



Energy consumption of private households and the tertiary sector (trade, commerce and services)

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1 Objective and methodology

The objective of the study was to obtain reliable, representative and internationally comparable energy-related data using empirical surveys for the sectors "private households" and "trade, commerce and services[1]" (referred to hereafter as the tertiary sector[2]), which account for around 45 % of final energy consumption in Germany. A degree of detail is targeted which goes beyond the level of whole sectors and which is underlaid with factors determining energy consumption based on sector-specific technical equipment. One aspect treated in more depth was the contribution of renewable energies, especially biomass, to energy supply. The experience gained with empirical instruments in these surveys should result in recommendations for the future so that reliable, up-to-date figures are available for both sectors at the lowest possible cost.

A written survey was conducted in the private household sector in December 2002 which resulted in a usable case number of 20 235 households. Even though some of the questions asked were difficult to answer, this method was selected because of the much lower costs compared to face-to-face interviews. The fieldwork was done by GfK within the scope of a multi-topic survey which was already being conducted in an existing household panel which further reduced the costs involved. Two pages of the questionnaire were dedicated to energy consumption and various influencing variables. The evaluation was weighted for representative household structures. The energy consumption data determined in the survey were extrapolated specifically for each energy source to the total consumption of private households in Germany. This was based on an extrapolation approach which uses floorspace as the main reference variable plus additional stratification by regions (old and new federal states) and building or household size (see Table 1-1).

Exclusive, face-to-face interviews were carried out in the tertiary sector at the beginning of 2003 in a total of 2 121 workplaces by trained interviewers of the GfK. The main issues were energy consumption, equipment with energy-relevant cross-cutting technologies as well as questions on company structure and sector-specific questions. A quota was fixed for the survey, the sector was divided into 12 groups which were then each differentiated even further according to sectors which were as homogenous as possible so that modified questionnaires resulted for a total of 29 splits. The interviewers were also supposed to make sure that subgroups and different company sizes were represented accordingly. The company survey was supplemented by 40 in-depth interviews in selected sectors following the main questionnaire. In this way, energy-relevant technological details are to be surveyed for all

1 in German, "Gewerbe, Handel, Dienstleistungen "

2 often also referred to as commercial/service sector

sectors in a rolling system over the course of several years. A start was made this year with trade, the construction industry and agriculture. The consumption data surveyed were extrapolated to the total energy consumption of the tertiary sector in Germany using the number of employees (see Table 1-1).

Table 1-1: Comparison of the methods used in surveying the household and the tertiary sectors

	Households survey	**Broad survey tertiary sector**
Sample size	20325 households (27000 gross)	2121 workplaces (quota 2000)
Sample selection	Representative panel	Quota
Type of survey	written	face to face
Size of questionnaire	2 pages incl. cars; within the standard survey of the GfK household panel	3.5 pages, of which 1 page sector-specific
Data check and error handling	specific energy consumption and average costs; exclusion of over 30 %	specific energy consumption exclusion of max. 20 %
Reference variables	floorspace, households	employees
Stratification	Region, type of building, type of household	12 groups, 29 splits, subsplits
Energy structure	from microcensus	from survey
Inventory data	Microcensus 2002	Microcensus 2002 ET3 and other sources
Secondary statistics	-	for agriculture and airports
Supplemented by	-	In-depth interviews for trade, construction industry and agri-culture

Basically, there are two possible approaches to assess the bio-energy consumption in households and the tertiary sector: via the total stock of heating systems with the corresponding specific utilisation factors and via the total revenue of biofuels in the corresponding sectors. To determine the heat supply from biomass in this study, existing statistical data were put together, from which conclusions can be drawn about the present utilisation, and these were supplemented by targeted primary data.

2 Private Household Sector

The household survey took place in December 2002 in over 27 000 representatively selected German private households within the GfK Mail Panel. The total number of respondents can be characterised as very good at 20 325 or 75% of the gross sample, especially as some of the information required was relatively complex. This is especially true for the key questions on the amount of energy used and energy costs. The evaluation of the data resulted in an extrapolation of the energy consumption for the year 2002 on the one hand and, on the other, in analyses of energy related equipment and structural features as well as influencing variables on the energy consumption.

Extrapolation of the energy consumption

When projecting the amounts of energy determined in the survey to the total consumption in Germany, it was helpful that the 2002 microcensus (Statistisches Bundesamt 2003) was available as a statistical base of the parent population for the year examined.

The floorspace was taken as the reference variable for most of the energy carriers in the extrapolation since this correlates best with the consumption for heating (the dominant application in terms of amount of energy used). A combined extrapolation using floorspace and residence was done for coal and wood due to a lower dependence of consumption on area, the extrapolation for electricity (without electrical thermal storage heating) was done using the number of households.

The extrapolations are grounded on a stratification according to region and building size or household type. The data for estimating the energy structure are mainly based on the survey's results. In the case of gas and lignite, these results are adjusted using data from the microcensus. To project the consumption of heating oil and district heat, only data of the microcensus are used.

The extrapolation methods selected for the individual energy carriers are described in Table 2-1 summarised according to reference variables, stratification and energy carrier structure. The quality of the consumption data underlying the survey is also assessed.

Table 2-1: Selection of the extrapolation methods in the private household sector

	Ref. Variable	Stratification		Energy structure	Data quality
Elec. with ESH	Floorspace	Building size	(Region)	Survey	3
Elec. w/o ESH	Household	Household size	Region	(100 %)	2
Gas	Floorspace	Building size	Region	Survey, MC	3
Liquid gas	Floorspace	-	-	Survey	5
Heating oil	Floorspace	Building size	Region	MC	3
District heat	Floorspace	Building size	-	MC	5
Hard coal	Floorsp., dwell.	-	-	Survey	5
Lignite	Floorsp., dwell.	-	Region	Survey, MC	4
Wood	Floorsp., dwell.	-	Region	Survey	4

Explanations	
ESH	Households with electric storage heater
Wood	Logs and other wood without pellets or woodchips
Floorspace	in occupied dwellings in buildings (excl. homes)
Dwell.	occupied dwellings in buildings (excl. homes)
Building size	1, 2, 3 and more dwellings in residential buildings (excl. homes)
Region	Old federal states, new federal states
Survey	according to (complete) application uses given in the survey
MC	Microcensus 2002
Data quality	Quality of the energy consumption data in the survey, Notes 1 to 6

A total energy consumption of 700 TWh resulted from this extrapolation for households in 2002 which can be split as follows: 18 % for electricity, 38 % for gas, 31 % for fuel oil, 5 % for district heating, 1 % for coal and 7 % for wood and other energy sources (Table 2-2). Compared with the consumption shown by the Arbeitsgemeinschaft Energiebilanzen (2003), the extrapolations resulted in lower consumption figures in total and for all energy carriers with the exception of heating oil. However, the overall difference of almost 7 % should not be rated as very large in view of the uncertainties connected with the survey and the extrapolation itself. The main factors of uncertainty were incomplete or incorrect information of the households on energy consumption, sample distortions of the factors determining consumption, as far as these were not able to be considered using appropriate stratification (mainly the building size of multi-family houses and building age), as well as demarcation problems with regard to the statistical basis of the parent population (among others, how to deal with empty apartments or households with secondary apartments). However, because of the experience gained with this study, it can be expected that such uncertainties will be able to be reduced in future surveys.

Table 2-2: Extrapolation of the energy consumption of private households in Germany in 2002 compared with the energy balance statement

	Energy balance [1]		Extrapolation		
	TWh	**%**	**TWh**	**%**	**En.bal.=100**
Electricity	133.9	17.9	125.2	17.9	93.5
Natural gas	285.8	38.1	255.5	36.5	89.4
Liquid gas	8.9	1.2	*8.2*	*1.2*	*92.3*
Heating oil [2]	215.3	28.7	219.8	31.4	102.1
District heat	44.7	6.0	*37.8*	*5.4*	*84.6*
Hard coal	3.3	0.4	*1.4*	*0.2*	*43.4*
Lignite	5.0	0.7	4.4	0.6	87.0
Wood [3]	52.8	7.0	47.2	6.8	89.5
Total	749.7	100.0	699.6	100.0	93.3

1) preliminary figures, dated August 2003
2) Heating oil in energy balance incl. other oil products
3) Wood in energy balance incl. other energy sources

Data shown in italics only robust to a limited extent

Sources: Arbeitsgemeinschaft Energiebilanzen, calculations of the DIW Berlin based on the household survey of energy consumption and the microcensus 2002

Further influencing factors on energy consumption

The survey of the households provided a wealth of useful information on energy consumption and its structural and socio-demographic determinants above and beyond the extrapolation itself. Alongside technical data on the type of building, size, age, heating and hot water system, equipment with electrical appliances, all the important social structure data such as household size, age, occupation or house ownership were recorded and also behavioural data on room temperature and ventilation habits. The large sample allowed detailed evaluations of correlations with energy consumption. However, it must be taken into account that only about one third of those questioned were able to provide usable information about energy consumption; home owners are greatly overrepresented here. As a result, these analyses were always differentiated by house type. The data on living and heating behaviour, in contrast, showed a distribution across the house types corresponding to the parent population. Furthermore, only fuel consumption was regarded here, since it is not possible to distinguish between heating use and other applications for electricity.

Certain technical features have the biggest influence on energy consumption: the annual fuel consumption of detached and semi-detached houses at 202 kWh/m^2 is

clearly above those of multi-family houses with 145 kWh/m^2. Consumption decreases continuously with more recent years of construction, overall by 38 %, this is true for all types of houses. The energy consumption, however, does not drop as much as could have been expected due to the stricter thermal insulation standards; this is probably due to poor workmanship and changes in habits (higher temperatures, more uniform heating of the rooms). However, a steady drop in consumption over the years indicates that the diffusion of better quality standard construction parts has played a main role. The age of the boiler also has a noticeable effect, which can be seen in all building age groups of the houses concerned. The interviewee's estimation of the thermal insulation of the building also showed a clear correlation with the fuel consumption.

Of all the behavioural factors, ventilation intensity has the greatest effect on energy consumption. Almost half of those questioned use energy-efficient intermittent ventilation in winter in the living room and bedrooms, but another large proportion of 38 % open the windows only briefly in the living room but have tilting windows which are left ajar in the bedrooms for longer periods. In comparison with this, the influence of room temperature is smaller. The majority stated that this was between 20 and 22° C in the living room and between 15 and 18 °C in the bedroom. Personal hygiene habits vary widely but play only a comparatively minor role. If the figures for hot water consumption per shower and bath are taken from past experience, a weekly consumption of around 200 litres per person can be estimated from the statements made by the respondents.

To analyse the household's electricity consumption, its equipment with electrical appliances and lights as well as the use of appliances was registered. Large domestic appliances as well as televisions, computers, air conditioners, small heaters, waterbeds, aquariums and saunas were included. Almost all households have a washing machine, a refrigerator - sometimes combined with a freezer - a television, and an electrical cooker; around 50 % of all households have more than one television and refrigerator/freezer. The electricity consumption which was 3 340 kWh on average per household, is significantly influenced by the number of appliances - on average eight per household. Only a small proportion of the respondents were able to provide information about the energy efficiency classes of their appliances: between 7 % for electrical cookers and 23 % for washing machines. On average, half of these households mentioned energy efficiency class A. Alongside the appliances, lighting also played a role for power consumption. The respondents counted an average of 25 lamps in their home, of which about every seventh was an energy-saving one.

Passenger car use in private households

Data were recorded on the passenger car use of private households using an additional array of questions. The main structural features were recorded about the car, its intensity of use and its fuel consumption. The focus here was to compare the survey results with data from other sources, especially the current study "Mobility in Germany 2002" (DIW/infas 2003).

Even if ex post surveys are only limited in their suitability to determine the actual fuel consumption, comparisons have shown that, based on the survey, not only important structural features but also intensity of use and fuel consumption can be comparatively well recorded for cars in private households.

According to the results of the survey of private households, on average 13 112 km are driven each year with a passenger car, with an average consumption of 8.1 litres per 100 km. The mileage and consumption of a car depends heavily on the engine size in terms of cc (cubic capacity) and the type of engine (Table 2-3). Larger cars are generally used more intensively and have a higher specific fuel consumption than smaller ones. Diesel cars are much more efficient compared to cars with Otto engines and are therefore used mainly for a higher annual mileage. The data given by households on vehicle mileage have a broad spread; the very high mileage given in some cases are probably due to a commercial use of the vehicle.

Table 2-3: Mileage and consumption of passenger cars in private households by type and size of engine

	Mileage in km per year			Consumption in litre per 100 km		
	Otto	Diesel	Total	Otto	Diesel	Total
Cars with engine size						
up to 999 ccm	8,723	17,034	9,036	6.7	4.9	6.6
1000 to 1499 ccm	10,220	16,870	10,328	7.3	5.7	7.3
1500 to 1999 ccm	12,212	21,088	13,805	8.4	6.4	8.1
2000 and more ccm	13,874	22,931	16,471	10.1	7.9	9.5
Total	11,661	21,570	13,112	8.3	6.9	8.1

3 Tertiary Sector

The methods and data procurement selected for the tertiary sector are oriented on the experience gained in earlier detailed studies (DIW/EWI/RWI 1982, 1986) and primarily in the last recent survey on "Energy consumption and energy saving in the trade, commerce and service sector" in the mid nineties (Geiger/Gruber/Megele 1999). These studies opened up a whole row of possibilities of simplifying data acquisition which could be implemented in this study.

Basic survey

First of all, within the scope of a basic survey, face-to-face interviews were conducted in 2 121 workplaces of twelve groups in the tertiary sector. To start with, several characteristic values were able to be derived by a cross-comparison of the twelve groups involved which refer to the kind of workplace, the company size and floorspace as well as the heating and hot water used (see Table 3-1). Since the data given on electricity and fuel consumption are not directly checkable, specific consumption values were formed on this base, defined as energy consumption per employee, per m² heated floorspace and per floorspace. These were critically examined based on plausible upper and lower limits for the specific consumption values in question and those lying in extreme ranges outside the distribution of the specific consumption were excluded from further examination. Overall, the quality of the data proved to be very good which was mostly due to the type of survey involved – face-to-face interviews on location.

Extrapolation of the energy consumption

Projecting the electricity and fuel consumption as well as the floorspace presumes a sufficient sub-division of existing, statistically backed and regularly available variables for all workplaces which make it possible to portray an image of Germany's tertiary sector. The most plausible reference variable for the majority of groups proved to be the number of employees[3]. This could be taken from the current microcensus of the Federal Statistical Office (2002, ET3) for the survey year. Since these do not, however, distinguish between employees in the tertiary sector and those in the industrial sector, it was necessary to do a complex demarcation to the industrial sector.

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3 For Group 6 (hospitals, schools, public baths) other reference units were taken as even more appropriate for describing the energy consumption: number of beds, pupils or pool size, for Group 11 (airports) the employees of the airport companies.

Table 3-1: Characteristic values of the tertiary sector groups included in the basic survey

		1 Construction Industry	2 Offices (Public and Private)	3 Production Firms	4 Retail Trade, Wholesale Trade	5 Hospitals, Schools, Baths	6 Hotels, Restaurants, Hostels	7 Food Industry	8 Laundries, dry cleaners	9 Agriculture	10 Horticulture	11 Airports	12 Textile and Clothing Industry, Forwarding
Number of companies	[1]	139	369	135	305	143	204	105	46	94	20	3	4
Medium size of company	[Empl./comp.]	14.9	18.8	12.6	10.7	207.9	10.6	9.1	8.7	3.9	6.8	270.0	85.3
of it: 1-10	[%]	73.4	78.0	69.6	78.7	11.2	78.9	72.4	76.1	92.6	80.0	66.7	0.0
11-25	[%]	21.6	10.3	21.5	14.8	20.3	10.3	25.7	21.7	5.3	15.0	0.0	50.0
> 25	[%]	5.0	11.7	8.9	6.6	68.5	10.8	1.9	2.2	2.1	5.0	33.3	50.0
Medium floorspace	[m²/comp.]	577	490	888	676	10906	1082	360	284	2708	8549	66413	7470
of it: Sale, Office, ...	[%]	24.9	74.0	24.7	60.5	21.9	44.9	25.9	32.3	7.6	14.8	18.3	6.0
Production	[%]	43.2	4.6	56.7	14.0	9.4	10.0	55.0	60.0	43.6	76.6	1.9	66.2
Storeroom, others	[%]	31.9	21.4	18.6	25.6	68.7	45.1	19.1	7.6	48.8	8.6	79.8	27.8
Sale/Office floorspace	[m²/comp.]	144	363	219	409	2388	486	93	92	206	1266	12170	449
> 18°C	[%]	93.6	98.6	88.7	87.4	92.9	94.5	71.9	73.2	81.2	16.4	100.0	100.0
< 18°C / not heated	[%]	6.4	1.4	11.3	12.6	7.1	5.5	28.1	26.8	18.8	83.6	0.0	0.0
Production floorspace	[m²/comp.]	249	23	503	94	1020	108	198	170	1181	6552	1252	4944
> 18°C	[%]	19.1	85.3	73.1	44.2	84.4	83.3	36.8	36.9	20.6	67.2	98.0	97.1
< 18°C / not heated	[%]	80.9	14.7	26.9	55.8	15.6	16.7	63.2	63.1	79.4	32.8	2.0	2.9
Storeroom floorspace	[m²/comp.]	184	105	165	173	7498	488	69	22	1321	731	52991	2077
> 18°C	[%]	8.0	56.0	13.1	13.5	86.9	64.6	8.3	2.4	10.8	2.3	25.4	31.1
< 18°C / not heated	[%]	92.0	44.0	86.9	86.5	13.1	35.4	91.7	97.6	89.2	97.7	74.6	68.9
Floorspace with air conditioning	[%]	4.2	12.8	25.7	15.3	13.4	16.0	32.5	28.1	7.6	55.6	11.0	11.4
Heating													
From outside	[%]	8.6	33.9	15.6	23.9	26.6	15.7	1.0	15.2	3.2	10.0	0.0	50.0
Own heating system	[%]	91.4	66.1	84.4	76.1	73.4	84.3	99.0	84.8	96.8	90.0	100.0	50.0
of it central	[%]	92.9	90.6	92.1	90.1	92.4	93.0	96.2	89.7	83.5	100.0	100.0	50.0
decentral	[%]	3.9	7.0	3.5	7.3	0.0	4.1	1.9	5.1	14.3	0.0	0.0	0.0
Lowering of temperature	[%]	72.7	68.6	77.8	66.2	88.1	72.5	83.8	67.4	47.9	75.0	66.7	75.0
Medium hot water consumption	[l/d*empl.]	3.21	5.19	6.82	44.74	82.61	147.83	66.66	76.58	57.70	8.80	34.57	9.16

On this basis, the extrapolations for electricity and the total fuel consumption were made for all defined groups. In a second step, the fuels were split into individual energy sources (coal, wood, liquid fuels, gaseous fuels, district heat). In addition, more consumption components have to be taken into account for electricity, which were not able to be determined via the survey (mainly street lighting, self-generated electricity) and which amount to almost 6 TWh per year. The result of this extrapolation is shown in Table 3-2 for the branches considered in the survey and the total sector. Servey result A includes the data derived for all groups directly from the interviews, supplemented by the additional electricity use of workplaces not included in the survey. According to this projection, the total energy consumption in the tertiary sector in 2001 amounted to around 395 TWh in Germany, of which 28 % is accounted for by electricity, 34 % by gas, 25 % fuel oil, 9 % district heat, 1 % coal and 3 % wood and other energy sources.

The energy consumption for three of the twelve groups examined - agriculture, horticulture and airports – was also calculated using secondary statistics (Table 3-2, survey result B). In total the consumption calculated in this way is a good 3 % below the survey result A. However, for the majority of energy carriers, the results coincide to a large extent. The largest deviations are found in wood consumption. The reason for this is probably that the secondary statistics do not record the total amount of wood used in the case of agriculture and horticulture, whereas in the extrapolation, based on the results of the survey, non-traded wood is recorded as well.

If the study results are compared with the data in the national Energy Balances (Arbeitsgemeinschaft Energiebilanzen 2003), it can be seen that there is generally a good agreement for fuels in total and, to a wide extent, also for the individual fuels concerned (Table 3-2). The consumption value given for wood in the energy balance statement is the only one which is clearly lower, which also implies that the amount of wood recorded in the energy balance is too low[4]. In contrast, the electricity consumption calculated in this study is almost 15 % lower than in the energy balance statement[5] which could be due to a systematically caused under-recording, especially in the sector of public services. This sector should therefore be treated more comprehensively and in more detail in future surveys.

The survey also allowed an extrapolation of energy consumption by purpose. About 86 % of fuel consumption is applied to space heating, 13 % to process heat. Electricity consumption is dominated by lighting (36 %) and power consumption (30 %), each 11 % of electricity consumption is applied to process heat, process

4 This assumption is also supported by the alternative calculations of the IE Leipzig which cites a wood consumption of 7.2 - 10.6 TWh for the tertiary sector (see Chapter 4, Table 4-5) and thus lies exactly inbetween study results A and B.

5 The study of Geiger/Gruber/Megele (1999) for the year 1999 also includes an under-coverage of electricity, compared with the data of the energy balance statement and the VIK statistics.

cold and information and communication technologies. Figure 3-1 shows the specific energy consumption by branches and purpose.

Table 3-2: Extrapolation of the energy consumption in the tertiary sector in Germany in 2001 and comparison with the energy balance statement

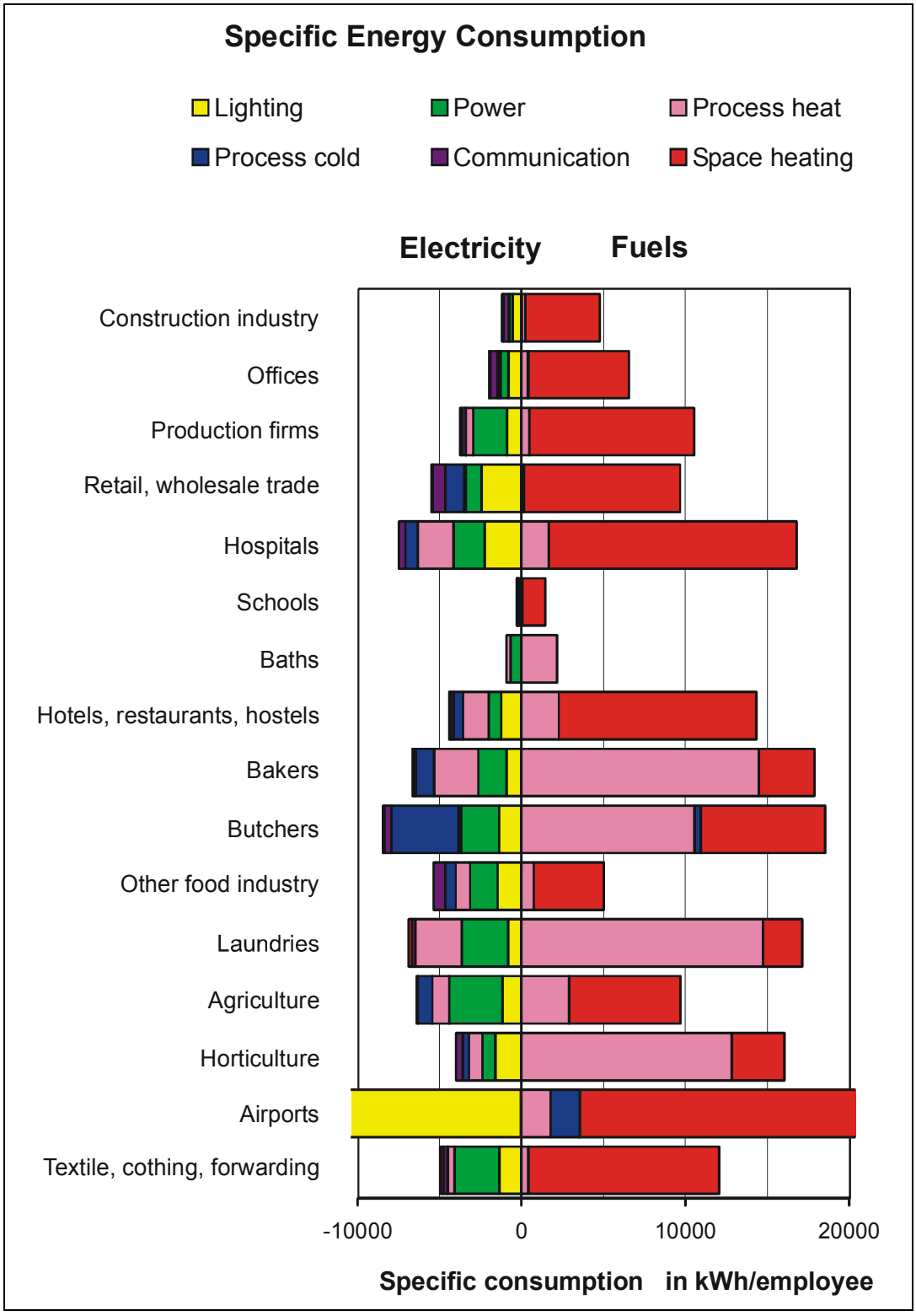
	Employees	Energy consumption						
		Coal	Wood	Heating oil	Gases	District heat	Electricity	Total
	[1000]	[TWh]						
Construction industry	2750.0	0.09	1.47	6.48	4.66	0.47	3.31	16.48
Offices (public/ private)	9911.9	0.37	0.96	26.00	29.74	7.93	19.70	84.69
Production firms	1766.4	0.31	0.55	9.03	6.00	2.72	6.61	25.23
Retail/wholesale trade	5084.0	0.44	0.89	17.29	27.57	3.06	27.97	77.23
Hospitals [1] Schools [1] Baths [1]	(552.5) (15496.0) (4649.5)	0.00	0.00	5.07	21.49	15.48	12.69	54.72
Hotels, restaurants, hostels	3127.0	0.51	1.32	12.80	25.04	5.21	13.78	58.66
Food industry	365.1	0.01	0.21	2.48	3.57	0.00	2.66	8.94
Laundries, dry cleaners	86.0	0.00	0.00	0.55	0.92	0.01	0.59	2.07
Agriculture [secondary statistics]	669.0	0.30 [0.00]	7.56 [0.00]	7.16 [4.44]	0.60 [0.37]	0.18 [0.00]	4.28	20.08 [9.09]
Horticulture [secondary statistics]	206.0	0.00 [0.00]	0.00 [0.00]	5.30 [3.29]	2.74 [1.70]	0.00 [0.00]	0.82	8.86 [5.81]
Airports [secondary statistics]	34.0	0.00 [0.00]	0.00 [0.00]	0.15 [0.23]	0.64 [0.98]	0.00 [0.00]	1.17	1.96 [2.39]
Textile and clothing industry, forwarding	614.3	0.00	0.00	2.03	5.38	0.00	3.04	10.45
Other consumption [2]	2381	0.22	0.39	6.34	4.21	1.91	12.91	26.00
Total tertiary sector								
Survey result A Survey result B [3]		**2.3 [2.0]**	**13.4 [5.8]**	**100.7 [96.0]**	**132.6 [131.6]**	**37.0 [36.8]**	**109.8 [109.5]**	**395.6 [381.7]**
Consumption according to energy balance		**2.5**	**0.8**	**95.6**	**140.8**	**31.7**	**127.8**	**399.2**

1) For this group other reference units were taken as even more appropriate for describing the energy consumption: number of beds, number of pupils and water volume.

2) Especially energy consumption of military and additional parts of electricity consumption.

3) Result A: Consumption projected for all groups directly from the survey. Result B: For the groups agriculture, horticulture, and airports alternative calculation from secondary statistics.

Figure 3-1: Specific electricity and fuel consumption per employee[1)] by purpose



1) Hospitals: per number of beds; schools: per number of pupils, baths: per water volume.

More detailed sector-specific analyses

Detailed questions on sector-specific energy-relevant equipment provided information on factors influencing electricity and fuel consumption. For example, refrigerators, production facilities and office appliances were recorded for each sector. The additional in-depth interviews proved to be indispensable for the interpretation of the results and especially for assigning energy consumption to its intended uses.

Detailed analyses were conducted based on six sectors as examples – wholesale and retail, construction industry, agriculture, butchers, restaurants and the banking and insurance industry. Different to the extrapolation, they were based on analyses in which the data of all the companies questioned were entered without having been weighted. In view of the number of cases, the data are not strictly representative; since however the quota was essentially met in the subgroups as well, the results are still very useful for a detailed insight into the sectors.

The *wholesale/retail trade* is the largest branch in the tertiary sector with over 4.5 million employed persons. There is a significant difference in energy consumption between food and non-food companies among the retailers. In retail, the usually heated salesrooms are the largest part of consumption, among wholesalers these are the usually unheated storage areas. Refrigerators and freezers were surveyed in detail as major energy consumers in the food trade. This also showed that the appliances in the salesrooms are only rarely covered to save energy during the day, but about two-thirds of them are covered at night. Significantly more hot water is used in the food than in the non-food sector. In addition, electrically-powered on-site ovens are being increasingly used in salesrooms; in this survey, this was the case in 38 % of food stores.

The *construction industry* is a very heterogeneous sector with regard to company size and structure. Its main areas include structural and civil engineering and prefabricated building; fitters, painters and varnishers are the biggest lines of business in the finishing trade. The 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, main construction industry companies operate many more energy-intensive appliances in their facilities and on the building sites. Almost all the appliances are operated electrically apart from forklift trucks and dump trucks. There are considerable problems in the construction industry with recording energy consumption, primarily on building sites, e. g. for site electricity and heating containers, because the costs for this 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 partially to the transport sector.

Agriculture is characterised by relatively small-sized enterprises. In most cases these involve a mix of farming and livestock. For farming, the energy is mainly required for tractors, to a lesser extent for combine harvesters and also for drying crops and hay. These machines were therefore surveyed in detail. In livestock farming, most energy is consumed for dairy cattle, and breeding cattle and calves as well as fattening and breeding pigs, for heating pens and ventilation, hot water for cleaning the pens and milk containers, and lighting. The corresponding structural data were recorded here as well.

Among *butchers,* only companies with fewer than 20 employees count as belonging to the tertiary sector. The main area of energy consumption is in producing sausages, principally the cooking, drying and smoking involved here as well as producing hot water. Electricity is mainly used for refrigerators and freezers. These systems were surveyed in the same way as for the food retailers. The larger the butcher, the more likely they are to undertake energy efficiency measures e. g. heat recovery, for example from refrigeration or reducing room temperature at night.

Inns and guesthouses are relatively heterogeneous with regard to energy-relevant characteristics, e. g. the food offered, opening times, size etc. The main energy consumer is space heating, prinicipally for the guest rooms. The production area is very small. Process heat is used in the kitchen, mainly for cooking, heating and keeping food warm, heating water for drinks, preheating crockery and washing dishes. Electricity is used primarily for cold storing of food as well as for lighting purposes.

In the *banking and insurance industry,* predominantly characterised by offices, the main focus was on office appliance equipment. These include servers, large computers, PCs, laptops, monitors, printers and copiers. The companies surveyed had access to over 272 of these appliances per 100 employees. A third of the companies had a computer network. Another main feature of this sector is an above average share of air conditioned rooms of 18 %, which increases with company size.

4 Producing heat from biomass in private households and the tertiary sector

For methodological reasons, heat production from biomass in private households and the tertiary sector was analysed separately for solid, liquid and gaseous energy sources.

Solid biofuels

Extensive evaluations of already existing data sources[6] were done to record the plant stock for the use of solid bioenergy sources in Germany and supplemented by surveys of the Institut für Energetik und Umwelt gGmbH of plant manufacturers/system producers, associations and system operators. The results of the household survey conducted by the GfK proved to be the most suitable base for the private household sector, which was extrapolated for the whole of Germany (see Chapter 2) and, for the service sector, the measurement statistics of the Federal Association of Chimney Sweeps.

Almost 9 million systems using solid biomass are estimated for *private households* in Germany (see Table 4-1). The vast majority of such systems are for additional heating; there are only around 750 000 systems used as the main heating (central heating, stove heating). Based on this stock, the total consumption of solid biofuels was determined for Germany. The specific wood consumption per system type assumed for these calculations is based on the results from the household survey conducted within the scope of this study, which was supplemented by detailed technology analyses and IE's own research. Accordingly, a total solid biofuel consumption of around 10.4 million tonnes or 154 PJ or 43 TWh results for 2002 (Table 4-1). This figure is about 10 % below the projected wood consumption figures of private households calculated based on floorspace and the number of occupied dwellings (see Chapter 2, Table 2-2) and thus represents a rather cautious consumption figure[7].

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6 Especially analysis of the survey conducted by GfK within the scope of this study of households and companies in the tertiary sector, the surveys in households conducted for many years by Rheinbraun Brennstoff GmbH together with the GfK, the statistics of the Bundesamt für Wirtschaft und Ausfuhrkontrolle (BAFA), the 2002 microcensus of the Federal Statistical Office and the measurement statistics of the Federal Association of Chimney Sweeps based on the Federal Immission Control Act.

7 Compared to the consumption figures determined by Rheinbraun Brennstoff GmbH, the deviation is around 20 % below.

Table 4-1: Systems and wood consumption for heat production in private households in Germany 2002

	Number of systems	Specif. fuel consumption kg/a	Total consumption t/a	Average heating value MJ/kg	Total consumption TJ / a
Central heating	180 000	8400	1 512 000	14.7	22 200
Stove heating	576 000	1900	1 094 400	14.8	16 200
Wood/coal-burning stoves	1 801 000	1300	2 341 300	14.8	34 700
Tiled stoves	4 109 000	1100	4 519 900	14.8	67 100
Open fires	1 352 000	400	540 800	14.9	8 000
Additional stove	908 000	400	363 200	14.8	5 400
Total			**10 371 600**		**153 600**

To determine the stock in the *tertiary sector* the main reference were the measurement records of the Chimney Sweep Guild. The legal basis (Federal Immission Control Act) for solid fuel burners in the capacity range >15 to 1000 kW of heat output demands a one-off measurement obligation at the initial start-up or an annually repeated measurement obligation depending on the type of boiler (handfired or mechanically fired). After extensive analysis of the available data a stock of wood-burning boilers of almost 73 000 results for the tertiary sector in the capacity range >15-500 kW (see Table 4-2)[8]. In order to calculate the wood consumption of these boilers first of all estimates were made of the average rated output in the individual performance categories of the range of hours of full utilisation and of the annual utilisation degree.

The resulting total wood consumption in the service sector was in the order of approx. 1.8-2.6 million tonnes in 2002 (corresponding to around 26.1-38.2 PJ or 7.2-10.6 TWh). This total amount can be split into roughly 50 % woodchips/pellets and 50 % split logs/other wood (Table 4-2). The wood consumption calculated here using the stock of systems in the tertiary sector lies exactly between that determined in the study results A and B using persons employed or the secondary statistics (see Chapter 3 Table 3-2).

8 Overall, the stock of systems for the total capacity range >15 - 1000 kW is around 138 000, derived from the measurement records. The almost 1 million systems in the capacity range between 500 and 1000 kW are, however, primarily to be allocated to the manufacturing industry. Private and commercial users are shown separately - based on the statistics of the BAFA - and in the lower range up to 100 kW around half of the over 130 000 boilers are used in private households.

Table 4-2: Number of boilers assigned to the tertiary sector and amount of wood consumed in 2002

		Capacity range of systems			
		> 15-50 kW	**> 50-100 kW**	**> 100-150 kW**	**>150-500 kW**
Mechanically fired systems [number]		2 599	2 437	1 504	2 988
Handfired systems [number]		58 092	4 147	533	296
Total systems in tertiary sector		**60 691**	**6 584**	**2 037**	**3 284**
Average rated power [kW]		40	81	114	282
Heating value [MJ/kg]		14.7	14.7	14.7	14.7
Annual utilisation degree [%]		80	85	85	85
Full capacity hours [h]		1 000-1 200	1 500-2 000	2 000-3 000	2 500-4 5000
Installed capacity in total [kW]		2 427 638	533 304	232 396	924 875
Wood consumption in tertiary	[GWh/a]	3 035-3 641	941-1 255	546-820	2 723-4 896
sector	[1000 t/a]	743.2-891.8	230.5-307.3	133.8-200.8	666.9-1 199.1
	[PJ/a]	**10.9-13.1**	**3.4-4.5**	**2.0-3.0**	**9.8-17.6**

Liquid biofuels

Of the liquid biofuels the use of fatty acid methyl ester (RME or biodiesel) dominates. Energetic use is also made of other plant methyl esters (PME) pure plant oils or other processed fats. One major application of liquid biofuels is in cogeneration plants. After extensive survey among plant manufacturers and operators 128 locations were determined with combined heat and power plants (CHP) (Table 4-3). For the electricity demand-controlled systems there is usually a closed-loop concept for heat use so that the heat produced in the plant can also be regarded as used heat. Accordingly in 2002 using liquid biofuels approximately 59 GWh (212 TJ) heat was used in CHP plants. Almost 40 GWh electricity was produced. The contribution of privately operated plants is only around 2 % due to the low average performance of only 14 kW_{therm}. Using plant oil in oil burners is one option which may become interesting with increasing prices for heating oil. At present however a total installed capacity of maximum 4 MW and useful heat of 5.5 GWh can be assumed almost exclusively in the household sector which corresponds to a fuel consumption of approx. 640 t/a.

Within the scope of a specific survey on the consumption of biofuels in private transport biodiesel sales of 156 000 t were ascertained at the approx. 1 600 filling stations concerned in 2002. Compared to 2001 this is an increase by almost 9 %. The total sales of biodiesel - characterised by sales to fleet operators (shipping companies) as well as the sales at public filling stations - equalled roughly 550 000 t in 2002 and was thus over 20 % higher than in 2001.

Table 4-3: Stock of energetically used liquid biofuels in Germany in 2002

		Cogeneration plants				Boilers (oil burners)	Total
		<10 kWel.	10-100 kWel.	100-1000 kWel.	>1000 kWel.		
Privately operated plants [number]		45	2	-	-		47
commercially or municipally operated plants [number]		24	43	11	3		81
Total plants		**69**	**45**	**11**	**3**	**150**	**278**
Full capacity hours (annual)		1 600	2 500	6 500	7 500		
Operating control assumed		heat demand	heat demand	electricity demand	electricity demand		
Thermal output [kW]		970	2 230	5 300	2 300	4 000	14 800
Heat supplied	[MWh/a]	1 530	5 480	34 200	17 700	5 500	64 410
	[TJ/a]	**5.6**	**19.8**	**123.0**	**63.6**	**19.8**	**231.8**
Fuel demand	[t/a]	280	1.020	6.300	3.800	640	12040
	[TJ/a]	**10**	**37**	**229**	**142**	**24**	**442**

Gaseous biofuels

The identification of heat use based on the fuel supplied are not possible for the gaseous biofuels biogas sewage gas and landfill gas. It was only possible to take the stock of plants as a starting-point. For all three types of gas heat is produced as a by-product and is mainly used to maintain a steady process temperature. In addition it may be used in the facilities of the plant operator. For all gaseous biofuels the main aim when operating biogas CHP plants is to produce power and be remunerated for this under the Renewable Energies Act. Heat is a useful by-product which can be used according to the specific requirements on site but which is usually not recorded or measured.

There were approx. 350 *landfill gas plants* in Germany at the end of 2001 with an installed electrical capacity of about 250 MW. The electricity generated at these plants amounted to around 1 100 GWh. At an overall efficiency of 87 % (33 % electrical 54 % thermal) approx. 6 600 TJ heat were produced each year. The possibilities of using the heat resulting from landfill gas use are very limited since the facilities are usually situated a long way away from potential heat users. According to research of the IE heat use only occurs at about 20 % of all landfill CHP sites. These are generally larger plants which provide about 40 % of the installed electrical power. In these plants approx. 2 600 TJ heat are produced of which about 800 TJ are used energetically (12 % of the heat generated).

For *sewage plants* both pure boiler installations for heat production and CHP with heat extraction have to be considered. According to data of the Federal Statistical Office approx. 3.4 PJ sewage gas were used solely to produce heat in boiler units in

2001 and 9.9 PJ in plants for combined heat and power production. With the total sewage gas use of approx. 13.3 PJ approx. 735 GWh power and 7.7 PJ heat were produced. Approx. 80 % of the heat used was to sustain the decay process and 15 % for heating and providing hot water in the buildings on site.

In 2001 in Germany 1 370 agricultural municipal and commercial *biogas plants* existed with an installed electrical capacity of 120 MW (without plants for anaerobic wastewater treatment which are assigned to industry). Biogas was used energetically to produce approx. 3 600 TJ thermal energy of which 1 600 TJ (45 %) was used to sustain the biogas process (heating primary ferment). Only about 800 TJ were used as energy for space heating and hot water approx. 40 % of this in households and 60 % in the tertiary sector.

Summary

Table 4-4 gives a summary of the biofuel use for heat production in households and the tertiary sector. In the order of 154 PJ or 42.7 billion kWh result for total heat production in private households. Approx. 30 to 40 PJ (equivalent to 8.1-11.5 billion kWh) are used energetically in the tertiary sector.

Table 4-4: Use of biofuels to produce or use heat[1)] in private households and the tertiary sector

	Amount of fuel					
	TJ		**Natural units**			
	Min	Max	Min	Max	Dimension(heating value)	
Private households	**approx. 154 000**					
Wood (2002)	153 600		10 400		1 000 t/a	(14.7 MJ/kg)
Liquid biofuel equivalent (2001)	32		855		t/a	(37.2 MJ/kg)
Biogas equivalent (2001)	400		18.5		mill. m^3	(21.6 MJ/m^3)
Tertiary sector	**29 230**	**41 335**				
Wood (2002)	26 100	38 200	1 800	2 600	1.000 t/a	(14.7 MJ/kg)
Straw (2002)	20	25	1,450	1 800	t/a	(13.8 MJ/kg)
Liquid biofuel equivalent (2001)	410		11,185		t/a	(37.2 MJ/kg)
Landfill gas equivalent (2001)	1 000		55		Mio. m^3	(18 MJ/m^3)
Sewage gas equivalent (2001)	1 100		50		Mio. m^3	(21.6 MJ/m^3)
Biogas equivalent (2001)	600		30		Mio. m^3	(21.6 MJ/m^3)

1) Only energetically used heat was considered for liquid and gaseous energy sources and given as fuel equivalent; the heat produced with solid energy sources is used completely.

5 Conclusions and recommendations

Valuable database for quantitative analyses of energy consumption and its determinants

The surveys of energy consumption in households and the tertiary sector provided a statistically and scientifically valuable database for both sectors which can be used for quantitative analyses of the energy consumption and its structural and socio-demographical determinants. For households it can be concluded that the analysis results presented are exemplary and pathbreaking for future field surveys due to the fine differentiation by relevant influencing factors, which was possible due to the large sample. This is particularly true for the data collected within the household survey on the use of renewable energies of biomass in particular as well as on car use. In the tertiary sector the energy consumption structures as well as the equipment with energy-relevant appliances and the economic frame conditions of the companies were able to be examined on very differentiated sectoral levels. With the supplementary surveys on the use of biofuels in both sectors a foundation has been created for further quantitative data to determine the contribution of renewable energies to the energy supply via the analysis of existing systems and their use.

Filling the gap in energy statistics and adding important supplements to the energy balances

For both consumption sectors the data collected on energy consumption and its determinants - in combination with statistical data of the parent population - made an extrapolation of the energy consumption possible by energy source. It proved to be especially helpful for the extrapolation that current data on the parent population were available from the microcensuses of the Federal Statistical Office which are conducted every 4 years. Generally the results of the extrapolations of the energy consumption for Germany are relatively comparable with the energy balance. However for both sectors the totals are below those of the energy balance (see Table 5-1). In view of the uncertainties connected with the surveys and the extrapolation this deviation should be assessed as relatively small.

Table 5-1: Extrapolation of the energy consumption of households and the tertiary sector based on the surveys and comparison with the energy balance

	Households			Tertiary		
	2001 (AGEB)	2002 (AGEB)	Extrapolation	2001 (AGEB)	2002 (AGEB)	Extrapolation[1)]
	TWh			TWh		
Electricity	134.4	133.9	125.2	127.8	132.7	109.5
Gas	299.7	294.7	263.7	140.8	138.3	131.6
Oil	248.9	215.3	219.8	95.6	83.0	96.0
District Heat	46.4	44.7	37.8	31.7	30.8	36.8
Coal	9.5	8.3	5.8	2.5	2.5	2.0
Wood/others	52.8	52.8	47.2	0.8	0.8	5.8 (13.4)
Total	791.7	749.7	699.6	399.2	388.1	381.7 (389.3)

1) Based on Survey Result B i. e. taking into account secondary statistic analyses; for wood: in parentheses Survey Result A which is a more realistic representation of the amount of non-traded energy sources used.

The results determined within the additional surveys on the use of biofuels of approx. 42.7 billion kWh in households and 8.1-11.5 billion kWh in the tertiary sector fit in well with the results of the extrapolation based on the surveys. Whereas in the households there is an almost exclusive use of wood as a biofuel in the tertiary sector liquid and gaseous biofuels also contribute to meeting demand with a 10 % share in the total use of biofuels.

Improving the database for extrapolations and forecasts of energy consumption

The data provided by the surveys are not only suitable for analyses and extrapolations but also for forecasting energy consumption. The differentiation of the data by building characteristics and heating systems in the household sector and by consumer groups in the tertiary sector allows a very detailed database for short- to medium-term extrapolation of these figures.

Recommendations

For the **household sector** it is recommended to repeat the survey every two years to start with and to use an improved questionnaire based on the experience gained in this survey. It is essential that one survey year is identical with that of the microcensus which is conducted every four years. In spite of the problems the households had with answering the complex questions on quantities and purposes of energy consumed it is nevertheless recommended - primarily for cost reasons - to keep the written questionnaire within the framework of the already existing GfK household panel and to first test the suggestions for its improvement. Because of the experience gained in this survey it can be expected that this will lead to a better quality of answers. The size of the sample (20 000 households) should be retained to make differentiated analyses by structural characteristics possible. If the household survey is conducted in a two-year rhythm supplementary surveys could be done in the intermediate years on sub-aspects of energy consumption in which there are currently insufficient data.

Repeating the basic survey every two years is also recommended for the **tertiary sector** and using the experience gained in this survey to exploit any potentials for improvement. In the intermediate years the rolling detailed survey already begun in this study should be continued in individual subsectors. The results on energy consumption determined for the tertiary sector by energy source and subsector could also be continued annually and could provide important supplementary information to the energy balance. For the subsectors of the construction industry and agriculture these data can then be used directly to fulfil international reporting obligations.

Based on the increasing significance of **biofuels for heat production** in households and the tertiary sector and the existing uncertainties concerning their quantification in the energy balances it is recommended that the additional survey "Heat from biomass" conducted here for the first time should be repeated annually to start with in the next two to three years. Its main focus should be on solid biofuels. The data sources used for this are to be qualified to a greater extent in cooperation with the relevant companies and associations. In addition both future and retrospective consumption figures should be made available to the Working Group on Energy Balances.

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