

Energy consumption of the tertiary sector (trade, commerce and services) for the years 2004 to 2006

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SUMMARY

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Contents

	Page
1 Starting point and objective.....	1
2 Methodology.....	2
2.1 Definition and demarcation of the tertiary sector.....	2
2.2 Concept of the study.....	3
3 Extrapolation of energy consumption in the tertiary sector for the years 2001 to 2006	6
3.1 Characteristic variables of the surveyed workplaces	6
3.2 Employees and floorspace in the tertiary sector	8
3.3 Extrapolation of energy consumption in the tertiary sector	9
3.4 Balances of energy applications	16
4 Sector-specific analyses	20
5 Use of renewable energies in the tertiary sector	29
6 Conclusions and outlook	35
7 References.....	36

List of figures

	Page
Figure 1: Electricity consumption of individual branches of the tertiary sector 2001-2006	14
Figure 2: Fuel and district heat consumption of individual branches of the tertiary sectors 2001-2006	14
Figure 3: Specific electricity and fuel consumption per reference unit in 2006 ¹⁾	19
Figure 4: Types of lamps in production 2007 (mean per sector)	25
Figure 5: Equipment with servers, PCs and laptops 2007	26
Figure 6: Share of enterprises with air conditioning	26
Figure 7: Activity indicator of energy management by sector	28

List of tables

	Page
Table 1: Differentiation of the tertiary sector by groups and splits	2
Table 2: Study concept of the surveys of energy consumption in the tertiary sector	3
Table 3: Characteristic values of the groups covered in the broad survey for the survey year 2006	7
Table 4: Employees in the tertiary sector by groups and individual splits 2003-2006 and floorspace 2006	9
Table 5: Projected energy consumption in the tertiary sector by consumer groups (in PJ)	13
Table 6: Projected consumption of fuels by energy source in the tertiary sector for 2006	15
Table 7: 2006 balances for electricity and fuel/district heat by application	18
Table 8: Inventory of renewable installations in the tertiary sector derived from the survey	29
Table 9: Derived projected results from the survey on the use of renewable energy sources in the tertiary sector for 2006	30
Table 10: Use of renewable energies in the tertiary sector and primary energy saving in 2006	34

1 Starting point and objective

In 2006, 1461 PJ or around 16% of the total final energy consumption in Germany were accounted for by the sector of trade, commerce and services, which is also referred to as the tertiary sector (Working Group Energy Balances - AG Energiebilanzen 2008). Efforts have been made for several years now by Germany and other countries as well as at the level of the EU and the IEA to record the energy consumption of this very heterogeneous sector or parts of its energy consumption more precisely and in more detail. The EU Directive on energy end-use efficiency and energy services (2006/32/EC; ESD directive) places high demands on the availability of energy statistics. Public institutions, which make up a subsector of the tertiary sector, are assigned an exemplary role in improving energy efficiency in the ESD.

A comprehensive survey of energy consumption in the tertiary sector in Germany was already done in the mid nineties (Geiger/Gruber/Megele 1999). Another survey for 2001 with a comparable methodology led to a further improvement of the database for this sector (Fraunhofer ISI et al. 2004). The project conducted here offered the chance to further develop an efficient survey and evaluation method which actually motivates those affected and gets them involved. This method makes it possible to illustrate the main consumption and structural data in the tertiary sector by consumer group and application and to compare these data with the results of the previous survey. This should further improve the energy statistics for this sector and satisfy the requirements for information about energy.

In view of climate issues and limited fossil fuel resources, renewable energy sources are expected to become more and more important. The large number and variety of technologies for using renewable energies mean that there are only partially reliable data about the amount of energy actually contributed. The same is true for the application side, i.e. the typical contributions used to meet the energy demand and, on top of this, the allocation to the four consumption sectors "industry", "households", "transport" and "tertiary". Through a more in-depth survey of the use of renewables in the tertiary sector, this study also aims at improving the data situation with regard to their use there.

2 Methodology

2.1 Definition and demarcation of the tertiary sector

The consumption sector "trade, commerce, services", i. e. the tertiary sector, is defined in the same way as in the German national energy balances (AG Energiebilanzen 2008). From manufacturing industry, the energy consumption of small firms and enterprises with up to 19 employees (small industrial enterprises) is assigned to the tertiary sector. These enterprises are therefore also included in the survey conducted here. Demarcation is performed using the German national classification system based on sectors of the economy (WZ 2003 corresponding to NACE Rev.1.1) and the size of workplaces in the manufacturing industry (<20 workers). As in the energy balance for Germany, "agriculture and forestry/horticulture" and "military services" are also included in the tertiary sector. With regard to German railways and airports, also similar to the energy balance, the total mobile energy consumption is allocated to the transport sector, but stationary energy consumption is classified as belonging to the tertiary sector. For the survey, the so-defined tertiary sector was then divided into 12 groups, which were further subdivided into more detailed splits (Table 1).

Table 1: Differentiation of the tertiary sector by groups and splits

Grp.	WZ 2003*	Definition of sector in survey	Grp.	WZ 2003*	Definition of sector in survey
1	45	Construction	6		Hotels, restaurants, homes
2		Office-like enterprises		55.11-55.12	Hotels
	65-67	Financial, insurances		55.3-55.5	Restaurants
	22.1	Publishing		85.3, 91	Non-profit organisations with accommodation/homes
	71-74, 85, 93	Other business services	7		Food industry
	75	Public admin./compulsory social security		15.81/82	Bakers
	64.1	National post		15.1, 15.2	Butchers
	64.3	German Telecom		15.61, 15.9	Other food & beverages
	60.1	German national railways (Deutsche Bahn AG)	8	93.01	Laundries & dry-cleaning
3		Manufacturing	9	01.11, 01.2-3	Agriculture - crops and livestock
	28-33, 36.2-5	Metalworking	10	01.12, 01.41	Horticulture
	34	Automobile trade	11	63.23	Airports
	20, 36.1	Wood and wood products	12		Textiles, clothing, freight forwarders
	36.1	Woodworking		17	Textiles
	21, 22.2	Pulp & paper, printing & publishing		18	Clothing
4		Trade		19	Leather
	52.1 - 52.6	Retail trade		63.40.1	Freight forwarding, other transport activities
	51	Wholesale trade		63.12.1	Storage and warehousing
	50.1, 50.3, 50.4	Sale of motor vehicles/motorcycles and parts	13		Others
	50.5	Retail sale of automotive fuel		52.62, 52.63	Market stalls etc.
5		Hospitals, schools, public baths		25.13-25.23	Non-ferrous metals, plastics, rubber
	85.11	Hospitals		26.21-26.30	Ceramics
	80	Schools			Unclassified sectors
	92.61.0	Public baths		36, 37	Furniture, jewelry, music, recycl., travel ag., social w.
				90, 40, 41	Sewage and waterworks, energy supply
				02, 05	Forestry, fishing
				72.22	Military

WZ 2003* German national classification of the sectors of the economy 2003 (corresponding to NACE Rev. 1.1)

Secondary data sources are used for those areas not covered by the survey. The criteria used for the group divisions chosen here were comparability with the results of the previous surveys (Geiger et al. 1999; Fraunhofer ISI et al. 2004) and the highest possible degree of homogeneity in the structure of energy consumption.

2.2 Concept of the study

The study conducted here of energy consumption in the tertiary sector actually consists of two sub-studies, which differ with regard to the concept and method used (Table 2):

- The **main survey** of energy consumption in the tertiary sector. This is being conducted for the second time and consists of several sub-modules.
- A multi-stage **special survey** to record the use of renewable energy sources (RES) in the tertiary sector, which took place for the first time in this form.

Table 2: Study concept of the surveys of energy consumption in the tertiary sector

	Main survey tertiary	Special survey RES
Size of sample	approx. 2,000 workplaces	approx. 20,000 workplaces
Selection of sample	Quotas (stratified sample)	Quotas (stratified sample)
Type of survey	face-to-face interviews	telephone
Survey modules	(1) Abridged broad survey for the year 2004 (2) Comprehensive broad survey for 2006 (3) In-depth interviews in 10 sectors (25 interviews per sector)	(1) Short questionnaire whether renewable energies are used at all (2) Follow-up to clarify any mix-ups and misunderstandings (3) Detailed survey of 300 actual users of renewable energies
Questionnaires	Several stages: <ul style="list-style-type: none"> ▪ General questions about company structure, energy consumption and level of equipment with relevant energy technologies ▪ Sector-specific questions ▪ Questions about energy management 	Dependent on stage: <ul style="list-style-type: none"> ▪ Short questions: limited number of closed questions on industry classification, company size and use of renewable energies ▪ Detailed questions: technical data of the installation, mode and hours of operation etc.
Data checks, margins	Specific energy consumption; exclusion of max. 20%	Characteristic values of the installations per employee; plausibility checks of survey results by experts
Main reference variable for the extrapolation	Employees	Employees
Stratification	12 groups, 29 splits, sub-splits	10 technologies, 12 groups
Secondary statistics	Agriculture, airports	As plausibility check

The results of both survey rounds for the years 2004 and 2006 then served as the basis for the extrapolation of energy consumption in the tertiary sector in Germany by sector and energy source. The fuel and electricity consumption of the companies in the groups and splits were determined from the survey results and related to the number of employees documented in the questionnaire. Interpolations were made for the prior and interim years not covered by the original surveys. The averages of the specific electricity and fuel consumption derived from the survey were then extrapolated for Germany using the total number of employees in the individual groups and splits. The number of employees was selected as a reference variable because it was necessary to have a variable for the extrapolation which is available from the official statistics for all groups and splits in the tertiary sector. This is not the case for other variables such as, e.g. heated floorspace, which may actually be more suitable for certain sub-sectors than the number of employees, because so far there are no official, differentiated statistics available for this.

In addition to the two broad surveys, in-depth interviews were conducted in summer 2007 at 25 organisations in 10 of the 12 groups differentiated here.¹ The objective of these in-depth interviews was to gain additional information about energy-relevant details which formed the main data basis for breaking down energy consumption in the tertiary sector by application for the survey year 2006. Because the enterprises are equipped with different energy technologies, sector-specific questionnaires were specially developed for all groups and individual splits.

Special survey on the use of renewable energies in the tertiary sector

Questions about the use of renewable energy sources were also included in the main survey in the tertiary sector, but quantities were only requested for wood and biodiesel. For the other energy sources – solar thermal, photovoltaic, wind, small hydro and heat pumps – it was only recorded whether they were used or not, what electrical power or collector area they have and how the energy obtained is used. In the special survey on the use of renewable energies, to start with, 20,000 workplaces were contacted by telephone in order to find out how many enterprises actually use renewable energies. A stratified sample was taken in the same way as for the broad survey. The GfK carried out the fieldwork using CATI (Computer Assisted Telephone Interviews). For cost reasons, the short interviews were not supposed to last longer than two to three minutes. The questionnaire therefore consisted of only a few closed questions as well

¹ All the groups were covered with the exception of agriculture, construction industry and trade for which in-depth interviews were already begun in the previous survey (Fraunhofer ISI et al. 2004). The retail trade was questioned again because of its significance and the altered framework conditions (development of equipment, changes in shop opening hours).

as information about sector and company size. The various renewable energy sources² were cited to interviewees, who were then asked whether the company "used" this energy source. Although there were no indications of possible misunderstandings either in the pre-test or the interview phase between May and September 2006, it became clear in the subsequent evaluation that the results of the short interview were partially extremely implausible concerning the frequency of use of individual energy sources. For this reason, around 1,650 of those enterprises which had stated that they used renewable energies were questioned again in order to check the plausibility of the results. It then became clear that while technologies such as the use of renewable solid or liquid fuels, biogas and bio-fuels were generally correctly judged and identified, other statements originally made about all the other technologies of renewable energy use were sometimes changed when careful follow-up questions were asked. This was caused by mistakes and misunderstandings on the part of the respondents concerning what is meant by the "use" of renewable energies. Based on the evaluation of the follow-up survey, the plausibility of the results of the short telephone interviews were checked for all respondents.

A final step within the special survey was to carry out more detailed interviews with users of renewable energies. The enterprises questioned – in total around 300 – were selected from among those which had stated that they use one or more renewable energy sources. Obviously, mainly those enterprises were questioned whose statements had passed the plausibility check in the follow-up survey. Technical data were requested on the existing installations (e.g. installed power, installation size), operating modes and hours as well as the amounts of energy produced in the case of bio-fuels, vehicle stocks and annual kilometres driven. This was done in order to derive values for the use of renewable energies per employee which were typical for the technology and the branch structure involved. These then formed the basis, like in the main survey, for extrapolating the contribution of renewable energies in the tertiary sector via the number of employees in this sector and their group affiliation. Since knowledge gaps showed up in the in-depth interviews as well for many of the respondents about the technical data of existing installations, the results of the more detailed interviews had to be corrected to some extent as well. On the basis of all the available results from the two main surveys and all stages of the special survey as well as other additional data sources such as the statistics of organizations and associations, studies etc., the extrapolation of the use of renewable energies in the tertiary sector was then made based on the number of employees.

² Photovoltaic installations, solar collectors, wind power, hydropower, heat pumps, block heating stations, solid fuels (biomass), liquid fuels (biomass), biogas, bio-fuels.

3 Extrapolation of energy consumption in the tertiary sector for the years 2001 to 2006

3.1 Characteristic variables of the surveyed workplaces

When comparing the 12 groups with each other, several characteristic variables of the workplaces can be derived from the two broad surveys which are shown in Table 3 for the survey year 2006. These are:

- the number of workplaces,
- the average company size, differentiated according to 3 classes,
- the average floorspace, differentiated by sales, production, storage and other,
- area of heated floorspace,
- heating control possibilities,
- type of supply (own system, external installation) as well as
- the average hot water consumption per employee and day.

With the exception of the groups 11 (airports) and 12 (textiles, clothing, freight forwarders), sufficiently sound case numbers are reached in order to derive the following information:

- The average company size is predominantly small; most workplaces (more than 72%) have 1-10 employees. This size is untypical only for "hospitals, schools and public baths", "airports" and "textiles, clothing, freight forwarders".
- The average floorspace varies widely among the different groups and lies between 244 m² in "laundries" and 12,490 m² in "hospitals, schools, public baths." How the areas are used also varies considerably. The share of "sales, offices, dining areas" in total company floorspace reaches 72% in office-like businesses and only 6% in "textiles, clothing, freight forwarding". The share of production areas reaches 87% in "horticulture" and 8% in "airports". "Storage, other" account for around 59% of the floorspace used in "hospitals, schools, public baths" and "airports" and 6% in "horticulture." This underlines the large spread in how the areas are used from group to group.
- The characteristic values which can be derived from the survey for the amount of heating, its operation and hot water production formed an important basis for the detailed breakdown of energy consumption by application.

Table 3: Characteristic values of the groups covered in the broad survey for the survey year 2006

2006		Group												
Quest.	Description	1	2	3	4	5	6	7	8	9	10	11	12	
		Construction	Office-like	Manufacturing	Trade	Hospitals, schools, baths	Hotels, restaurants, homes	Food	Laundries	Agriculture	Horticulture	Airports	Textiles, clothing, freight forwarding	
1	Number of enterprises	[1]	179	470	165	390	182	254	125	49	98	22	0	13
3	Average size	[empl./comp.]	10.4	18.5	18.6	17.3	218.7	11.1	8.4	5.9	3.2	8.3	-	28.1
	of which: 1-10	[%]	76.0	74.9	75.2	73.8	18.7	81.5	76.0	83.7	96.9	81.8	-	76.9
	11-25	[%]	19.6	12.8	17.0	13.8	15.4	9.4	20.8	14.3	2.0	13.6	-	7.7
	> 25	[%]	4.5	12.3	7.9	12.3	65.9	9.1	3.2	2.0	1.0	4.5	-	15.4
4	average floorspace	[m ² /comp.]	472	771	1906	1744	16363	648	289	309	1850	1709	-	1160
5a	of which: sales, offices, dining, ..	[%]	23.9	65.0	23.8	36.6	22.7	30.5	26.1	21.7	2.5	14.4	-	35.6
	production	[%]	23.7	6.7	34.2	23.9	59.7	49.9	46.4	72.8	56.1	75.8	-	2.2
	storage, other	[%]	52.4	28.3	42.0	39.5	17.6	19.6	27.6	5.6	41.4	9.7	-	62.2
5b	Sales area	[m ² /comp.]	113	501	453	639	3711	198	75	67	46	247	-	413
	heated	[%]	92.8	99.8	99.7	95.3	96.8	99.1	93.3	99.2	92.8	97.3	-	96.5
	unheated	[%]	7.2	0.2	0.3	4.7	3.2	0.9	6.7	0.8	7.2	2.7	-	3.5
5b	Production, workshop	[m ² /comp.]	112	51	652	416	9773	323	134	225	1038	1296	-	26
	heated	[%]	63.5	98.5	93.1	75.9	99.9	98.9	71.0	74.8	47.6	85.0	-	77.3
	unheated	[%]	36.5	1.5	6.9	24.1	0.1	1.1	29.0	25.2	52.4	15.0	-	22.7
5b	Storage, other	[m ² /comp.]	247	218	801	689	2879	127	80	17	766	166	-	721
	heated	[%]	44.4	85.9	77.3	67.9	75.6	62.7	45.4	59.1	14.6	39.8	-	84.7
	unheated	[%]	55.6	14.1	22.7	32.1	24.4	37.3	54.6	40.9	85.4	60.2	-	15.3
8	Heating													
	via third parties	[%]	18.4	29.4	13.3	27.9	20.3	18.9	5.6	28.6	1.0	0.0	-	38.5
	own system	[%]	81.6	70.6	86.7	72.1	79.7	81.1	94.4	71.4	99.0	100.0	-	61.5
	split: central	[%]	87.7	97.6	90.2	95.0	98.6	94.7	94.9	94.3	84.5	90.9	-	100.0
	decentral	[%]	12.3	2.4	9.8	5.0	1.4	5.3	5.1	5.7	15.5	9.1	-	-
9	Temperature drop	[%]	63.1	69.1	69.1	61.8	92.3	69.7	66.4	65.3	54.1	68.2	-	46.2
10	avg. HW consump. per employee	[l/d*empl.]	8.23	8.93	12.14	8.59	31.33	55.06	61.35	40.77	58.78	9.18	-	5.72

3.2 Employees and floorspace in the tertiary sector

The main reference variables for the extrapolation of energy consumption in the tertiary sector are statistically sound data on workplaces in the tertiary sector's population including data on all employees. The latter is not without problems since there are no separate workplace statistics for the tertiary sector. Instead, tertiary sector workplaces are part of the national classification system of industrial branches (WZ 2003) and have to be separated here from the other energy consumption sectors (industry, households, transport, transformation sector). The following data on employment in Germany were used to do so, taken from the Federal Statistical Office (2008a, 2008b):

- *Statistics on the workforce from the German national accounts* allow a rough classification of all employees in 16 sectors following the German national classification of industries (WZ 2003).
- The *job market data from the micro census*, a representative, official statistic for the population and the job market in Germany, provides general data for all employees for individual years (here: 2004) by profession.
- The *business register* of the Federal Statistical Office (2008a) available since the survey year 2003, in which all employees liable for compulsory social insurance contributions are registered at company level, which can be classified by industrial branch (WZ 2003) and differentiated by company size.³

Based on this, it was possible for the purposes of this study to allocate all the employees in the tertiary sector to the different groups and splits (Table 4). For the two survey years 2004 and 2006, the total number of employees in the tertiary sector was just above 28 million; this was a bit lower in 2003 and 2005. The employee figures in the years 2003 to 2006 were also used to a large extent for the extrapolation of the energy consumption in the tertiary sector. An exception was made for the groups 5 and 11, for which the energy consumption seemed better captured by using the following reference units:

- Hospitals: Number of beds
- Schools (incl. universities): Number of pupils/students
- Public baths: Water volume (m²)
- Airports: Traffic units (number of passengers and 100 kg freight).

³ This does not cover government employees, professional groups like doctors and dispensing chemists and entrepreneurs, family members who help out in businesses and casual workers not making social insurance contributions.

Table 4: Employees in the tertiary sector by groups and individual splits 2003-2006 and floorspace 2006

Grp. No. Split	2003	2004	2005	2006		
	Number of employees				Floorspace m ² /employee mill. m ²	
1 Construction industry	2,322,000	2,254,000	2,165,000	2,159,000	69	150
2 Office-like enterprises	10,087,049	10,319,779	10,307,157	10,567,360	47	495
3 Manufacturing enterprises	843,610	876,973	840,984	833,253	105	87
4 Retail trade	5,593,708	5,603,944	5,567,011	5,548,589	92	509
5 Hospitals, schools, baths	2,715,129	2,685,459	2,665,186	2,660,017	60	161
21 Hospitals ¹⁾	721,690	707,806	698,303	683,484	101	124
22 Schools ¹⁾	14,532,131	14,589,642	14,470,281	14,382,821	19	26
23 Baths ¹⁾	4,650,000	4,650,000	4,650,000	4,650,000	404	11
6 Hotels, restaurants, homes	3,595,945	3,664,651	3,670,792	3,700,025	77	285
7 Food industry	171,598	173,610	161,127	163,041	50	8
5 Bakers ¹⁾	86,948	87,867	82,111	83,096	39	3
6 Butchers ¹⁾	70,140	70,506	64,788	65,558	42	3
7 Other food ¹⁾	14,510	15,237	14,228	14,397	145	2
8 Laundries	38,530	39,902	36,973	37,412	39	2
9 Agriculture	689,834	685,183	671,059	665,520	455	303
10 Horticulture	186,166	182,817	176,941	175,480	343	60
11 Airports	34,683	34,948	34,630	34,371	880	30
Airports ¹⁾	175,027,044	190,496,889	202,254,003	214,096,642		
12 Textiles, clothing, leather	747,286	791,576	784,359	793,677	36	29
Sum Groups 1 - 12	27,025,538	27,312,842	27,081,219	27,337,745		2092
Rest	692,321	722,014	695,159	694,829		
Total tertiary	27,717,859	28,034,856	27,776,378	28,032,574		

¹⁾ Alternative reference variables for extrapolation: hospitals: number of beds; schools/univ.: number of pupils/students; public baths: water volume (m²); airports: traffic units (number of passengers and 100 kg freight)

Employees: compiled by TUM-Ife, based on data of the Federal Statistical Office on number of employees 2003 to 2005 from the business register as well as on employees 2003 to 2006 taken from the national accounts. Workforce data of the airlines are taken from the Arbeitsgemeinschaft Deutscher Verkehrsflughäfen (ADV) 4.

Floorspace: Specific floorspace per employee from survey; extrapolation via number of employees.

Alongside employees, floorspace represents a useful reference variable for energy consumption in the tertiary sector. To make comparisons based on area possible, the area used in the tertiary sector in Germany was calculated from the survey results by relating the companies' floorspace recorded in the survey to the number of employees in the companies and extrapolating this to the total number of employees in Germany at the level of groups and splits (Table 4).

3.3 Extrapolation of energy consumption in the tertiary sector

Extrapolating energy consumption in the tertiary sector was done separately for electricity and fuels. First of all, the average electricity and fuel consumption were determined from the two broad surveys at the level of groups and splits for the survey

years 2004 and 2006 and related to the average number of employees in the enterprises questioned. 2001 was also included because specific electricity and fuel consumption data were also available here from a previous survey (Fraunhofer ISI et al. 2004). For the interim years not covered by a survey (2002, 2003 and 2005), the specific consumption values were interpolated. The absolute electricity or fuel consumption was calculated by multiplying the survey value by the actual number of employees in Germany or by the alternative reference units in groups 5 and 11 (Table 4). For electricity, several components of electricity consumption which were not documented in the survey were added to the consumption value determined from the survey (mainly electricity for street lighting, for shared installations in multi-purpose buildings and for supply and disposal functions), which make up a good 10% of the total electricity consumption in the tertiary sector.

Unlike the procedure described above, the energy consumption of agriculture and forestry (groups 9, 10) and airports (group 11) was determined using data from secondary statistics and the survey results were mainly used as accompanying information and to qualify the structure of energy sources and their main applications. In spite of the relatively large case numbers, it is only possible to roughly determine the electricity and fuel consumption for these groups from the survey because of their complex organisational and functional structures. Reference is made here to other energy consumption statistics. For agriculture and horticulture, these were provided by figures documenting the expenditure on energy which are published annually by BMVEL⁵ (2002 to 2008) and the average prices for fuels and lubricants, heating materials (gas and oil) and electricity, which could then be used to determine the annual energy consumption for the above mentioned energy sources. There are no data available from the statistics for solid fuels (coal, wood). Here, it also has to be assumed that, in agriculture, considerable amounts of non-traded energy (predominantly wood) are being used. The use of these amounts of energy was therefore estimated based on the application structure of energy sources identified from the survey.

The entire civilian air traffic volume can be documented using structural data from the statistics on 19 international airports and 41 regional airports and landing strips in Germany (ADV 2008). For 7 large airports (Frankfurt, Munich, Düsseldorf, Hamburg, Hannover, Berlin-Tegel and Osnabrück), which account for around three quarters of the air traffic volume and thus a large proportion of the energy consumption, there were additional energy consumption data available from the business and environmental

⁵ Federal Ministry of Food, Agriculture and Consumer Protection

reports of the airports. The annual energy consumption of airports in Germany can be relatively reliably determined based on these statistics.⁶

Table 5 shows the fuel and electricity consumption in the tertiary sector determined on this basis for the 12 different groups and individual splits. The total determined energy consumption in the tertiary sector in 2006 was around 1439 PJ. Electricity accounted for 434 PJ of this (or 118 TWh) and fuels and district heat for 1015 PJ. The row "others" contains additional components of energy consumption which were not able to be determined via the survey, especially the energy consumption of the military and the electricity used for street lighting and communal installations. In addition, for the survey years 2003 to 2006 covered by this study, a first estimate was made for the energy consumption of the remaining group 13 which was not documented by the surveys.⁷ Even if this group appears less significant when measured by the number of employees, some of the workplaces involved are still very electricity-intensive so that ignoring it completely would result in an underestimation, especially of electricity consumption. In future surveys, this group should therefore be specifically targeted and documented.

When comparing the extrapolated electricity and fuel consumption with the corresponding figures of the German Working Group Energy Balances (2008), it can be concluded that the extrapolated figures for electricity are between 7 und 15% below those of the energy balances depending on the year. On the one hand, this may be due to electricity consumption components which were not able to be determined via the survey. On the other hand, the tertiary electricity consumption figure from the energy balances contains statistical differences which do not enter the tertiary calculations made here. In general, the tertiary consumption figures given in the energy balances are determined to a large extent as the balance to other consumption sectors, i.e. as a remainder, with all the associated upstream uncertainties this implies. Despite this, there is still a generally good agreement between the extrapolated figures and the energy balance figures for fuel and district heat consumption with regard to consumption level and trend (Table 5). 2005 is the only exception; here the Working

⁶ This should be qualified by the fact that the fuel consumption determined for airports also partially includes the heat supply of restaurants, shops, offices, lounges and rest rooms etc. which should actually be allocated to other groups of the tertiary sector but which is not possible due to a lack of data. The resulting double counting of fuel consumption is estimated to be 1 PJ maximum.

⁷ For the years 2001 und 2002, which were calculated based on the results of a previous survey (Fraunhofer ISI et al. 2004), an estimate for the remaining group 13 was not possible.

Group Energy Balances show a not quite plausible drop in consumption followed by a significant rise in 2006.

Regarding the comparison of energy consumption figures over time, the following should be noted (Figure 1 and Figure 2):

- The results show the actual energy consumption in the tertiary sector in each year by analogy with the national energy balance and were therefore not temperature-adjusted. However, the years 2001 to 2005 in this period shared very similar climatic conditions. Only the year 2006, which had clearly above average temperatures during the heating season, probably shows a temperature-related under-consumption of around 90 PJ. Reliable statements about trends can therefore be made for six years based on these values.
- Only the period 2003 until 2006 is strictly consistent methodologically. For the years prior to this there are inconsistencies because of the absence of the business register of the Federal Statistical Office, which contains a somewhat differently structured database for employees only from the year 2003, as well as because of a slightly different method for determining the specific consumption values from the earlier survey for 2001 (Fraunhofer ISI et al. 2004).
- Changes within the space of four or even six years and within one group cannot be defined or analysed as "typical" or "characteristic" if consumption is basically stagnating since several influences may overlap: changes within a sector (technology, marketing), broader economic developments and the economics at sector level, changes in the statistical demarcation of sectors or the allocation of employees to one sector or even a change in how grid suppliers allocate businesses to industry and to tertiary (special contract clients, commercial clients in industry, tertiary).

Overall, the projected results over the period 2001 to 2006 show a stagnating trend for electricity and a slightly declining one for fuels. To supplement the extrapolations of total fuel consumption, in another step, the fuel consumption was also broken down to the level of individual energy sources. The energy consumption data of the individual workplaces from the two surveys formed the basis for doing so. By analogy with the specific electricity or fuel consumption previously used for the extrapolation, the specific consumption based on energy source can then also be determined on this basis, defined as the energy consumption of an energy source per reference unit. The following energy sources can be distinguished for fuels: coal, wood, liquid fuels, gaseous fuels and district heat. The absolute fuel consumption by energy source is again extrapolated for the whole of Germany using the respective reference units (usually number of employees) (Table 6).

Table 5: Projected energy consumption in the tertiary sector by consumer groups (in PJ)

Energy unit: PJ Grp. No./ Split Definition	2001			2002			2003			2004			2005			2006		
	Elec.	Fuels, district heat	Total	Elec.	Fuels, district heat	Total	Elec.	Fuels, district heat	Total	Elec.	Fuels, district heat	Total	Elec.	Fuels, district heat	Total	Elec.	Fuels, district heat	Total
1 Construction industry	12	49	61	12	44	56	13	44	58	13	43	56	13	40	53	13	38	51
2 Office-like enterprises	79	234	313	88	230	318	93	249	341	94	254	349	92	256	348	92	261	353
3 Manufacturing enterprises	24	67	91	19	41	60	14	24	38	14	25	39	14	24	38	14	23	37
4 Retail trade	100	177	277	109	169	278	122	186	308	122	187	309	113	170	283	105	151	256
5/21 Hospitals	19	44	63	18	40	58	18	40	59	18	40	57	22	43	65	25	45	71
5/22 Schools	15	76	90	13	67	81	12	69	80	12	69	81	13	70	82	14	70	83
5/23 Public baths	15	36	51	16	43	59	16	51	67	16	51	67	17	48	65	18	45	63
6 Hotels, restaurants, homes	49	161	210	58	173	231	65	207	272	66	209	275	62	193	256	60	176	236
7/5 Bakers	5	12	17	4	9	13	3	6	8	3	6	9	2	5	7	2	5	7
7/6 Butchers	4	10	14	4	6	9	3	3	6	3	3	6	2	2	5	2	2	4
7/7 Other food	1	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	1	1
8 Laundries	2	5	7	2	4	5	1	2	3	1	2	4	1	2	3	1	1	3
9 Agriculture	14	144	157	18	150	168	18	137	154	18	134	152	17	120	137	19	131	150
10 Horticulture	2	19	21	2	24	26	2	24	25	2	22	24	2	18	20	1	14	15
11 Airports	5	6	11	5	6	11	5	7	11	5	7	12	5	7	13	5	7	12
12 Textile, clothing, leather	11	27	38	7	25	33	4	35	39	4	37	41	3	21	25	3	7	10
13 Remaining group*	25	0	25	0	0	0	5	1	6	6	1	7	5	1	6	5	1	6
Others **	44	31	74	44	31	74	43	28	71	43	28	71	43	28	71	44	37	81
Total tertiary from extrapolation	423	1.098	1.521	420	1.062	1.482	437	1.112	1.549	441	1.118	1.559	427	1.049	1.476	424	1.015	1.439
Total tertiary from energy balance	486	1.084	1.570	500	1.043	1.543	470	1.049	1.520	485	1.048	1.533	473	868	1.341	493	968	1.461

* Remaining group 13: for the survey years 2003 to 2006, a first estimate was made for the energy consumption of the remaining group 13 which was not documented by the surveys. For the years 2001 und 2002, which were calculated based on the results of a previous survey (Fraunhofer ISI et al. 2004), an estimate for the remaining group 13 was not possible.

** Group "others": additional components of energy consumption which were not able to be determined via the survey (military, street lighting, communal installations).

Figure 1: Electricity consumption of individual branches of the tertiary sector 2001-2006

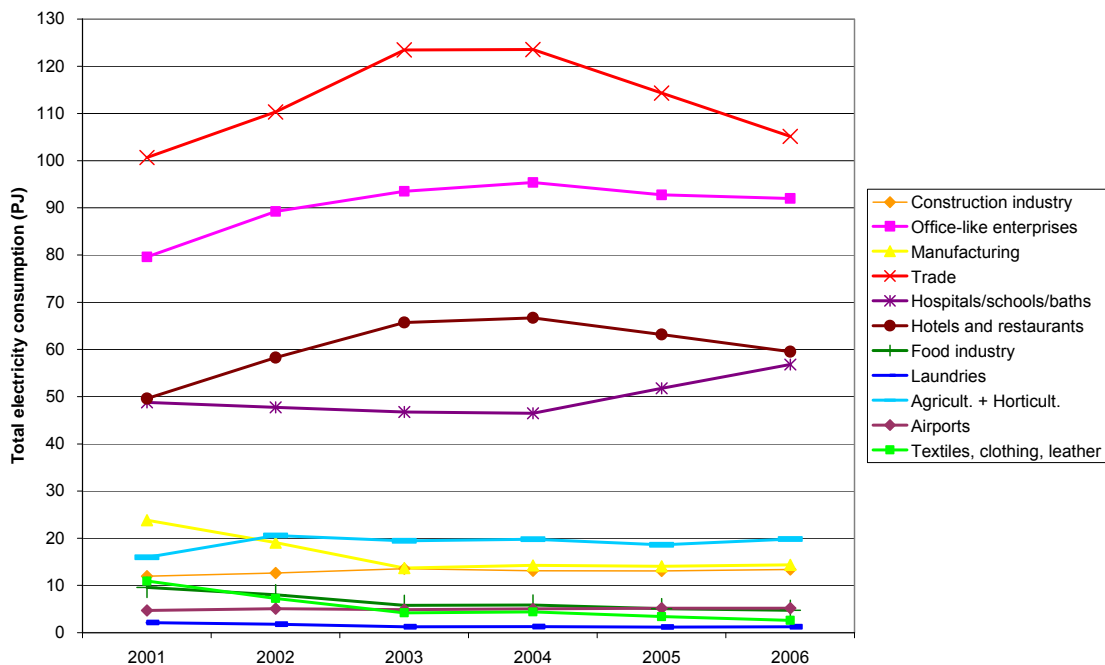


Figure 2: Fuel and district heat consumption of individual branches of the tertiary sector 2001-2006

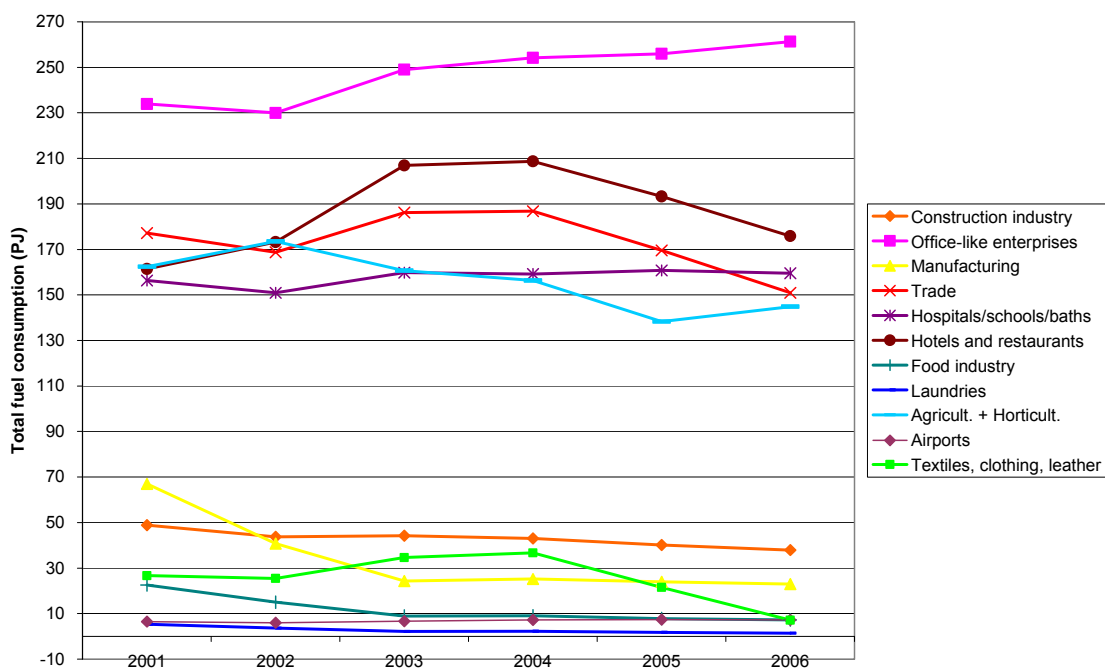


Table 6: Projected consumption of fuels by energy source in the tertiary sector for 2006

2006		Specific consumption						Ref. **	Absolute consumption					
		Fuel *	Coal	Wood	Liquid	Gas-eous	District heat		Fuel *	Coal	Wood	Liquid	Gas-eous	District heat
Sum									967,3	1,8	58,7	333,6	434,2	139,0
Grp.	Split	[MWh/ref.]						[1000]	[PJ/a]					
1	Construction industry	4,9	0,0	0,8	1,9	2,0	0,2	2.159	37,8	0,4	6,5	14,4	15,5	1,1
2	Offices	6,9	0,0	0,1	2,9	3,2	0,7	10.567	261,7	0,0	4,0	109,1	120,2	28,4
3	Manufacturing enterprises	7,7	0,1	1,1	3,1	2,7	0,7	833	23,0	0,0	3,2	9,4	8,3	2,2
4	Retail trade	7,6	0,0	0,1	2,2	4,5	0,7	5.549	150,8	0,7	2,2	44,3	90,4	13,3
5	21 Hospitals	18,5	0,0	0,0	1,6	10,6	6,3	683	45,4	0,0	0,0	4,0	25,9	15,5
5	22 Schools	1,3	0,0	0,0	0,1	0,9	0,3	14.383	69,5	0,0	0,0	7,2	45,0	17,3
5	23 Public baths	2,7	0,0	0,0	0,1	1,3	1,3	4.650	44,6	0,0	0,0	1,1	21,2	22,3
6	Homes and restaurants	13,2	0,0	0,6	3,7	6,5	2,4	3.700	176,0	0,7	8,3	49,0	86,4	31,7
7	5 Bakers	15,7	0,0	0,3	8,0	7,3	0,0	83	4,7	0,0	0,0	2,5	2,2	0,0
7	6 Butchers	8,3	0,0	0,5	2,8	5,1	0,0	66	1,8	0,0	0,0	0,7	1,1	0,0
7	7 Other food	10,6	0,0	0,0	7,1	3,4	0,0	14	0,4	0,0	0,0	0,4	0,0	0,0
8	Laundries & dry-cleaners	10,4	0,0	0,0	4,1	5,5	0,8	37	1,4	0,0	0,0	0,7	0,7	0,0
9	Agriculture	54,5	0,0	14,5	35,7	4,3	0,0	666	130,7	0,0	34,6	85,7	10,4	0,0
10	Horticulture & gardening	22,5	0,0	0,0	13,7	8,8	0,0	175	3,9	0,0	0,0	2,4	1,5	0,0
11	Airports	0,0	0,0	0,0	0,0	0,0	0,0	214.097	7,2	0,0	0,0	1,8	1,8	3,6
12	Textiles, clothing, leather	2,5	0,0	0,0	0,2	1,1	1,2	794	7,6	0,0	0,0	0,7	3,2	3,6
13	Rest	0,9	0,0	0,1	0,4	0,3	0,1	320	0,7	0,0	0,0	0,4	0,4	0,0
Extrapolation result									967,3					

* with district heat and incl. fuels of agriculture and forestry and airports

** Reference unit: usually number of employees; alternative reference units for hospitals (no. beds), schools/univ. (no. Pupils/students), baths (water volume m2) and airports (no. of passengers or 100 kg freight).

3.4 Balances of energy consumption by energy uses

One of the main elements of the two broad surveys and especially of the in-depth interviews was to collect information about energy use within the individual groups. Based on this, the electricity and fuel consumption determined here for 2006 were divided into the following energy uses (Table 7):

- *Space heating*: The electricity used for heating rooms as well as the amount of electricity resulting from the additional heat demand via fans and radiators. Fuel and district heat used for heating commercially used buildings.
- *Process heat*: Electricity used for hygiene (hot water) and for thermal processes (heating, boiling, frying, melting, welding, tempering, drying etc.). The energy used to meet the hot water demand in the businesses for personal hygiene (hand washing, showering, bathing) and for process technology procedures (washing and cleaning, boiling and cooking, sterilising, burning and welding etc.) as well as to meet the heat demand of swimming pools and under-glass constructions.
- *Cooling*: The electricity consumption of stationary and mobile electrically-powered compressors for producing cold for central and decentral air conditioning systems and space cooling as well as the gas used to operate absorption chillers for air conditioning commercial areas.
- *Process cooling*: The power consumption of electrical chillers in cold stores, walk-in coolers of refrigerated display cases, freezers and fridges which are supplied by absorption chillers. The gas used by cold stores, walk-in freezers and cold stores, centrally supplied freezers, refrigerated displays, freezers and fridges supplied using absorption chillers.
- *Mechanical energy (power)*: Electricity used to power machines and appliances excluding the consumption of compressors used for process cooling and to produce cold for air conditioning and space cooling. On top of this, the fuel used to power combustion engines in agriculture (tractors etc.), in the construction industry (to generate electricity and compressed air, for diggers and wheel loaders etc.), at airports (airplane tractors, buses etc.) and used for stationary purposes in businesses.
- *Lighting*: Electricity used for lighting commercially used rooms and lighted open spaces, advertising and shop windows and street lighting.
- *Information and communications*: the electricity consumption of appliances to obtain, process, disseminate, store and document information (computers, servers, printers, copiers etc.), for communications (telephones, mobile phone chargers etc.) as well as for cash registers etc.

Even if there are boundaries to the depth of information desired because sound data on the technical installations and company processes can only be obtained to a limited extent given the duration of the interview, it was still possible to compile an

approximate balance characteristic for tertiary sector applications based on the data from the broad and detailed survey, secondary studies and expert knowledge. The differentiation of energy uses chosen here is more detailed than that of the Working Group Energy Balances, the BDEW⁸ project group on useful energy balances and the national application balances compiled by the IfE/TU Munich for all consumption sectors (Tzscheuschler et al. 2008). As well as the areas of process heat, space heat, power, lighting and ICT distinguished there, this study also treated air conditioning and cooling separately. This was done in order to take account of the growing importance of these energy applications and increase the international comparability of the data.

According to these energy consumption calculations (Table 7), lighting is the dominant use with 40%, followed by the electricity for motor drives (power). The share of air conditioning (for cooling) in power consumption is still low today; only at airports does it reach a share of about 10%. Process cooling plays a bigger role in the tertiary sector, especially in the retail trade, in hotels and restaurants and in parts of the food industry.

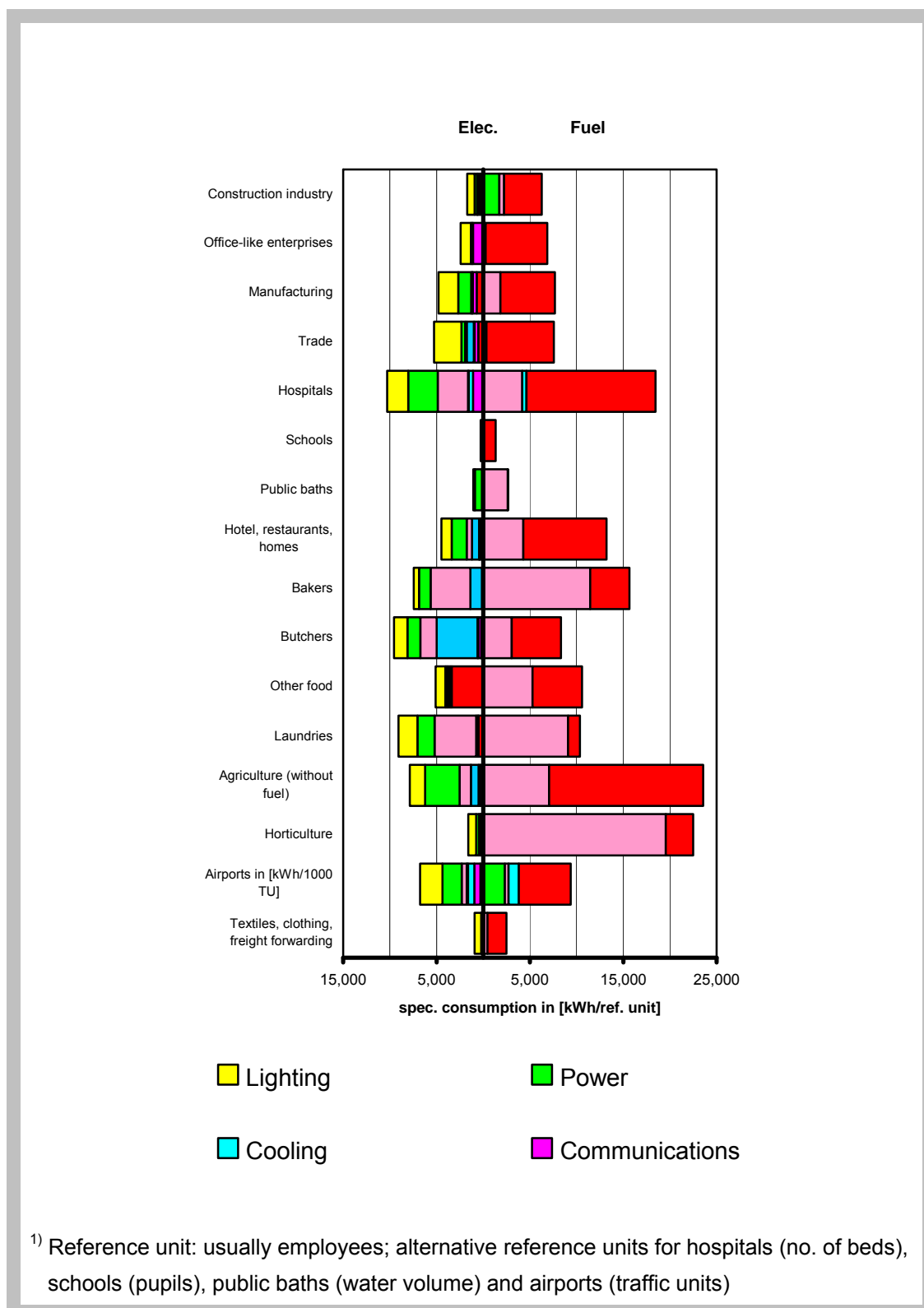
The application structure for fuels is less differentiated; more than 70% of the energy demand in the tertiary sector is accounted for by space heating followed by process heat with almost 18%.

Figure 3 shows the electricity and fuel consumption values in the various groups of the tertiary sector related to the respective reference units by energy uses in 2006.

⁸ German Association of the Energy and Water Industries

Table 7: 2006 balances for electricity and fuel/district heat by energy uses

2006 Grp. Split Definition No.			Consumption		Shares											
			Elec. absolute [TWh]	Fuels & district heat absolute [TWh]	Electricity							Fuels and district heat				
					Lighting	Power	Process heat	Process cold [%]	AC	Commu- nications	Space heating	Power	Process heat	Process cold [%]	AC	Space heating
1	Construction *	3.7	13.5	46.0	15.5	4.9	0.5	0.2	13.5	19.3	27.4	8.2	0.0	0.0	64.4	
2	Office-like companies	25.6	72.6	44.9	3.1	4.1	0.9	2.0	41.8	3.1	0.0	3.6	0.0	0.2	96.2	
3	Manufacturing enterprises	4.0	6.4	44.0	29.2	2.2	0.3	1.0	8.6	14.7	0.5	23.3	0.0	0.0	76.1	
4	Retail trade	29.2	41.9	55.5	7.6	3.1	14.6	1.5	8.0	9.8	0.0	4.3	0.3	0.1	95.2	
5	21 Hospitals	7.0	12.6	22.0	30.6	31.5	0.9	4.5	10.6	0.0	0.0	22.6	0.0	2.5	74.9	
5	22 Schools	3.8	19.3	66.9	9.6	2.0	1.8	1.5	11.5	6.6	0.0	5.4	0.0	0.1	94.5	
5	23 Public baths	4.9	12.4	14.5	71.5	13.5	0.0	0.1	0.4	0.0	0.0	98.8	0.0	0.0	1.2	
6	Hotels, restaurants, homes	16.5	48.9	24.2	36.1	12.7	17.4	0.3	2.8	6.6	0.0	32.5	0.0	0.0	67.5	
7	5 Bakers	0.6	1.3	7.5	16.8	57.3	16.6	0.1	1.6	0.2	0.0	73.2	0.0	0.0	26.8	
7	6 Butchers	0.6	0.5	15.0	14.6	18.2	45.7	0.9	3.4	2.3	0.0	36.5	0.0	0.0	63.5	
7	7 Other food	0.1	0.2	20.3	3.0	2.6	0.2	4.5	3.5	65.9	0.0	50.0	0.0	0.0	50.0	
8	Laundries	0.3	0.4	22.3	20.3	49.1	0.1	1.7	0.9	5.6	0.0	87.8	0.0	0.0	12.2	
9	Agriculture	5.2	36.3	20.8	46.9	15.6	10.4	2.1	3.1	1.0	56.8	13.0	0.0	0.0	30.3	
10	Horticulture	0.3	3.9	52.3	17.4	11.6	1.2	2.3	11.6	3.5	0.0	86.9	0.0	0.0	13.1	
11	Airports	1.4	2.0	35.4	30.3	8.1	2.0	10.1	9.6	4.5	24.9	4.0	0.0	11.9	59.3	
12	Textiles, clothing, forwarders	0.7	2.0	77.0	1.1	5.0	0.6	0.0	13.2	3.1	0.0	18.6	0.0	0.0	81.4	
Sum Groups 1 - 12		104.1	274.2	40.8	19.2	8.6	8.2	1.6	15.4	6.3	9.1	18.0	0.1	0.3	72.7	
13	Rest	1.4	0.3	44.0	29.2	2.2	0.3	1.0	8.6	14.7	0.0	30.0	0.0	0.0	70.0	
Extrapolation result		105.5	274.5	40.9	19.3	8.5	8.0	1.6	15.3	6.4	9.9	17.7	0.1	0.3	72.1	
	Street lighting	3.4		98.0	0.0	0.0	0.0	0.0	2.0	0.0						
	Share installations MFH	1.3		29.0	70.0	0.0	0.0	0.0	1.0	0.0						
	Military	1.2	7.3	44.9	3.1	4.1	0.9	2.0	41.8	3.1	41.1	6.8	0.0	0.0	52.1	
	Others	6.3		10.9	75.6	4.8	0.8	0.9	6.8	0.1						
	Undocumented	12.2	7.3	40.5	46.8	2.9	0.5	0.7	8.3	0.4	41.1	6.8	0.0	0.0	52.1	
Calculations tertiary		117.7	281.8	40.8	22.2	7.9	7.3	1.5	14.5	5.8	9.9	17.7	0.1	0.3	72.1	
* incl. fuels for building site operations																

Figure 3: Specific electricity and fuel consumption per reference unit in 2006¹⁾

4 Sector-specific analyses

In addition to the extrapolation, the data collected in the two broad surveys for 2004 and 2006 as well as in the interviews in the various branches of the tertiary sector can also be used to examine energy consumption in the businesses more closely. The analyses concentrate on general and sector-specific energy-relevant features as well as indicators and their correlation with energy consumption. Generally recorded aspects included ventilation and air conditioning, lighting, office equipment, break rooms and canteens. Unlike the extrapolation, these evaluations are based on raw data, into which the data of all the enterprises surveyed were entered without being weighted. In view of some low case numbers in individual groups, the statements are not strictly representative. However, since the quota was essentially fulfilled, even in the sub-groups, the results are still very useful for obtaining a more detailed insight into the sectors. The questionnaires in the broad survey for 2006 and some of the in-depth interviews were supplemented by an "energy management" element containing questions on how the topic of energy is handled, energy consumption monitoring, conducting energy-saving measures, information and decision behaviour, energy consultation and motivating employees.

Energy technology equipment by sector

From the wealth of sector-specific data obtained, only a few energy-relevant features of tertiary sector branches can be illustrated here as examples. These are mainly based on the results of the second broad survey which was conducted at the end of 2007/beginning of 2008, as well as the detailed interviews of summer 2007. While the broad survey explicitly asked about the energy consumption for the survey year 2006, the answers to questions about the features mainly reflect the situation at the time of the interviews.

The *construction industry* is a very heterogeneous sector with regard to company size and structure. Structural and civil engineering and prefabricated building are the main components of the building trade; plumbers/fitters and painters/varnishers are the biggest lines of business in the finishing trade. Energy consumption is split into space heating and production in the companies as well as numerous machines and appliances on building sites and building site traffic. As was to be expected, businesses in the main building trade operate many more energy-intensive appliances both within companies themselves and on the building sites. Almost all the appliances are electrically powered apart from forklift trucks and dump trucks. There are considerable problems with recording energy consumption in the construction industry, especially on building sites, e.g. for site electricity and heating containers, because the costs for

these are borne by the building owner. It is also difficult to correctly split the diesel consumption of building site vehicles which is partly assigned to the tertiary sector and partly to the transport sector.

The industrial branches grouped together here under the heading of "*office-like enterprises*" cover a wide range of public and private services: banks and insurance offices, public utilities and other business services, some with an obvious office character such as lawyers, solicitors or tax advisors, but others with more energy-relevant aspects like waste disposal services, hairdressers, cleaning services or doctors. From the viewpoint of energy, however, most of these have similar structures. Space heating dominates followed by electricity applications for lighting, ventilation and air-conditioning, information and communication technologies. The share of air conditioned, cooled or ventilated rooms is around 10% on average in this group. About one third of the businesses with air conditioning or cooling have a central air conditioning system, two thirds have small units; mobile units are more common than split ones. The lighting system may be as old as 45 years; the average of 11.7 years is a bit lower here than in the other branches. In customer-occupied and office areas, the share of fluorescent and energy-saving lamps is relatively high at around 70%; halogen lamps are used especially in shop windows and open spaces. As expected, office-like enterprises have more office equipment than other branches of the tertiary sector; this is especially valid for banks, insurances and public institutions.

Metalworking, the automobile trade, wood, paper and printing businesses all count as *manufacturing enterprises*. Alongside general features such as heating, lamps, office equipment and ventilation and air conditioning, sector-specific process technologies play a greater role in this group, especially with regard to electricity. Fuels, in contrast, are predominantly used for space heating. *Metal working* encompasses heterogeneous industrial branches with different energy intensities. Relatively, mechanical and electrical engineering, locksmiths and welding shops, the production of medical and orthopaedic products and other metal products have the biggest shares in the tertiary sector. The variety of production technologies used is correspondingly large; most of these are electrically powered, e.g. compressed air production, moulding/shaping and separating. As well as for space heating, fuels are also used for processes involving heat treatments such as, e.g. hardening, tempering, welding etc. The *automobile trade* is made up of car repair garages, car dealers and mixed services. The main field of activity for the repair garages is motor mechanics followed by bodywork and paintwork. There are office and sales rooms on top of this. Electricity in these companies is mainly used for lighting, powering pumps and equipment as well as for compressed air for the repair and service areas. *Wood and wood products* covers the manufacturing of furniture (three quarters of those surveyed) and building components (11%), each with

relatively little energy-intensive equipment; the other businesses are sawmills. Suction systems represent the biggest power consumers in carpentry/joinery with a share of approx. 40% in the total electricity consumption. In the *paper and printing trade*, the small enterprises comprise printers, bookbinders, copy services. Electricity is mainly used for printing machines followed by cutting, folding and stitching. Digital printing machines, compressed air, lighting, air conditioning and operating systems in standby-mode are also relevant.

Alongside offices, *wholesale and retail trade* is the largest branch in the tertiary sector with more than 5.5 million workers. There is a significant difference in energy consumption between food and non-food lines of business. The food trade has a high demand for refrigeration and freezing. But space heating demand is also a main energy consumer. Lighting represents a large factor in trade on the electricity side. The air conditioning of salesrooms also has a noticeable impact in food retailers. Although the number of retail trade businesses is declining as a result of the concentration process, the sales areas have been increasing for years which will probably influence energy consumption. Since the last survey, shop opening hours in Germany have increased slightly from Mondays to Fridays and significantly on Saturdays (21% more than eight hours compared to 8% previously). More and more grocers and food stores have areas where baked products and small snacks are served, which are equipped with ovens to bake or heat bread, meat and processed meat products. 24% of the businesses questioned have one or several ovens of this type. The energy demand of modern cash registers is also not negligible.

Hospitals, schools and public baths vary greatly with regard to energy and should therefore be regarded separately. Since the specific energy consumption based on the number of employees is limited in its meaningfulness in this sector, more suitable reference units – the number of beds, number of pupils/students and water volume - were used here. *Hospitals* are characterized by high space and process heat demand. The latter is particularly relevant if the hospital runs its own laundry. Apart from lighting, electricity is required mainly for ventilation and air conditioning. *Schools* are a very heterogeneous group ranging from kindergartens right up to universities. Space heating demand dominates the energy consumption here. Electricity is mainly used for lighting. The main distinction with regard to *public baths* is between indoor swimming pools and outdoor ones. "Leisure pools" represent a combination of the two which is becoming more common. A large share of the energy consumption in public baths is for the process heat used to heat the water, but also for space heating in indoor pools. Modern public baths are equipped with very complex building technology, mainly for ventilation, electrical engineering and pool technology which causes considerable electricity consumption. In addition, pools are also increasingly equipped with additional installations

which are energy-intensive such as saunas, solariums, wellness and health-related areas, fitness rooms, restaurants etc.

The hotel and restaurant sector consists of catering and accommodation. It is true that, as a service sector, there are businesses of every size in the tertiary sector, but this area is dominated by small to very small enterprises. Space heating and thus fuel consumption is the most important in both sectors from the viewpoint of energy consumption. The second largest energy consumer after space heating is process heat for kitchens, mainly for cooking food, but also for heating food and keeping it warm, preheating and cleaning dishes. Electricity is also used mainly for cooking, followed by refrigerators/freezers, then for dishwashing, laundry and lighting. Refrigerators and freezers are becoming more significant because of the growing use of frozen products due to a greater flexibility. Lighting also plays a relatively important role for energy consumption.

Bakers and butchers are the main lines of business in the tertiary sector belonging to the *food industry*. Baking ovens have the biggest energy consumption in *bakers*. In the *bakers* covered here, which tend to be quite small enterprises, mostly discontinuous processes are used, e.g. rack ovens or deck ovens. Today outlets and production facilities including a retail outlet often have an electric oven directly in the salesroom to finish baking pre-produced raw pastries and rolls. Electricity is additionally used mainly for cooling devices. Comparatively low shares of electricity are accounted for by power applications (machines, e.g. to sieve, mix, knead and stir, as well as ventilation), lighting and hot water production. In *butchers*, the main consumption of energy is for producing sausages and processed meat products. Various heating processes are carried out in large cooking boilers and combi-ovens. Making raw sausages is done in maturing chambers and smokehouses. Production plants are mostly fuel-heated, fewer use electricity. The main electricity share is due to heating water, refrigerating and freezing. Electricity consumption for refrigeration and freezing is on the increase because more and more refrigerated and frozen products are being used or sold.

The group of *laundries* covers the entire textile cleaning industry, i.e. laundries, dry cleaners, textile rental services, dyeing works, ironing and rotary iron services. This is a comparatively energy-intensive sector. Energy is mainly used for heat processes: washing, drying, hot pressing/mangling, cleaning and ironing. The energy required for space heating is negligible. Due to the high demand for process heat, there is usually enough waste heat available to heat the production areas. Space heating is predominantly needed for separate rooms, e.g. sales, offices and canteens. The electricity demand comes from lighting to a lower extent, but is mainly due to the electric motors used to drive machines and provide ventilation.

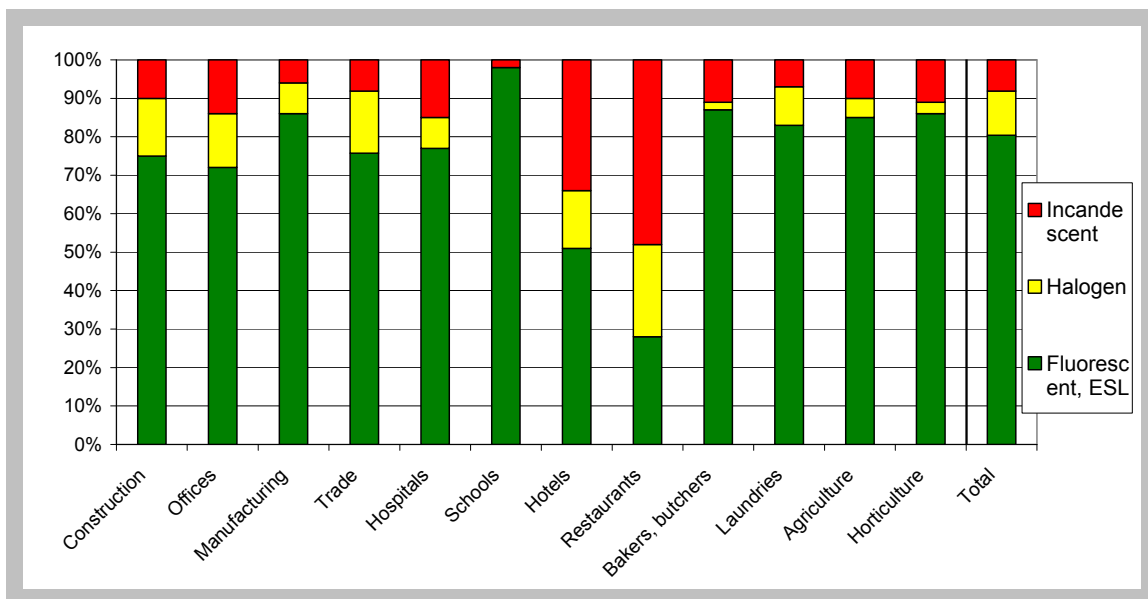
Based on the number of workers, *agriculture* is quite an energy-intensive sector. This has to do with the low average number of employees per farm. The 116 agricultural enterprises questioned only have 3.4 workers on average, half of them actually only have one or two workers. Livestock farming has the biggest energy demand. Crop farming is not as energy-intensive with a few exceptions (grain drying), if the fuel consumption of farming vehicles is disregarded. The main electricity applications are power processes, mainly the ventilation of animal pens in intensive livestock farming, as well as for cooling milk. Process heat is needed for radiant heaters when rearing chicks and piglets. In horticulture, especially those enterprises with heated under-glass areas are very energy-intensive. Fuels are used to heat greenhouses; electricity is needed for lighting, ventilation and heating small areas of plants as well as for controlling automatic ventilation and irrigation processes.

Cross-sectoral comparison of energy-relevant features

In the following, a cross-sectoral comparison is made of lighting, office equipment, ventilation and air conditioning as well as company break rooms and canteens by evaluating the results of the second broad survey. The energy features concerned illustrate the situation at the time of the survey – end of 2007/beginning of 2008.

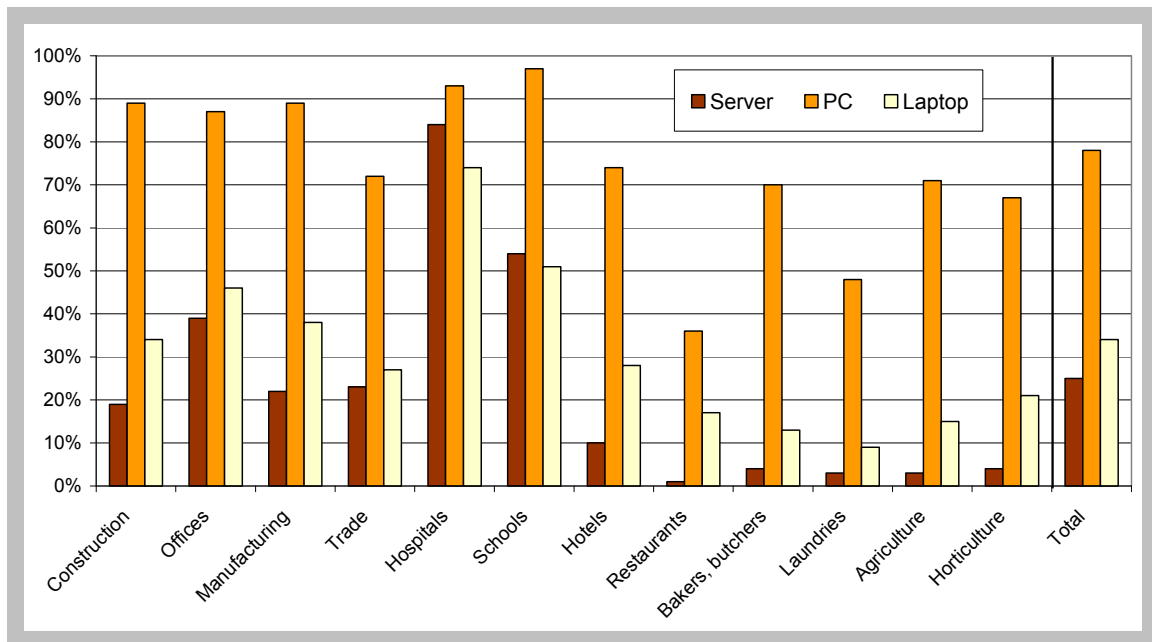
With regard to *lighting*, the rooms evaluated were those considered to be the most typical for each sector. The lighting in salesrooms was taken for the retail trade and in offices for office-like enterprises; otherwise the lighting in production was selected. In restaurants, this means the kitchens, for hotels and hospitals, the rooms, and in schools, the classrooms. It is apparent that fluorescent and energy-saving lamps are most often found in schools and least often in restaurants and hotels. With the exception of these last two branches, the share of these lamps always exceeds 70% (Figure 4).

Figure 4: Types of lamps in production 2007 (mean per sector)



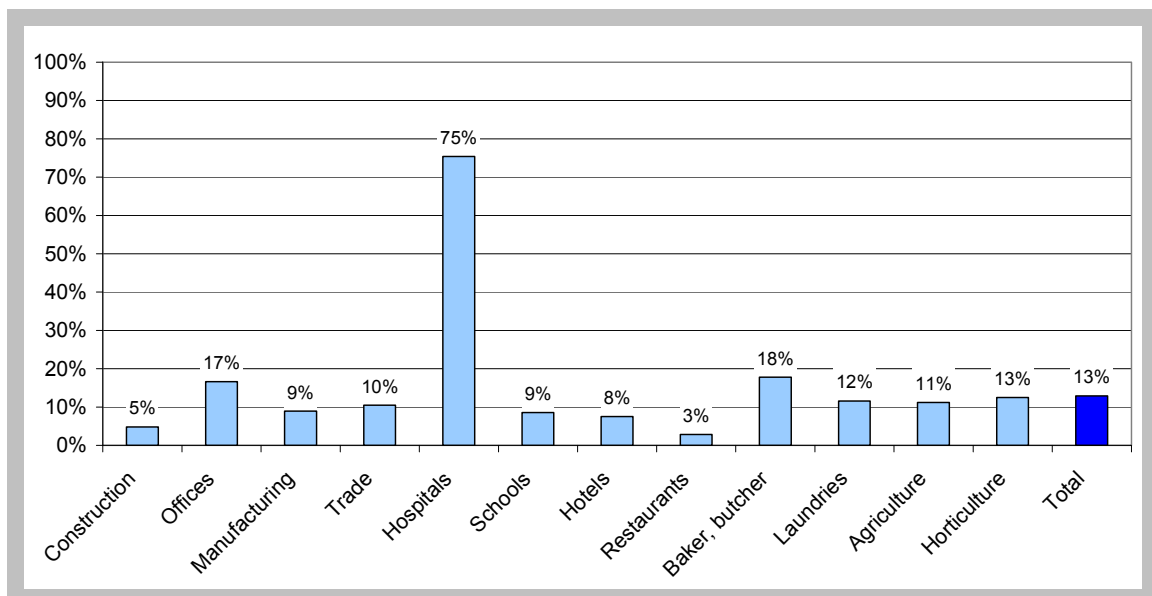
Among the group of *office appliances*, computers are particularly interesting (Figure 5). 25% of the questioned businesses have one or more than one server or mainframe computer, almost half of them in an average power range between 300 und 2,000 W, about 30% are smaller and 20% larger. On average almost 80% of all the businesses have an Internet connection, hospitals and schools are most likely to have one, restaurants and laundries least likely. There are similar differences between the sectors with regard to LAN and WLAN connections; 14% of all enterprises have WLAN on average. It is also possible to compare the group of office-like businesses with the results of the previous survey (Fraunhofer ISI et al. 2004). This shows that office equipment has increased in the five years which lie between these two surveys. A shift towards more powerful servers can be observed and a clear increase in the number of laptop computers. The number of laser printers has risen disproportionately and for photocopiers there has been a shift from large to smaller machines.

Figure 5: Equipment with servers, PCs and laptops 2007



Air conditioning or cooling in any form, whether this be with small mobile units, split appliances or a central air conditioning system, is used by 13% of enterprises, usually however only in some of the rooms. Hospitals really stand out among the different sectors, 75% of which have air-conditioned rooms (Figure 6).

Figure 6: Share of enterprises with air conditioning



Energy management in the enterprises

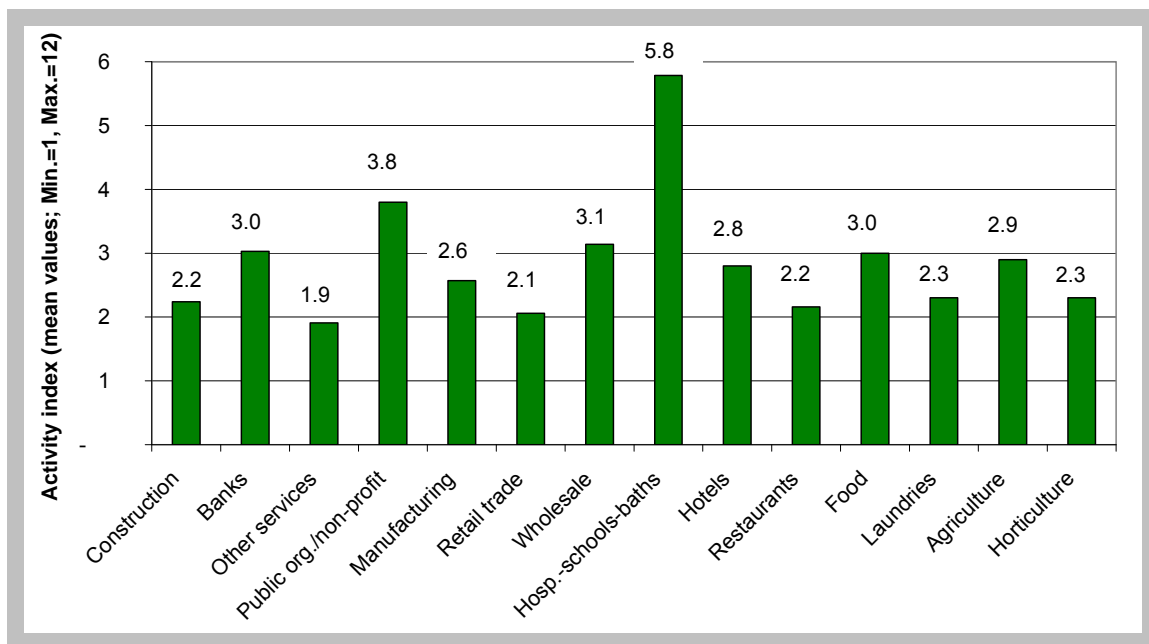
In the in-depth interviews in 2007, a short questionnaire on energy management was tested in the companies. This was then integrated in the second broad survey after minor improvements. Questions were asked about the energy efficiency measures conducted, monitoring energy consumption and information behaviour:

- There are persons responsible for energy or environmental issues in 23% of the companies. However, reporting on energy or environment issues is rare (8%). There is a strong correlation here with company size: the larger the company, the more likely it is for these two questions to be answered in the affirmative.
- Energy saving as an issue when making investments: 59% of those asked stated that energy saving is always a topic for new acquisitions, 25% take this into account sometimes, 11% rarely and 5% never. The answers are related to how influential the companies are: if they are branch offices or rent or lease their rooms, energy saving is less likely to be an issue.
- One quarter of the companies uses energy saving or environmental friendliness in their public image.
- Regarding the question whether energy-saving measures were carried out in the last 5 to 7 years, are being carried out, or are planned to be implemented in the near future, and whether there is a need for action, the following picture emerges for the majority of companies: 57% have conducted measures, 18% have ongoing ones and 29% see a need for action.
- Of the measures already implemented, the most frequent ones cited concern lighting: 64% mentioned switching off unnecessary lights or making the greatest possible use of daylight, 53% more efficient bulbs or lighting systems. One behavioural measure is also turning off energy-consuming installations (52%).
- Monitoring energy consumption and information behaviour are other important aspects of energy management. In around half of the companies, energy consumption is recorded and evaluated once each year. Public baths and hospitals have by far the most frequent energy consumption checks, whereas this is below average in other service companies, bakers, building companies and the retail trade. 17% of the respondents stated that they keep themselves informed about energy efficiency measures "continuously", 44% "occasionally" and 39% "seldom or never". The information sources most often mentioned in this context are official organizations, e.g. energy agencies.
- One way to overcome company-internal knowledge gaps is to call in the services of an energy consultant. 44% of the respondents have had an energy consultation at least once. For almost half of these, however, this only concerned advice on tariffs, the company's operation was analysed for 31% and 20% were given advice for a specific area or system.

- A final question concerned the involvement of the workforce and customers in the efforts to improve energy efficiency. The workforce is assigned a high level of influence for 27% of the respondents and a relatively high influence for 29%.

If an "activity indicator" is constructed from 12 items concerning energy management, it becomes clear that there is a correlation between company size and this indicator in almost all sectors: the larger the company, the more active it is. This indicator has the highest value for the group of hospitals, schools and public baths (Figure 7).

Figure 7: Activity indicator of energy management by sector



5 Use of renewable energies in the tertiary sector

An updated inventory of renewable installations in the tertiary sector was compiled from the sample drawn from the short telephone survey in over 20,000 workplaces of the tertiary sector in conjunction with the corrective, follow-up survey in almost 1,700 firms. This inventory, which distinguishes 10 technologies and 12 groups, serves as the main database for the extrapolation of the consumption of renewable energy sources. Other additional, technical details about the installations were drawn from the 300 in-depth interviews.

Table 8: Inventory of renewable installations in the tertiary sector derived from the survey

Group	All businesses	No. questionnaires with "YES"									
		Photovoltaic	Solar panels	Wind power	Small hydro	Heat pumps	solid biomass	liquid biomass	Biogas	Bio-fuels	of which biodiesel
1 Construction industry	1,875	286	288	0	21	131	138	0	4	101	77
2 Offices	5,149	212	312	15	0	123	181	15	13	130	83
3 Manufacturing enterprises	1,683	40	94	5	8	1	92	1	0	62	42
4 Retail trade	4,280	45	87	3	32	67	109	0	10	205	173
5 Hospitals/schools/public baths	1,905	127	143	6	9	104	22	4	3	10	0
6 Homes and restaurants	2,527	66	196	18	18	49	145	0	7	88	51
7 Bakers/butchers & other food	1,269	22	65	0	0	0	55	0	2	50	32
8 Laundries & dry cleaning	605	13	30	3	10	0	8	5	4	18	16
9 Agriculture	954	74	130	6	4	0	86	13	63	141	75
10 Horticulture	200	12	13	0	0	6	20	0	0	15	10
11 Airports	31	0	4	1	0	1	3	0	0	2	2
12 Others	116	1	4	1	1	9	5	2	0	18	15
Total	20,594	898	1,365	59	101	492	863	40	106	839	577

Table 9 gives an overview of the projected results of energy obtained from the use of renewables in the tertiary sector differentiated by the 12 groups. Because of the knowledge gaps of the respondents, which were apparent even in the in-depth interviews, these results should be treated critically, compared with other official statistics, reliable publications and study results and commented on.

Table 9: Derived projected results from the survey on the use of renewable energy sources in the tertiary sector for 2006

Renewable technology		All	Group										
			Construction industry	Offices	Manufacturing enterprises	Retail trade	Hospitals/schools/baths	Hotels and restaurants	Bakers/butchers	Laundries	Agriculture	Horticulture	Airports
Photovoltaic: electricity production	[TWh/a]	1.6	0.7	0.4	0.0	0.1	0.0	0.2	0.0	0.0	0.3	0.0	0.0
Solar collectors: heat production	[TWh/a]	2.5	0.6	0.7	0.1	0.1	0.1	0.7	0.0	0.0	0.2	0.0	0.0
Heat pumps: heat production	[TWh/a]	5.0	2.6	0.3	0.0	0.9	1.1	0.0	0.0	0.0	0.0	0.1	0.0
solid biomass: use	[TWh/a]	21.0	3.1	8.5	0.1	3.1	1.0	2.9	0.0	0.0	2.0	0.3	0.0
Biogas: electricity	[TWh/a]	5.9	0.0	0.2	0.0	0.1	0.0	0.1	0.0	0.0	5.5	0.0	0.0
heat	[TWh/a]	9.6	0.1	0.3	0.0	0.2	0.1	0.1	0.0	0.0	8.8	0.0	0.0
Biogas use	[TWh/a]	18.2	0.1	0.7	0.0	0.3	0.1	0.3	0.0	0.0	16.8	0.0	0.0
Bio-fuels: use	[bill. L/a]	2.5	0.3	0.1	0.0	0.3	0.0	0.1	0.0	0.0	0.3	0.0	0.0
of which biodiesel use	[bill. L/a]	1.7	0.1	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0

Photovoltaic

According to the extrapolation, a total of 1.6 TWh electricity was produced in 2006 by 16.2 million m² of photovoltaic modules in tertiary enterprises. Under the German Renewable Energies Act, approx. 2.25 TWh electricity were fed into the public grid from private households, public and commercial workplaces in 2006 according to data from VDN⁹ and the Bundesverband Solarwirtschaft¹⁰ (2008). Of this, around 0.6 TWh are probably from private households according to data from the 2006 survey of energy consumption of private households by RWI/forsa (2007). The remaining balance of the total amount of electricity fed into the grid (2.25 TWh) minus the contributions of the tertiary sector (1.6 TWh) and households (0.6 TWh) equals 0.05 TWh. This figure

⁹ German Association of Grid Operators

¹⁰ German Solar Industry Association

would then fall to industry and transport which seems plausible, since neither sector was very active in this technology application.

The 1.6 TWh of electricity produced using photovoltaics which was determined here for the tertiary sector for 2006 can therefore be seen as a relatively reliable figure. There are reservations about the contribution of the construction industry.

Solar collectors (solar thermal)

The extrapolation made in this study indicates a stock of collectors in the tertiary sector with an area of 5.9 million m² which produce solar thermal heat equalling 2.5 TWh. The total stock of solar thermal installations in Germany at the end of 2006 was around 8.6 million m² and generated approx. 3.3 TWh solar thermal energy (BMU 2007). According to calculations of RWI/forsa (2007), the solar thermal heat production of private households was 5.8 PJ or 1.6 TWh. Since there are no significant areas to be reckoned with in industry and transport, the remainder of 1.7 TWh can be largely assigned to the tertiary sector. Because the 2.5 TWh projected here for the tertiary sector is higher than this but is still estimated as relatively plausible, it could be that the reported total current solar thermal heat production of 3.3 TWh may actually be too low.

Wind power

According to the results of this survey, 0.2% of enterprises in the tertiary sector use wind power. With around 3.5 million enterprises in the tertiary sector – and assuming one wind turbine per enterprise using wind power – this would mean that approx. $3.5 \cdot 10^6 \cdot 0.2\% = 7,000$ installations are being operated. This figure also includes small public utilities, which may operate wind turbines for supplying energy. Since the total stock of wind turbines in 2006 was about 19,000 (BMU 2007), this rough estimate of 7,000 installations can therefore be regarded as quite feasible.

Small hydropower

The survey results indicate that 0.3% of enterprises in the tertiary sector use small hydropower plants. With around 3.5 million enterprises in the tertiary sector, this would mean that approx. $3.5 \cdot 10^6 \cdot 0.3\% = 10,500$ plants are being operated.

Since the total stock of small hydropower installations in Germany amounts to approx. 6,000, a deviation by a factor of 1.75 would result if one hydropower plant is assumed per enterprise. In fact, in some cases one small hydropower installation is used by more than one enterprise. The error resulting here is therefore reduced accordingly.

Heat pumps

According to this survey, 2.1% of all enterprises in the tertiary sector use a heat pump. At $3.5 \cdot 10^6$ enterprises, the resulting stock in the tertiary sector would be around $3.5 \cdot 10^6 * 2.1\% = 73,500$ heat pumps.

According to data of the German Heat Pump Association (BWP) (2008), at the end of 2006, about 300,000 heat pumps were installed in households and commercial businesses for heating purposes. An additional 60,000 installations were used for hot water production. Together, therefore, a total stock of 360,000 heat pump systems results in households and tertiary companies. According to HEA (2008), 150,000 heat pumps were installed in households in 2006 as heating technology; in addition to the 60,000 systems for producing hot water, this would mean a total of 210,000 heat pumps in private households. Together with the 73,500 heat pumps from this survey, this would result in a statistically reliable minimum stock figure of 283,500 heat pumps. However, based on the Association's data, the actual stock numbers are probably higher both in households and the tertiary sector, so that the figure of 5.0 TWh for heat pump generated heat indicated in Table 9 is probably underestimated.

Solid biomass

Unfortunately, there are no statistically sound data on the quantities of solid biomass actually used – meaning wood in almost every form and consistency – from firewood through wood off-cuts, waste timber down to sawdust. Referring to the data given by several authors, the following picture emerges: according to Staiß (2007), in total around 66.9 TWh of solid biomass were used in 2004 in households and the tertiary sector for heat production. The RWI/forsa-study (2007) cites an energy consumption of 47.7 TWh of solid biomass by private households for 2006. The difference between the two sources of around 19.2 TWh gives an idea of the lower limit of the actual consumption of solid biomass in the tertiary sector because the total turnover of solid biomass in 2006 can definitely be assumed to be higher than that of 2004. The projected energy use of 21.0 TWh solid biomass in Table 9 can therefore be regarded as completely reliable as far as secondary statistics are concerned.

Liquid biomass

According to this survey, 0.2% of all tertiary businesses used liquid biomass, mainly in agriculture and group 12. The share using this technology there equals 1.4% to 1.7%. Based on 3.5 million enterprises, this would mean around 70,000 companies using liquid biomass. Since liquid biomass use cannot be strictly separated from the use of bio-fuels (vegetable oil) or biogas (slurry), no further evaluation can be made here.

Biogas

Based on the broad survey and the in-depth interviews, around 0.6% of all the enterprises use biogas installations – mostly to generate electricity or connected to heat production. With 3.5 million enterprises, this would be equivalent to a stock of about 21,000 installations. The average capacity is relatively small, about 46 kW/plant. On the other hand, the German Biogas Association, Biogas e.V. (2008) cites a figure of 3,500 installations using biogas in 2006, albeit with a much higher average plant size of 314 kW_{el} per plant. This divergence can be explained by the fact that installations under 20 kW, which turned out to be relatively significant in this survey, are not registered by the Association. A direct comparison of the survey results with the Association's statistics is therefore not possible.

Bio-fuels

According to Table 9, a total of 2.5 billion litres of bio-fuels were consumed in the tertiary sector in 2006, of which 1.7 billion litres were biodiesel. Vegetable oils thus make up the difference of 0.8 billion litres. Official bio-fuel consumption data which can be used to verify this result are available from several sources: the Federal Office of Economics and Export Control (2008), the bio-fuel report of the Federal Ministry of Finance (2007), the Federal Office for Goods Transport and the Working Group Energy Balances, among others (2008). A detailed comparison with these data showed that the bio-fuel quantities extrapolated here for the tertiary sector can be considered sufficiently sound and very reliable.

Renewable energy use and primary energy saving

The contributions made by using renewable energies in the tertiary sector shown in Table 9 need further analysis and evaluation, especially as these partly concern end-use energy (photovoltaic, solid biomass, bio-fuels) and partly useful energy (solar collectors, heat pumps, biogas). In addition, technology-specific indirect energy needs to be considered (electricity), which is typical for solar collectors and heat pumps and essential for operating the plants, but which reduces the efficiency of the renewable source.

Table 10 demonstrates the impact of renewable energies in the tertiary sector in terms of the primary energy which can realistically be saved due to their use.

Table 10: Use of renewable energies in the tertiary sector and primary energy saving in 2006

	1	2	3	4	5	6	7	8	9	10
Renewable technology	Energy use / turnover			Energy prod.		Reference technology			Primary energy saving	
	ren. source [TWh]	Indirect energy Elec. [TWh]	PE equivalent [TWh]	Elec. [TWh]	Heat [TWh]	Type	Utilization ratio [1]	Energy use [TWh]		
Photovoltaic	¹⁾	-	-	1.65	-	Power stat.	0.36	4.58	4.58	
Solar collectors	¹⁾	0.10	0.28	-	2.47	Boiler	0.70	3.52	3.24 ²⁾	
Heat pumps	¹⁾	1.62 ³⁾	4.50	-	4.99	Boiler	0.85	5.87	1.37 ⁴⁾	
Solid biomass	20.99	-	-	-	16.37 ⁵⁾	Boiler	0.85	19.26	19.26	
Biogas	18.20 ⁶⁾	-	-	5.92	9.55	BHS	0.90	17.19	17.19	
Bio-fuels	24.50	-	-	-	-	Refinery	0.95	25.79	25.79	
Total				7.57	33.38				71.43	

1) Solar, ambient heat

2) $2.47 / 0.7 = 3.52$
 $3.52 - 0.28 = 3.24$ 3) COP $\epsilon = 3.08$ $1.62 * 3.08 = 4.99$
 $1.62 / 0.36 = 4.50$
 $4.99 / 0.85 = 5.87$
4) $5.87 - 4.50 = 1.37$ 5) Utilization ratio $g = 0.78$ $20.99 * 0.78 = 16.37$
 $16.37 / 0.85 = 19.26$ 6) Utilization ratio $g = 0.85$ $18.20 * 0.85 = 15.47 = 5.92 + 9.55$
 $15.47 / 0.90 = 17.19$

The Table first shows the extrapolation results for the individual technologies. The associated energy use was determined using typical annual utilization ratios; the indirect energy required using reference values. For each renewable technology shown in Table 10, the associated reference technology is given with the underlying utilization ratio and the related avoided energy use. On this basis, it is then possible to indicate the actual primary energy saving made in the last column, which amounts to around 71 TWh (257 PJ). Compared to this, the electricity and heat totals shown in columns 5 and 6, which add up to about 41 TWh, do not convey an adequate picture of the actual saving.

6 Conclusions and outlook

The study provides energy consumption data differentiated by consumer groups and energy sources which can serve as the basis for efficient and improved examination of the development of energy consumption structures in the tertiary sector. Of course the data cannot match the overall accuracy of the energy balances in mapping real consumption which is defined by a series of provisions. But they do provide differentiated results for areas where the energy balance is only able to present aggregated, unstructured information, and they give insights where conventional data sources fail to do so, e.g. in biomass use or for energy sources which are only traded to a limited extent. Because the survey has now been repeated, it was also possible for the first time to compile time series over a longer period - 2001 to 2006 - for energy consumption in the tertiary sector by branch and energy source for Germany which are comparable at least to a certain extent. This provides another source of information on energy consumption in the tertiary sector which promises to be interesting for international comparisons. On top of this, in contrast to the previous surveys, there is also a differentiated determination of energy consumption by application at sector level for 2006. This is particularly valid for air conditioning, an application which is expected to continue to grow in importance in the future.

The multi-stage telephone survey, which was conducted for the first time on the use of renewable energies in the tertiary sector, proved difficult to start with since there were obvious knowledge gaps among the respondents – mainly small and medium-sized enterprises from very different economic areas – regarding the topic of renewable energies. However, by conducting an intensive follow-up survey and through other technical supplements and corrections, it was possible to extrapolate the energy consumption in the tertiary sector for 2006 for a series of technologies using renewable energy and differentiated by sectors. Nevertheless, for several renewable energies, it was not possible to close all the data gaps or explain all the implausible results. In addition, some differences to data from other sources could not be fully explained here. Due to the low level of knowledge about the use of renewables in the enterprises, in future surveys it is at least recommended to question the users of renewables not only by telephone – as was the case up to now – but also face-to-face where possible, similar to the broad survey, in order to improve the quality of the survey results.

Above and beyond pure energy statistics, comprehensive sector-specific insights can also be gained from the survey regarding energy consumption structures, energy-relevant features, economic framework conditions and energy management in the businesses which can be used for numerous other purposes, for example, designing energy policy measures or structuring the advice given by energy agencies, energy consumer associations and energy supply companies.

7 References

- ADV (Arbeitsgemeinschaft deutscher Verkehrsflughäfen) (2005-2008): Angaben zu Beschäftigten der Flughafenunternehmen und zu Verkehrseinheiten von internationalen Verkehrsflughäfen, Regionalflughäfen und Verkehrslandeplätzen. (<http://www.adv.aero>).
- AG Energiebilanzen (2008): Energiebilanzen der Bundesrepublik Deutschland 1990-2006 und Auswertungstabellen 1990-2007 (inkl. zusätzliche Angaben zum Energieverbrauch des Militärs vom DIW Berlin, Herr Wittke, Stand 11/2005). Stand September 2008. DIW Berlin, EEFA, Köln (<http://www.ag-energiebilanzen.de>).
- ages GmbH (2008): Verbrauchskennwerte 2005. Energie- und Wasserverbrauchskennwerte in der Bundesrepublik Deutschland. 2. Aufl., Münster (<http://ages-gmbh.de>)
- Arbeitsgemeinschaft Qualitätsmanagement Biodiesel e.V.: pers. Mitteilung. Stand 9.4.2008
- BMF - Bundesministerium für Finanzen (2007): Bericht an den Deutschen Bundestag zur Steuerbegünstigung für Biokraft- und Bioheizstoffe – Biokraftstoffbericht 2007. Berlin
- BMU - Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (2007): Erneuerbare Energien in Zahlen – nationale und internationale Entwicklung. Stand Juni 2007. Berlin
- BMVEL (2002-2008): Statistisches Jahrbuch für Ernährung, Landwirtschaft und Forsten, versch. Jgg.
- Bundesamt für Güterverkehr: Marktbeobachtung Güterverkehr (2008): Nutzung von Biodiesel und Pflanzenölkraftstoff durch deutsche Transportunternehmen.
- Bundesamt für Wirtschaft und Ausfuhrkontrolle (2008): Mineralöl Daten für die Bundesrepublik Deutschland (Januar bis Dezember 2006).
- Bundesverband Wärmepumpen (2008): Mitteilungen.
- DIW Berlin/BMVBW (2006): Verkehr in Zahlen 2006/2007. Hamburg.
- DIW, Fraunhofer ISI, TUM-Ife (2000): Erarbeitung kostengünstiger Erhebungsformen zur Erfassung des effektiven Energieverbrauchs im Bereich Haushalte und Kleinverbraucher. Untersuchung im Auftrag des Bundesministeriums für Wirtschaft und Technologie (Projektnummer 27/99). Berlin, Karlsruhe, München. Oktober 2000.
- EWI/prognos AG (2005): Energiereport IV. Die Entwicklung der Energiemärkte bis zum Jahr 2030. Energiewirtschaftliche Referenzprognose. Untersuchung im Auftrag des Bundesministeriums für Wirtschaft und Arbeit. Köln/Basel, April 2005.

- Fachverband Biogas e.V. (2008): Erhebung bei Ministerien und angegliederten Behörden der Länder durch den Fachverband Biogas e.V.
- Fraunhofer ISI, DIW, GfK, IE, TUM-IfE [auch zitiert als Studie /2/] (2004): Energieverbrauch der privaten Haushalte und des Sektors Gewerbe, Handel, Dienstleistungen (GHD). Abschlussbericht an das Bundesministerium für Wirtschaft und Arbeit. Karlsruhe, Berlin, Nürnberg, Leipzig, München, April 2004.
- Geiger, B., Gruber, E., Megele, W. [auch zitiert als Studie /1/] (1999): Energieverbrauch und Einsparung in Gewerbe, Handel und Dienstleistung. Heidelberg: Physica-Verlag.
- HEA - Hauptberatungsstelle für Energieanwendung (2008): Mitteilungen
- Mühlbacher, H., Arndt, U., Schwärzer, M., Geiger, B. (2002): Wärmeerzeuger für die Raumheizung und Warmwasserbereitung. Verbundprojekt ISOTEG. Bayerische Forschungsförderung, ZAE Bayern e. V.
- RWI/forsa: Erhebung des Energieverbrauchs der privaten Haushalte für das Jahr 2005 (2007). Endbericht an das Bundesministerium für Wirtschaft und Technologie. Essen, Berlin
- Staiß, F. (2007): Jahrbuch Erneuerbare Energien. Berlin
- Statistisches Bundesamt (2004-2007): Statistisches Jahrbuch 2004, 2005, 2006, 2007. Wiesbaden.
- Statistisches Bundesamt (2008a): Auswertungen aus dem Unternehmensregister für die Berichtsjahre 2003-2005. Wiesbaden
- Statistisches Bundesamt (2008b): Volkswirtschaftliche Gesamtrechnungen. Fachserie 18, Reihe 1.4, Stand Februar 2008 sowie Mikrozensus zum Arbeitsmarkt für das Jahr 2004. Wiesbaden
- Tzscheuschler, P., Nickel, M., Wernicke, I., Buttermann, H. G.: (2008): Energieverbrauch in Deutschland. Stand 2006: Daten, Fakten, Kommentare. in: BWK Bd. 60 (2008), Nr. 3, S. 46-51
- VDN e.V. und Bundesverband Solarwirtschaft e.V. (2008): Entwicklung des deutschen Photovoltaikmarkts. Vorlesungsunterlagen IfE

Note: This list contains all the literature referred to during the research project.