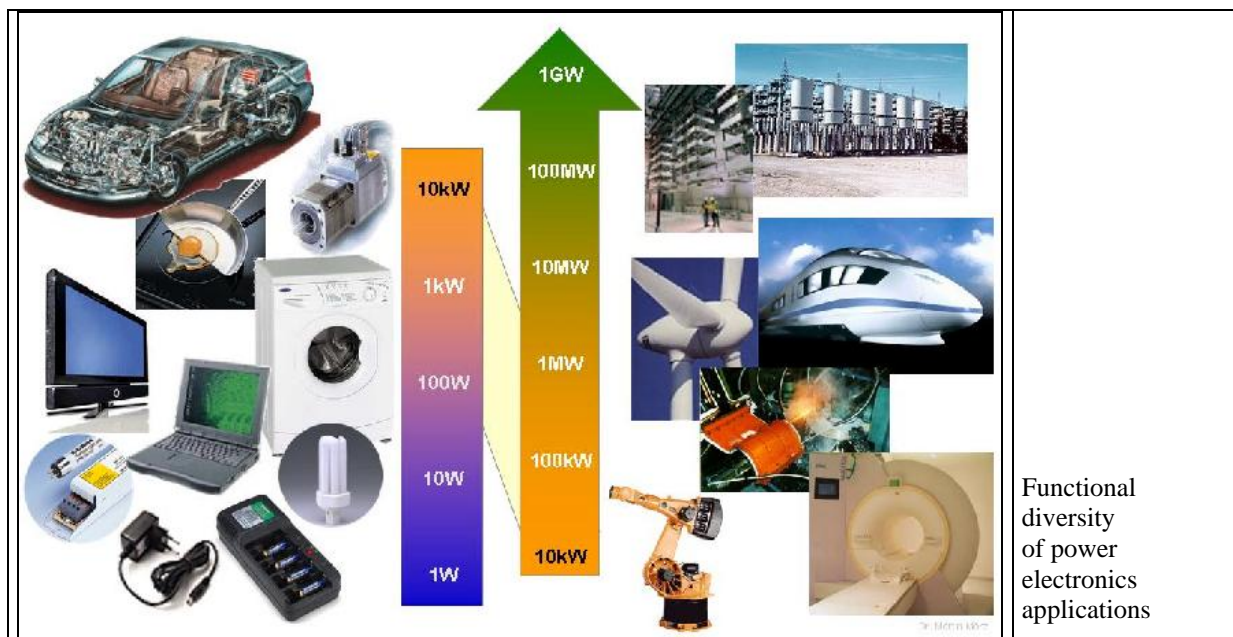
	Room Heating	Warm Water	Other Process Heating	Total Heating	Mechan. Energy	Lighting	Total Electric Energy
Industry	3.763	3.763	256.982	264.607	672.807	52.882	990.296
Tertiary	52.584	80.971	84.959	218.581	327.804	129.500	675.885
Domestic	117.735	109.904	125.566	353.273	266.862	54.952	675.087
Transport	3.118	0	0	3.118	56.130	3.118	62.367
Total	177.201	194.638	467.507	839.580	1.323.603	240.452	2.403.635

Electric energy consumption in EU countries (EU-15) in 2004 for sectors and kind of use

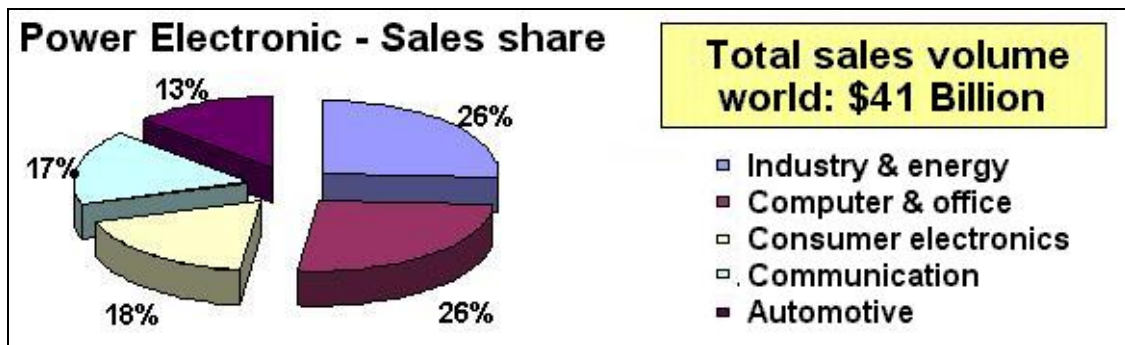
In this context, it is not only important to reduce **electric power consumption** or electric work, the product of power input and period of use. A systematic analyses shows that optimising time-dependent **load profiles** by avoiding, reducing, or deferring **peak loads** also reduces the energy offering that has to be provided to ensure a reliable supply and thereby can tap further efficiency gains in generation and distribution.

Our estimates show there is great **potential for efficiency gains**. Consumption of electric energy could be reduced up to 30 % with modern technology. That means savings up to 660.000GWh for the European Union (EU-15). Approximately 50% of this savings (327.000GWh) will be achieved with the application of **power electronics**.

In its broadest sense, the term **power electronics** stands for “controlling and converting of electric power”. Their function is to convert electric energy as efficiently as possible into a form the most divergent applications and users might require or to control the flow of power accordingly. Thus, power electronics are a typical interdisciplinary technology used in a virtually endless multitude of **applications**, e.g., in cars, computers, communications, industrial production processes, domestic appliances, consumer electronics, office equipment, medical engineering, energy technology, as well as transport and traffic engineering.



The high **significance of power electronics** is also mirrored by economic figures. With a global market volume of 41 billion dollars (2003) and an average growth rate of 7% p. a., power electronics are one of the most dynamic industries of our day.



Revenue shares of power electronics buyer markets

It should be noted that **measures aimed at improving energy efficiency of electric loads (saving electricity)** offer the **highest economical efficiency** (shortest payback periods) when comparing climate protection measures, i.e. the lowest specific costs (outlay in Euros per avoided ton of CO₂).

2 Electric Motor Systems

According to our estimate, some 1,335,460GWh are spent annually for mechanical energy in the European Union (EU-15 – 2004), amounting to approx. 56% of the total electric energy consumption. The industry accounts for 672,807GWh (50%) or the main part of this usage. The crafts, commerce, and services sector (air conditioning, lifts, escalators,) follows with 334,163GWh (25%) and after that, private households (domestic appliances) with 261,679GWh (20%). For transport (e.g., electrically powered trains), the directly attributed fraction of electrical energy consumption is around 56,130GWh (4%).

The following Synopsis shows typical applications for electric drives by sector:

Industry	Crafts, trade and services	Private households	Transport
Supplies, air conditioning	Heating and air conditioning equipment	Domestic appliances	Electrically driven trains
Ventilation equipment	Air conditioning	Cooling appliances	Long-distance railways
Air conditioning equipment	Heating circulation pumps	Deep-freeze appliances	Light rail transport
Compressors/compressed air	Cooling equipment	Washing machines	
Heating circulation pumps		Dishwashers	Electric vehicles
Water pumps		Vacuum cleaners	Electric cars
Manufacturing equipment	Conveying equipment	Mixers	Fork-lifts
Machine tools	Lifts		Hybrid vehicles
Assembly equipment	Escalators		Electric bicycles, scooters
Process engineering	Belt conveyors	Heating systems	
Pumps, compressors		Heating circulation pumps	Conveying equipment
Mechanical macerators		Burner blowers	Lifting gear, cranes
Stirring units, centrifuges		Ventilation fans	Belt conveyors
Conveying equipment			Warehouse logistics gear
Belt conveyors			
Lifting gear, cranes			

Typical applications for electric drives by sector

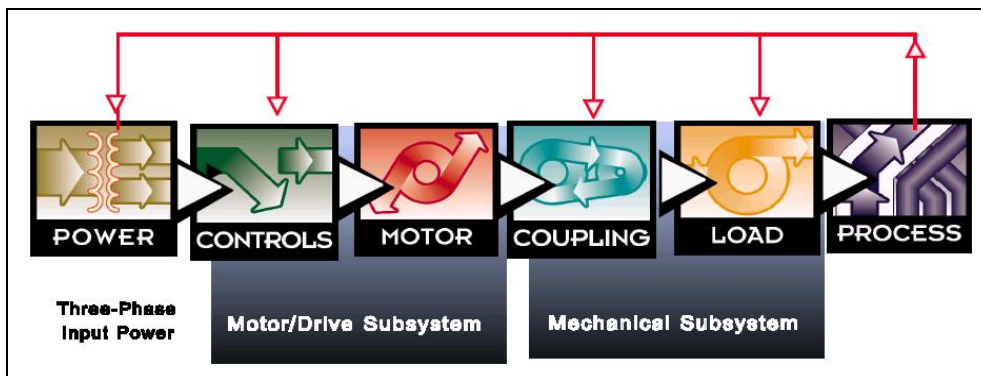
The energy consumption by electric drives in the industrial and tertiary sectors is mainly centred around pumps (20%), fans (18%), compressors for compressed air equipment (17%), compressors for refrigerating equipment (11%), and conveyors (4%).

Feasible technical measures for improving energy efficiency

In the following sections, basically possible as well as feasible approaches for improving energy efficiency of drives are detailed while specially accounting for the employment of power electronics. The complete system, its elements, and their interrelationships should be considered in this context. Only this way, potentials for energy efficiency improvement can be reaped to a larger extent.

The typical drive system elements include:

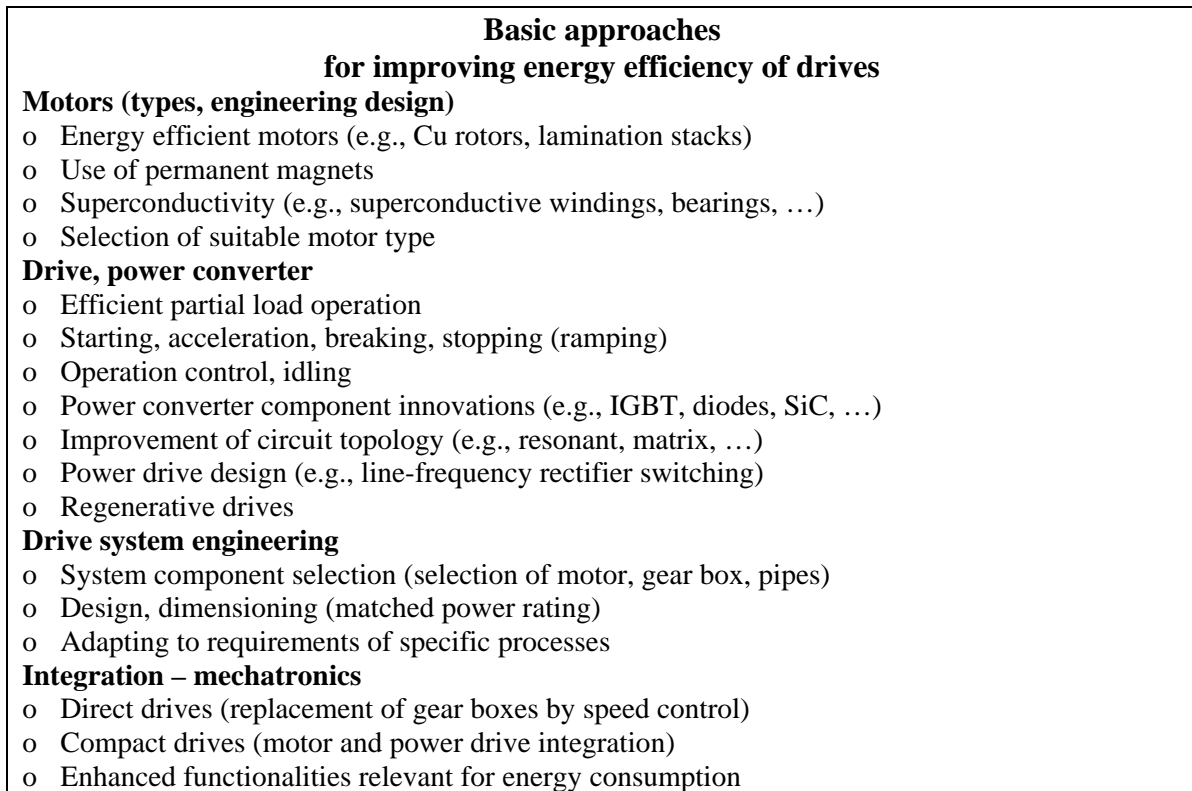
- o Power supply
- o Power converter
- o Motor
- o Gear box (speed reduction, coupling)
- o The process (pumping, compressing, lifting loads, machining materials, driving vehicles)



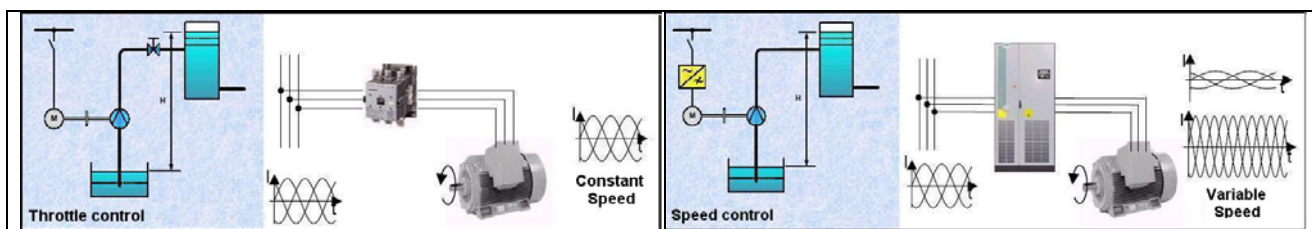
Elements of a drive system

Basic approaches for improving energy efficiency

The following synopsis details basic approaches for improving the energy efficiency of drives:



In a large part of their application areas, electric drives are only operated under partial load. In the past, controls were used for this purpose that reduced the power delivered to the process with throttles or swirl flaps while the motor output remained constant. The alternative is to control the motor output using power electronics. According to estimates, 40% of the electric energy supplied to drives in 2000 was provided via **power electronics**; in 2015, more than 80% are intended to be supplied to drives using power electronics



Assuming an annual energy consumption of 1,335,460GWh for mechanical drives in the **European Union (EU-15)** we would estimate the **technological potential** to be in the region of approx. **200 - 400,000GWh (15 – 30%)** including 10% for power electronics and 4% for energy saving motors, and the **economic potential** to be in the region of **135 to 270GWh (10 – 20%)**, including 6% for power electronics and 4% for energy saving motors.

Power converter component innovations

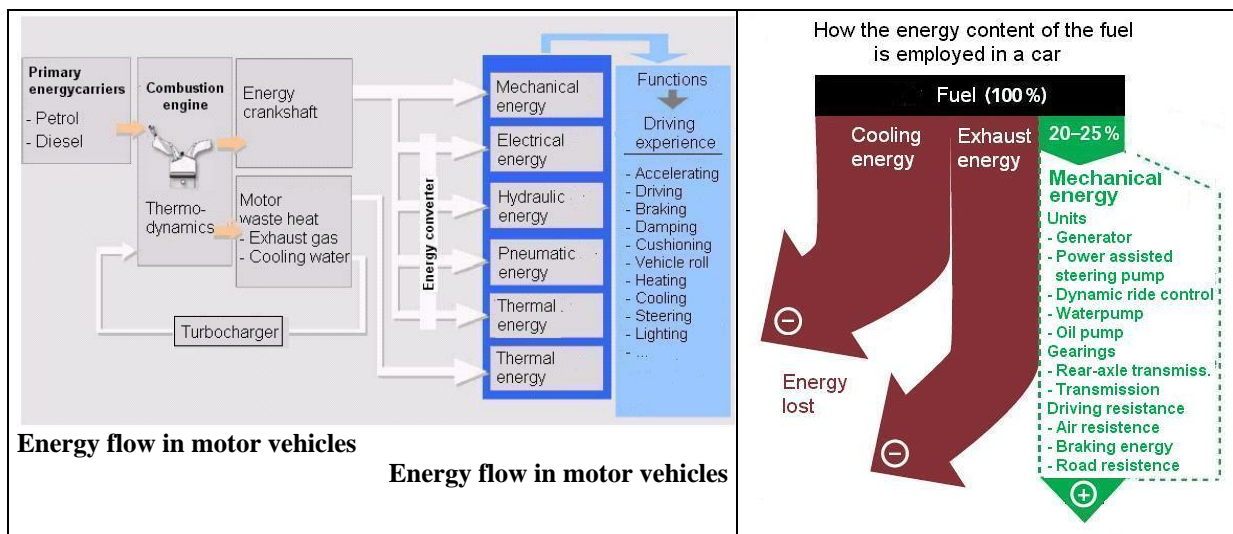
It is possible to improve the energy efficiency of drives by optimising the power converters themselves. By now, the efficiencies of power converters have reached values around 96%.

3 Transport

According to our estimate, some 62,367GWh are spent annually for transport in the **European Union (EU-15 – 2004)**, amounting to approx. 2% of the **electric energy** consumption. This energy consumption can be attributed mainly to the operation of electrically driven trains. Complementing the explicit electric energy consumption quoted here, **fuel consumption** for electric power should be added that is provided by electric generators driven by combustion engines in vehicles in road traffic in particular and that is used for electric loads in those vehicles. According to our estimate, some 26.2m toe or approx. 37,000GWh should be specified here, assuming an expenditure of 261m toe (EU-15).

Feasible technical measures for improving energy efficiency

Only 20 – 30% of the energy contained in fuel is utilised for traction.



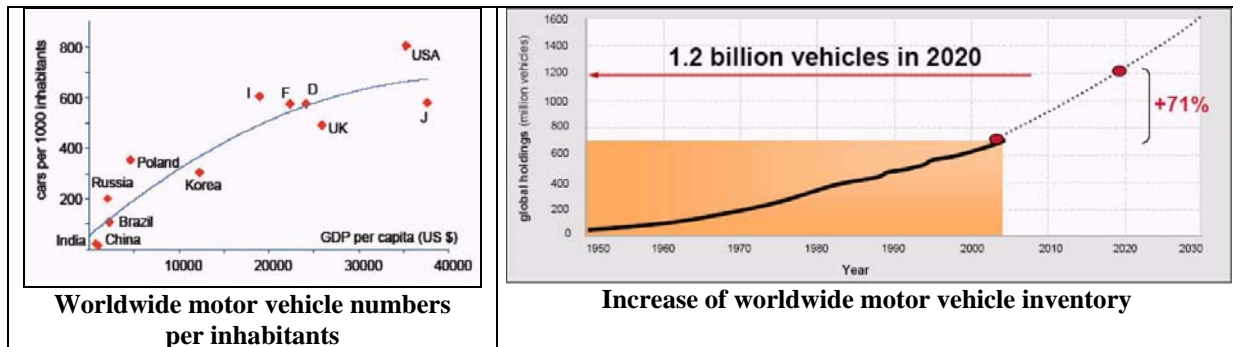
In conjunction with employing power electronics, the following basic approaches for improving energy efficiency in the transport area (vehicles) exist:

Basic approaches for improving energy efficiency

- o Improving energy efficiency by combining motors of differing kinds (hybrid power train: combination of combustion engine and electric motor)
- o Improving energy efficiency of the main propulsion by using direct drives (without gearing)
- o Recovery of energy when breaking or on downhill stretches
- o Improving the efficiency of the alternator (specifically, the partial load efficiency)
- o Reducing the power requirements of auxiliaries, particularly by replacing mechanical drives by electric motors
- o Energetically optimised use of main and auxiliary units (energy management)

Motor Vehicles

At present, some **750 million motor vehicles** exist **worldwide** (2006). For 2001, an inventory of some **521m passenger cars** and **210m commercial vehicles** is specified. The **global automobile production** is stated as 42.2m passenger cars and 18.8m commercial vehicles (2004). An increase of 71% to 1.23 billion vehicles is expected by the year 2020.



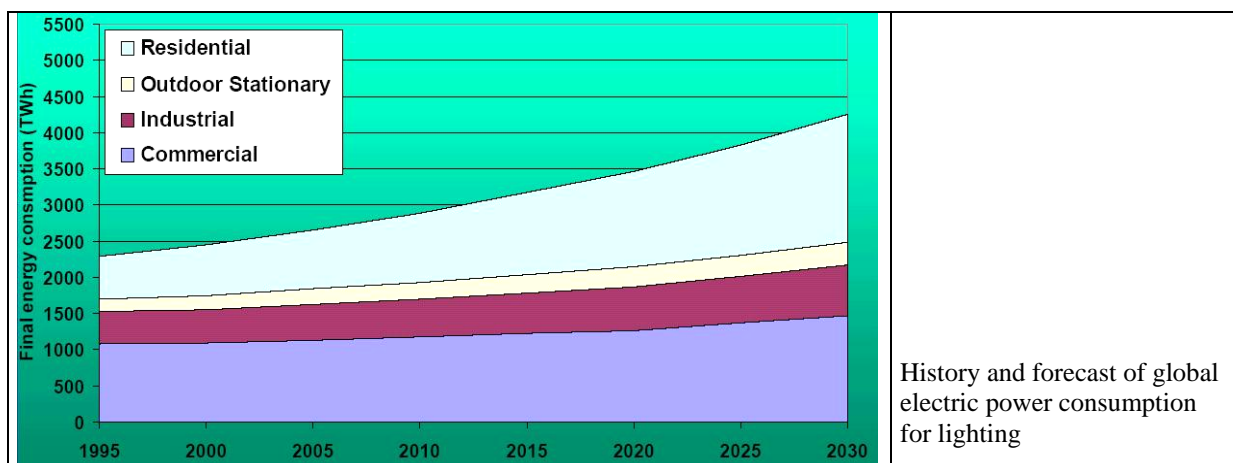
There were some 216m motor vehicles in the European Union member states (EU-15) as of 2003. Every year, around 16m vehicles are newly registered.

Saving potential estimates for the European Union

We would determine the **technical saving potential** of the **electrical energy consumption** in the European Union (EU-15) to be in the range of **21,000 GWh (20%)**, assuming an energy consumption of 105,000GWh where the area of electrically driven trains account for 62,367GWh and the area of the electric energy consumption of motor vehicles in road traffic for 44,500GWh. A saving potential of 78.3m (30%) toe results for the **fuel consumption** of road traffic in the **European Union (EU-15)**, assuming an energy consumption of 261m toe (2004).

4 Lighting

The International Energy Agency estimates the **global electric energy demand for lighting** at 2,550,000 GWh, that is, 19% of the electric power used globally. During the past years, the energy consumption used for lighting has been growing by some 2.4% annually (1.8% for OECD and 3.6% for non-OECD countries). It is expected that without energy efficiency measures, the energy demand for lighting will grow by approx. 1.9% per annum, primarily in private households and in the tertiary sector.



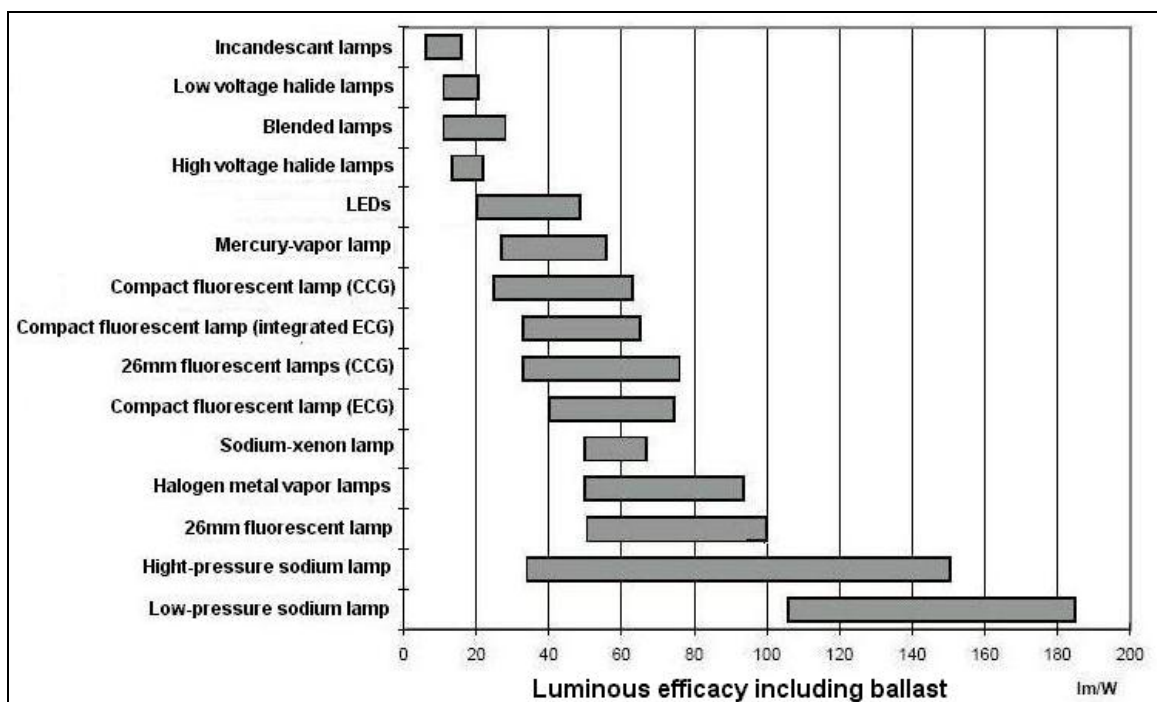
According to our estimate, some 236,000GWh are spent annually for lighting in the **European Union** (2004), amounting to approx. 10% of the total electric energy consumption. With a consumption of 132,012GWh (56%), **the crafts, trade, and services sector** accounts for the main part, with street lighting also taking a significant part. This is followed by **private households** and the **industry**, consuming approximately identical amounts of 53,885GWh (23%) and 52,882 GWh (22%), respectively.

Basic approaches for improving energy efficiency in the lighting area:

- o Demand driven layout (per application area / field of activity)
- o Adjusting illumination to current need (use of sensor technology), turning lighting on and off, lowering illumination level according to need
- o Energy efficient illuminants and ballasts
- o Daylight utilisation
- o Monitoring state of lighting equipment (deterioration, losses)
- o Light management in the course of energy management
- o Behavioural changes

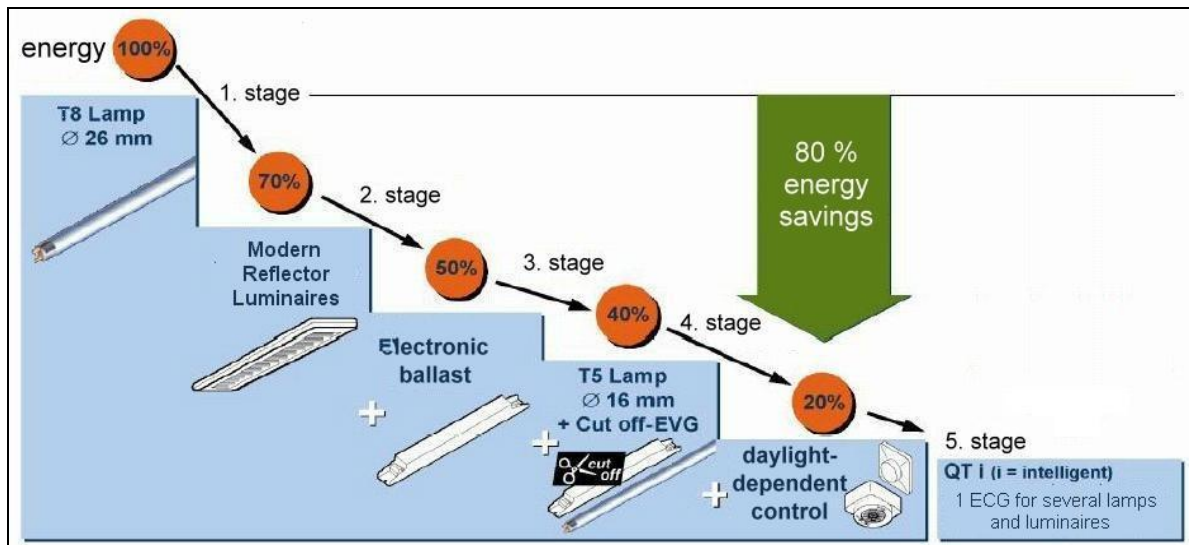
Measure: Employing energy-efficient illuminants

Choosing suitable illuminants is an essential approach for improving energy efficiency. Here, the range extends from traditional incandescent lamps with 10 lm/W via compact fluorescent tubes with more than 60 lm/W to sodium vapour lamps with over 150 lm/W.



Energy Efficiency Potential Assessment

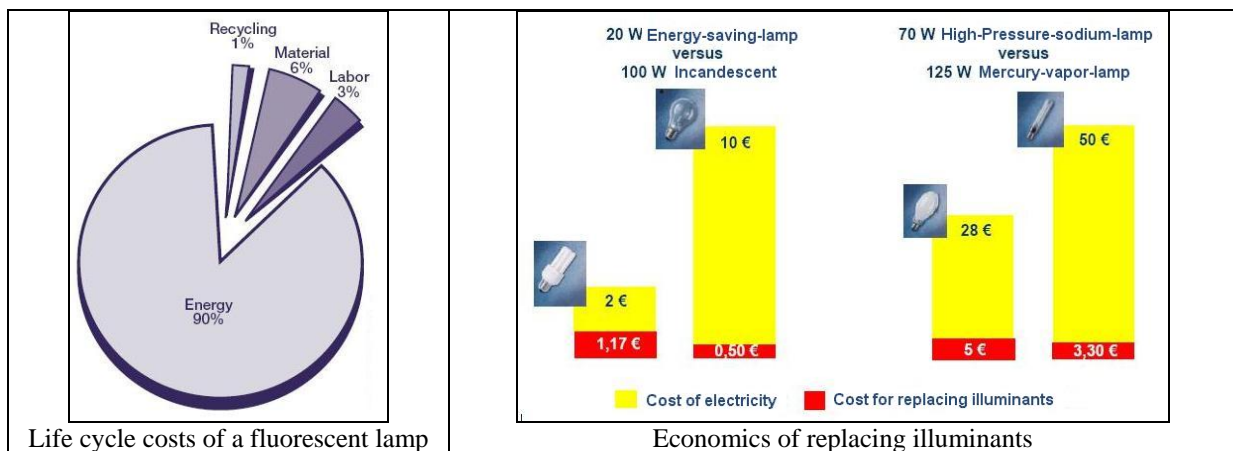
According to estimates of the ZVEI, 75% of the existing lighting systems are inefficient. In a synopsis, the illustration below once again depicts the efficiency improvement potentials of various technologies.



Efficiency potentials of lighting systems

The studies available to us disclose an **economic saving potential** ranging from 24 to 53% and a **technological saving potential** of up to 80%.

It is important to stress the fact that the **measures**, such as employing energy efficient illuminants, **in large part are already now cost-effective**.



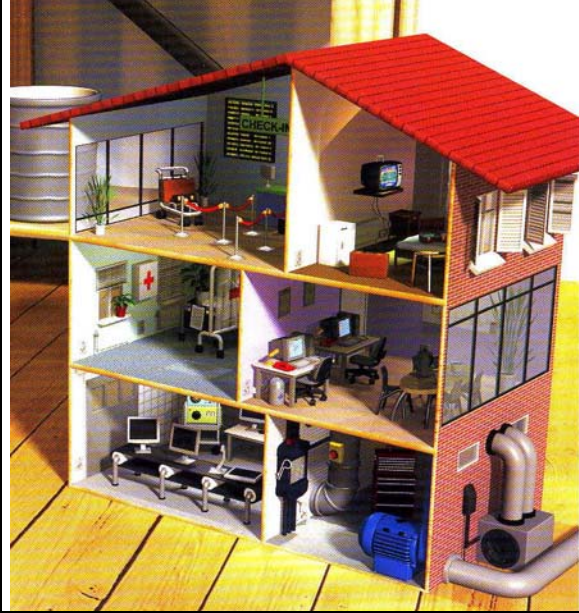
Assuming an energy consumption of 236,000 GWh for lighting in the EU (EU-15), we would estimate the **technological potential** in the range of **141,600GWh (60%)** and the **economical potential** in the range of **70,800GWh (30%)**.

5 Domestic Appliances and Building Services

There are approx. 154 million private households in the Member States of the **European Union** (EU-15) with a total of 387 million persons in 169 million dwellings. Each dwelling accommodates 2.4 persons on average (2.1 – 3.0). Household effects account for a mean expenditure in the range of 1003 Euro per annum (645 – 2114).

The **mean electric energy consumption of private households in the European Union** is in the region of 4354kWh per annum, with mean values of the various European countries lying in the range of 2976kWh/a (Italy) to 9056kWh/a (Finland).

The **total consumption of electric energy by private households of the European Union (EU-15)** is around 663,018 GWh (2004). According to our estimate, 115,449GWh of this was put to use for **space heating** (electric heating, heat pumps) in 2004, 107,770GWh for **hot water** (electric boilers), 123,128GWh for other **process heat** (electric ranges, microwave ovens, washing machines, dishwashers), 261,679GWh for **mechanical energy** (electric drives in washing machines, dishwashers, circulation pumps, exhaust hoods, air conditioning, etc.), and 53,885GWh for **lighting**.

	Average electric energy consumption of private households in Germany	
	<ul style="list-style-type: none"> Refrigerating and freezing Small appliances Hot water supply Electric range Lighting Washing and cooking TV, video, hi-fi, PC Electric space-heaters Dishwasher Other 	<ul style="list-style-type: none"> 21.5% 19.8% 14.1% 9.1% 8.8% 7.2% 6.5% 4.2% 2.7% 6.0%

Feasible Technical Measures for Improving Energy Efficiency

Basic approaches for improving energy efficiency

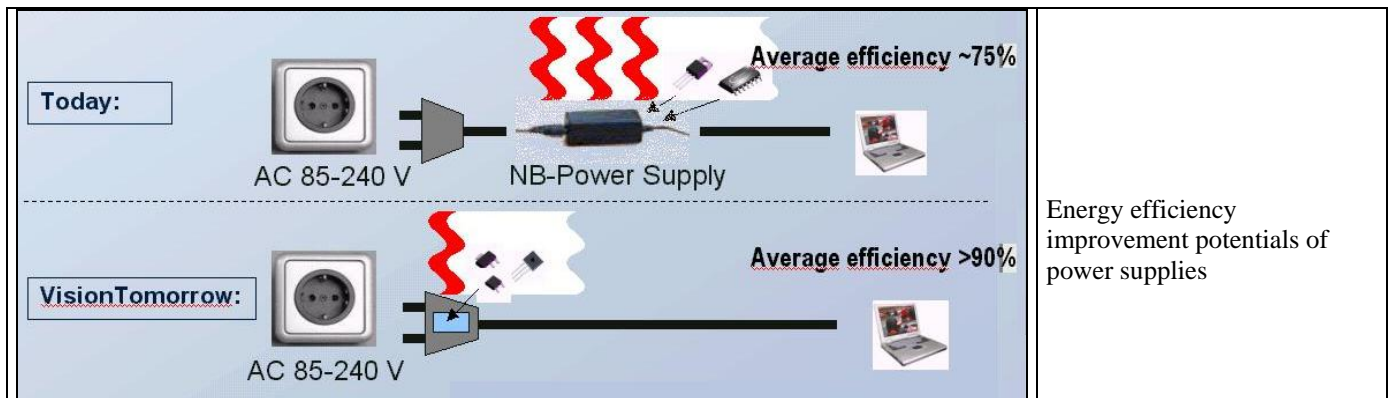
- o Employing energy efficient motors (e.g., PM motors)
- o Control of mechanical action and pump drives (power electronics)
- o Sensor technology for improved process control (loading, dampness, dirt, ...)
- o Direct drives (instead of belt drives / washing machine)
- o Energy efficient heating (e.g., cooking with induction heat / microwaves)
- o Exergy usage (hot water supply, heat pump)
- o Recycling of the energy used (tumble dryer with heat pump)
- o Selection and dimensioning of system components (customisation for specific processes)
- o Integration into device-spanning domestic energy management system
- o Use during off-peak periods (ripple control)

Battery powered devices

Typical battery appliances include: electric tools (power screwdrivers, power drills, etc.), domestic appliances (kitchen appliances, hand-held vacuum cleaners, shavers), and consumer electronics (remote control). Every year 117 million electric tools alone are sold worldwide. On a quantity basis, the market is growing at a rate of 2% annually.

Starting points for improving energy efficiency can be found in chargers and in battery management (storage batteries).

Measure: more efficient chargers, battery management



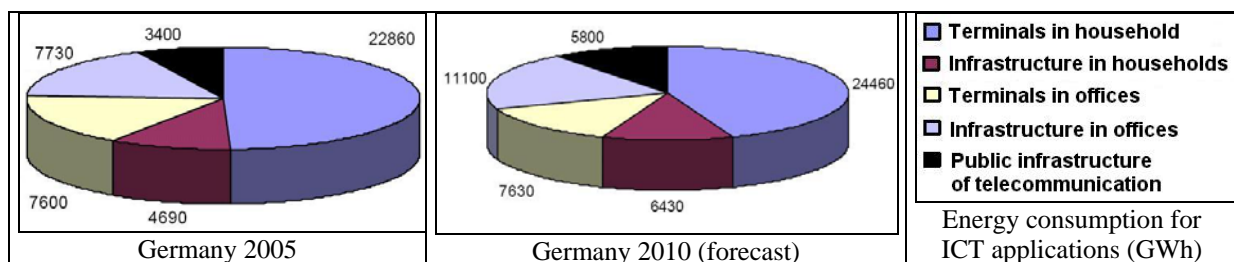
Saving potential estimates for the European Union

Assuming an **electric energy consumption** of 661,976GWh (2004) in the **European Union (EU-15)**, with, in 2004, **space heating** (electric heating, heat pumps) accounting for 115,449GWh, **hot water** (electric boilers) for 107.770GWh, **other process heat** (electric ranges, microwave ovens, washing machines, dishwashers) for 123.128GWh, and **mechanical energy** (electric drives for washing machines, dishwashers, circulation pumps, exhaust hoods, air conditioning, etc.) for 261,679GWh, we would estimate the **technical saving potential** for the energy consumption to be in the region of 198,000GWh (30%).

6 Information and Communication Technology

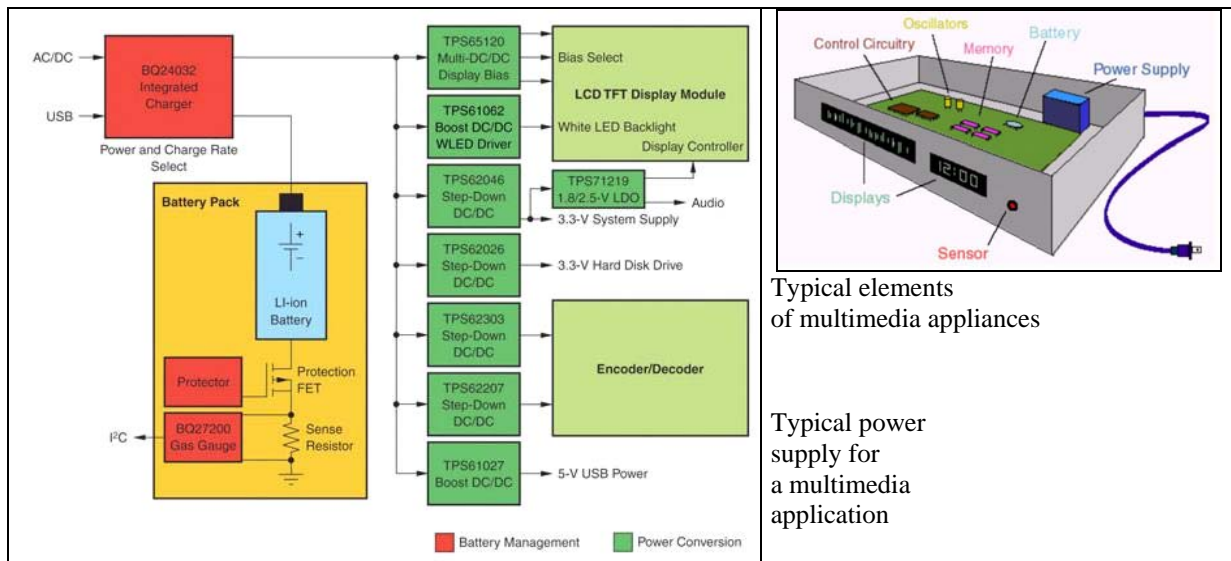
According to our assessment, the **electric energy consumption of ICT in households and offices in the European Union (EU-15)** is in the range of 210,000GWh (2005), or 11% of the total electric energy consumption.

The most important ICT applications (end devices, infrastructure):



Television sets (TV), servers, audio appliances, communication infrastructure of households, mobile telephone providers' infrastructures as well as computers and monitors in households and offices are by far the largest **energy consumers**.

Feasible Technical Measures for Improving Energy Efficiency



Typical elements of multimedia appliances

Typical power supply for a multimedia application

There is a great variety of end devices. In order to simplify this examination, we have grouped together similar appliance types and functions. You will now find formerly typical household appliances in offices as well (e.g., TV screens -> PC monitors) or typical office appliances in homes, too (e.g., printers, faxes, answering machines ...). Certain functional parts such as power supply assemblies can be found in all these products.

Main and typical elements of ICT systems

- o Power supply (power supplies, mains adapters)
- o Output peripherals, displays (screens / monitors, ...)
- o Input peripherals (key boards, scanners, mouses, ...)
- o Device control units (controllers, processors)
- o Data processing, signal processing (processors, tuners, amplifiers, graphics adapters, ...)
- o Storage (hard disks, RAM, ...)
- o Mechanical / physical / chemical processes
(e.g., paper transport of printers, fuse cylinder heating of copiers, light generation in screen devices)
- o Auxiliary units (cooling)

We will examine some technological areas of innovation relevant for the great majority of appliances in the ICT area as follows:

Basic approaches for improving energy efficiency:

1. More efficient **power supply** assemblies (switched-mode power supplies)
2. Improved **battery management** of chargers
3. Reducing the **power requirements** of information processing in a narrower sense (more efficient processors, ...)
4. New **cooling concepts** (head conduction, convection, doing without fans)
5. More efficient **displays** (light technology)
6. **Power management** (change to standby)

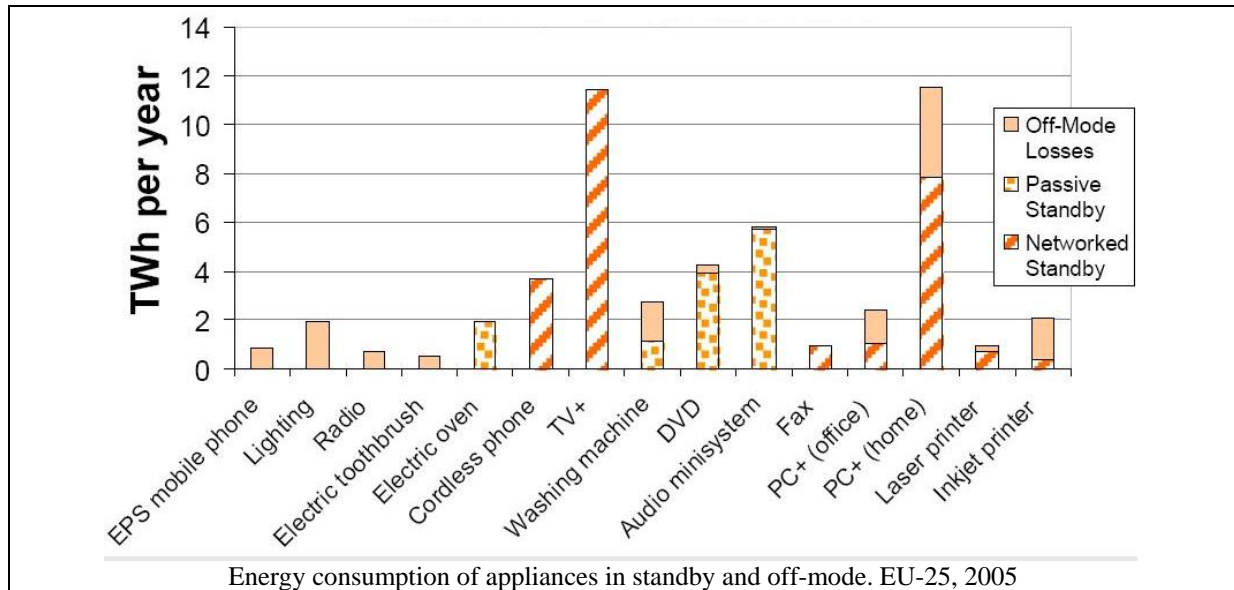
Saving potential estimates for the European Union

Concerning the **electrical energy consumption** in the **European Union** (EU-15), we would estimate the **saving potential** for ICT applications to be in the range of 21,000GWh (30%), assuming an energy consumption of around 210,000GWh (2004).

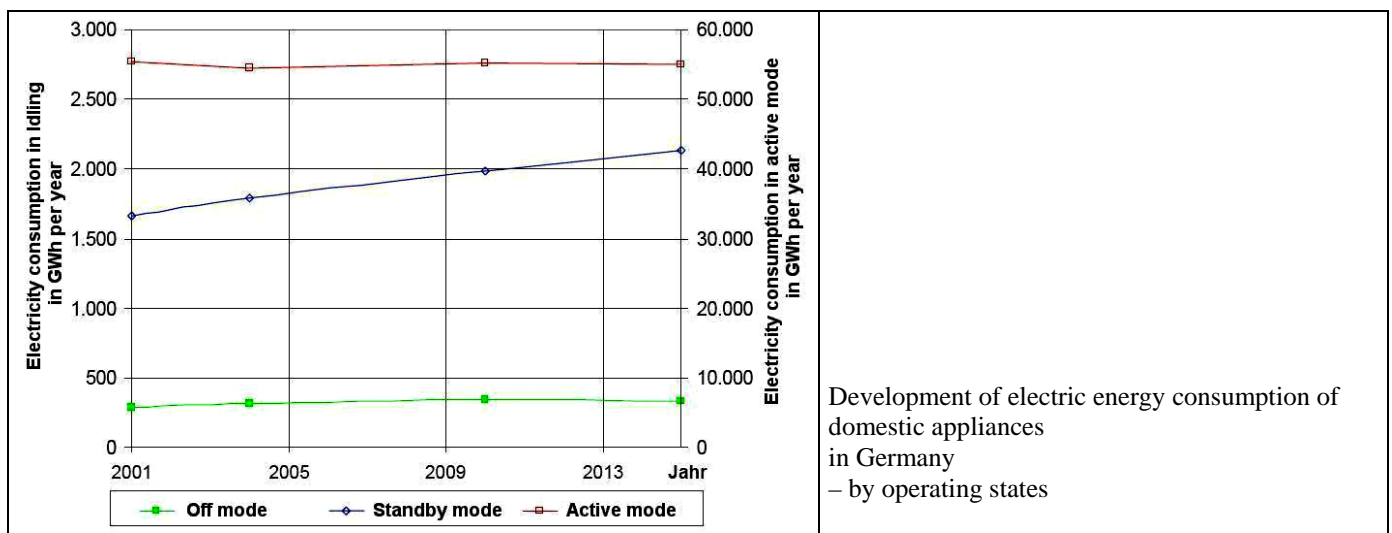
7 Standby and Off-Mode (Idling Losses)

Standby and Idling are special operating states of appliances. Those are operating states where the appliance is not performing its main function yet continues to consume electric energy.

The **energy consumption** of appliances in standby or off-mode is estimated at around 52,000GWh (52TWh) for the **European Union (EU-25)**, i. e., 4.7% of the total electric energy consumption. For **Germany**, an electric energy consumption in the range of around 17,700GWh for standby was determined for 2004 in the 2005 ISI study, i. e., 7.5% of the total electric energy consumption.



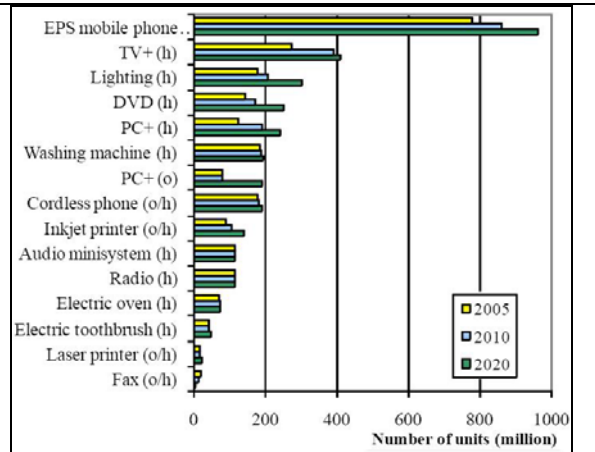
Television sets, audio devices, DVDs, mobile telephones, washing machines, and electric ranges are the **largest consumers**.



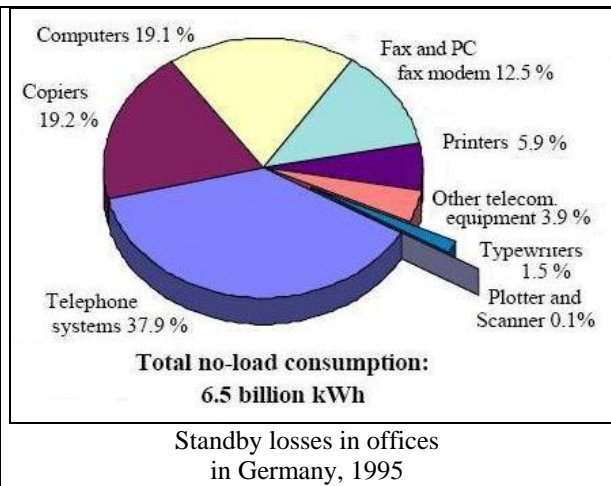
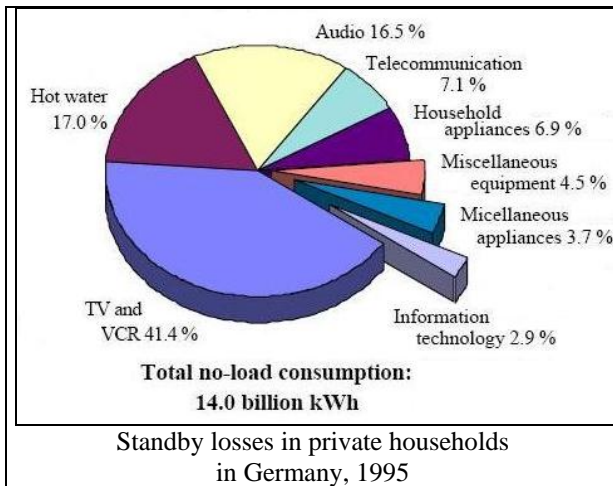
Criteria for the relevance of individual appliances result from:

- o Their numbers (inventory, growth)
- o Their operation times (standby, virtual-off)
- o Their specific energy consumption in standby or off-mode
- o Their efficiency potentials

Product case	Office (o) Household (h)	2005	2010	2020
EPS mobile phone	(o/h)	780	863	962
Lighting	(h)	179	209	304
Radio	(h)	114.4	115.7	116.8
Electric toothbrush	(h)	42.7	43.6	50.6
Electric oven	(h)	73.0	73.9	74.7
Cordless phone	(o/h)	179.6	184	190.5
TV+ #	(h)	275.9	391.5	410.8
Washing machine	(h)	184.6	189.4	195.5
DVD	(h)	143.3	174.0	253.4
Audio minisystem	(h)	114.4	115.7	116.8
Fax	(o/h)	20.0	13.2	5.6
PC+ (office) #	(o)	80.5	145	193
PC+ (home) #	(h)	126	193	243
Laser printer	(o/h)	16.6	18.5	22.6
Inkjet printer	(o/h)	90.2	105.0	140.4
Total		2420.2	2770.0	3279.7

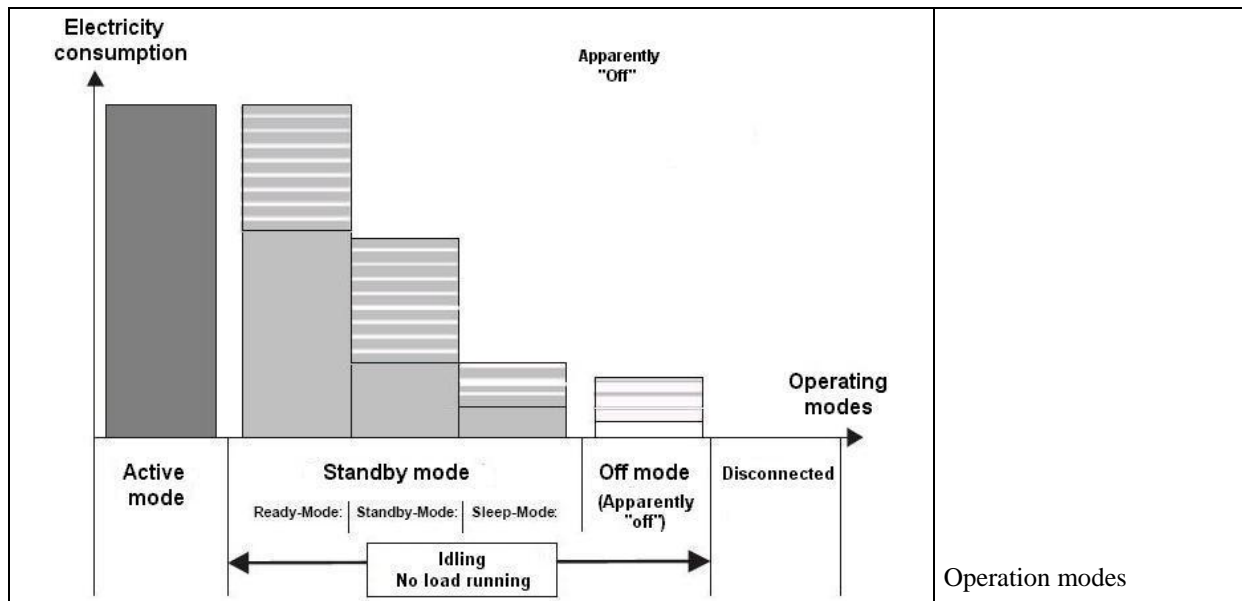


Appliance inventory in EU-25 (million units) featuring a standby or off-mode



The significance of **electric energy consumption in standby mode** has grown considerably during the last years – in absolute terms but particularly in relation to normal operation – and it will continue to grow in the years to come, according to the judgement of experts.

Relevant states of operation (operating modes)



Saving potential estimates for the European Union

Concerning the **electrical energy consumption** in the **European Union** (EU-25), we would estimate the **economic saving potential** to be in the range of 36,400GWh (70%), and **technical saving potential** to be in the range of 46,800GWh (90%), assuming an energy consumption for idling of around 52,000GWh (2004).

The following **concrete proposed measures** are detailed explicitly:

	Efficiency measures	Action plan
1	Dynamic energy performance requirements for products, buildings, services	Eco-design requirements for 14 priority products (2007-2009), eco-design requirements for further products (2008-2010), voluntary commitments for energy saving following stricter criteria (2007-2012), labelling electric water heaters (2007), new labelling and re-scaling of appliances after periods of five years (max. 10-20% in class „A“), new Energy Star Agreement on and Community labelling of office equipment (2007-2011), agreements on energy efficiency with CEER and ERGEG (2007), Community-wide White Certificate scheme (2008), European energy audit standard , establishing and supporting a centre to identify and improve technologies (2008), Implementation and amendment of the Energy Performance of Buildings Directive , expanding the role for the public sector in demonstrating new technologies (2009), minimum provisions or minimum performance requirements (kWh/m²) for large-scale renovation of buildings with the level of passive houses as a target (2009), inclusion of energy efficiency aspects in construction product standards (2008)
2	Improving energy transformation	Minimum efficiency requirements for electricity, heating and cooling facilities (below 20MW) (2008), guidelines for reducing transmission and distribution losses (2008), grid access and connection of decentralised electric power generation (2007), directive and measures for the promotion of combined heat and power generation (2007-2011)
3	Improvement in the field of transport	Measures to ensure that a 120g CO₂/km target is met by the year 2012, develop markets for cleaner, smarter, safer, and more energy-efficient vehicles (2007-2012) through providing funds for market launch (2007) and a vehicle fuel efficiency information directive (2007), minimum efficiency requirements for automobile air-conditioning systems (2007-2008), tyre pressure monitoring systems, specific measures for urban traffic (2007), shore-side electricity for harboured ships (2008-2009)
4	Financing energy efficiency	Elimination of legal barriers impeding the use of energy services (2007-2009), using funds, possibly co-financed by banks (EBWE, EIB Group and other IFIs) and European programmes (CIP), to finance energy audits and investments especially of SMBs and the public sector (2007-2009), facilitate energy efficiency improvements in the new Member States through the Structural and Cohesion funds, etc. (2007-2009), consider tax credits as incentives for enterprises and consumers to promote producing and purchasing energy-efficient appliances and equipment, respectively (2007), consider incorporating better energy efficiency and environmental aspects in indirect tax legislation (e.g., reduced value added tax – 2008), relate vehicle taxation to CO₂ emission (2007)
5	Changing personal behaviour	Strengthen the significance of energy efficiency in enterprise environment management (EMAS regulation – 2007), incorporate energy supply security and climatic change issues in national education curricula (2007), contest to award a prize for the most energy-efficient school (2007-2008), vocational education initiative on energy efficiency (2008), set up a “Covenant of Mayors” and network on energy efficiency for exchange and application of best practices (2007)
6	International co-operation and partnerships	Strengthen the significance of energy efficiency in enterprise environment management (EMAS regulation – 2007), incorporate energy supply security and climatic change issues in national education curricula (2007), contest to award a prize for the most energy-efficient school (2007-2008), vocational education initiative on energy efficiency (2008), set up a “Covenant of Mayors” and network on energy efficiency for exchange and application of best practices (2007)

Bestellung / order

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