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The German
Residential Energy Consumption Survey 2005

Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI Essen)

forsa Gesellschaft für Sozialforschung und statistische Analysen mbH

Extensive Summary

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Executive Summary

The aim of this study is to estimate the energy consumption of German households in 2005. A nation-wide survey of 6,533 households serves as the starting point to determine the consumption of various fuels, including from private car-usage. In addition to energy consumption, home owners were surveyed with respect to home renovation activities.

In recognition of the increasing importance of renewable energies, computer assisted telephone interviews among some 80,000 households were additionally conducted. The aim was to gain reliable insights into the distribution of heat pumps, wood pellets, photovoltaics, and solar heat panels in Germany.

To gauge the reliability of the findings, an evaluation of the survey data quality was undertaken. The survey responses provided by a sub-sample of the panel households was cross-checked by contacting the respective utilities for information regarding the households' electricity and district heating consumption.

Methodology

forsa.omninet: sophisticated inquiry tool with visual interface

The current study is in many respects comparable to its predecessor, the German Residential Energy Consumption Survey 2003, in which the forsa.omninet-panel was surveyed as well. The households of the forsa.omninet-panel are equipped with a visual interface that allows an easy implementation of complex questionnaires by filter techniques and visual assistance. This tool further allows for automatic consistency checks during the data input by the participant. By this means, the omninet-panel ensures that the collected data is of high quality.

The survey data are extrapolated to the national level, with the calculations distinguishing between the eastern and western parts of Germany. For each considered fuel, the calculations further distinguish three separate categories of buildings: single-family, two-family, and multi-family homes. Special attention was paid to so-called item-non-response cases for which a correlation between energy consumption and the ability to provide information

of its consumption might exist. It is likely that households that are less worried about their energy consumption are likewise less concerned about the energy bills, and are therefore less likely to provide reliable information. Ignoring such a pattern might lead to a substantial underestimation of the residential energy consumption.

Item-Non-Response cases are accounted for by the application of Discrete-Choice-Models. Using this econometric method, the response probability for each household with respect to a set of socio-demographic characteristics was estimated. The response probabilities provide the basis for a weighting scheme that gives more weight to households with a low likelihood of response.

Significant improvements in the survey design make the questionnaire more user-friendly

The actual study deviates in a few points from its predecessor. **First:** As is generally well-known and further confirmed from the 2003 survey, households often have serious difficulties to understand their energy bills. Above all, this applies to bills for space heating in multi-family houses with central heating. The complexity of such bills was addressed in this study by drawing heavily on the visualization and filter ability of the omninet-system. After sampled households had indicated their respective billing company, the survey procedure subsequently presented respondents an exemplary bill issued by the company. The system goes step by step through the details of the exemplary bill, while highlighting the parameters of interest (see Figure 1). By this means, both the error rate and drop-out quota of households living in multi-family houses with central heating were reduced substantially.

Figure 1: Screenshot of an exemplary bill

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Aufteilung der Gesamtkosten von	6.011,10	Gesamtbetrag :	Gesamteinheiten	=	Betrag/ Einheit	x	Ihre Einheiten	=	Ihre Kosten
1. Heiz- und Warmwasserkosten									
Heizkosten	**2.835,21**								
davon									
30% Grundkosten Heizung	=	**850,56** :	480,00 m² Wohnfläche	=	1,772000	x	60,00	=	**106,32**
70% Verbrauchsk.Heizung	=	**1.984,65** :	17.949,58 HKV-Einheiten	=	0,110568	x	792,50	=	**308,76**
Warmwasserkosten	**656,43**								
davon									
40% Grundk. Warmwasser	=	**262,57** :	480,00 m² Wohnfläche	=	0,[illegible]7021		60,00	=	**32,82**
60% Verbrauchsk. Warmw.	=	**393,86** :	180,00 m³ Warmwasser	=	2,[illegible]8111		25,60	=	**56,02**

Warmwasserkostenermittlung; Erwärmung auf 60C
lt. Formel § 9.2 Heizkostenverordnung

2,5 x 180,00 m³ x (60C - 10) / 10,00 = 2.250 ltr.Öl

= 18,8 % des Verbrauchs.

18,8 % der Kosten Heizanlage von 3.491,64 EUR

= 656,43 EUR

Ihre Heiz- und Warmwasserkosten	=	**503,92**

Second: Measuring consumption is particularly challenging for stockable fuels, such as fuel oil. Usually, only the delivered amount of fuel can be surveyed, which most likely deviates from the consumed amount. To mitigate such problems, the households' deliveries were surveyed for a whole period reaching from 2003 to 2006, rather than only one year. By summing up theses deliveries and accounting for the climate conditions in each year using *heating degree days*, household-specific fuel consumptions can be imputed: Each sampled household's specific monthly heating degree days was geographically interpolated to its place of residence using a grid of climate stations operated by the *Deutscher Wetterdienst*. This procedure, which corrects for household-specific climate conditions, should lead to time series data for the consumption of storable fuels that should be much more reliable than simple estimates provided by the survey respondents.

Third: The billing data of grid based fuels like electricity, natural gas, and district heating were surveyed accurately to the day. Usually, the billing period does not match the calendar year. To correct for this temporal mismatch, the billed amount of fuel was divided by the respective heating degree days in the billing period and then extrapolated to the calendar year 2005.

Fourth: In order to gain insights into the frequencies of usage for heat pumps, solar panels, wood pellets, and photovoltaic in German homes, a computer assisted telephone survey among some 80 000 households was conducted. To our knowledge, this is the world's largest household survey on renewable energy, delivering highly reliable figures on the usage of these technologies.

Results

Large telephone survey draws reliable picture for renewable energies

Although renewable energies are becoming increasingly important, their relative incidence is still sparse. Solar heating is used by 4.9 % of the occupied buildings, while the share of heat pumps and photovoltaic installations amount to 1.8 % and 2.4 %, respectively. Wood pellets are used in some 2.2 % of the occupied buildings (Table 1).

Table 1: Usage of Heat Pumps, Wood Pellets, and Solar Techiques in German Homes 2006

	Single Family	Two Family	Multi Family	Total
Solar Heating	8.5%	7.6%	1.7%	4.9%
Heat Pump	3.7%	2.8%	1.4%	2.4%
Photovoltaic	2.7%	2.7%	0.8%	1.8%
Wood Pellets	3.8%	3.0%	0.8%	2.2%
None of this	83.5%	85.5%	93.7%	88.8%

The total number of used renewable energy installations can be obtained by multiplying the frequencies from Table 1 with the number of occupied residential houses (about 16.8 million). This yields roughly 300 000 photovoltaic installations, a figure confirmed by the estimate of the German Solar Industry Association (BSW 2007).

German residents **consumed some 2 609 Petajoule** (PJ) of energy **in 2005**, not considering the energy consumption due to private car usage (Table 2). With some 957 PJ, most of the consumption is accounted for by natural gas. Fuel oil and electricity accounted for an additional 728 PJ and 476 PJ, respectively . The consumption of wood, wood pellets, chips, and briquettes, amounted to 227 PJ. Thus, wood and wood products are the most important renewable energy fuels in the residential sector.

With about 1 600 PJ, roughly 38% of the total residential energy demand arises from private car usage. An alternative extrapolation using data from the German Mobility Panel yields a comparable consumption of around 1 500 PJ.

Photovoltaic production 2 PJ

Table 2 does not contain the results for photovoltaic, since the solar electricity produced by the households is usually fed into the public grid, rather than consumed by the households. The extrapolation of the surveyed data yields some 2 PJ of electricity produced by the photovoltaic panels of German residences. Hence, households accounted for roughly 50 % of total photovoltaic production in 2005 (VDN 2006).

Table 2: Energy consumption 2005 of German residents in PJ, including standard errors

	West		East		Total	
	Petajoule	Std. Error	Petajoule	Std. Error	Petajoule	Std. Error
Electricity	395.7	7.9	80.5	2.5	476.2	8.3
Natural Gas	792.0	18.7	165.4	6.5	957.4	19.8
LPG	18.7	2.8	10.1	2.7	28.8	3.9
Fuel Oil	635.7	32.3	92.4	10.9	728.1	34.1
District Heating	75.8	11.4	54.4	5.2	130.2	12.5
Lignite	3.7	0.7	10.1	2.4	13.8	2.5
Hard Coal	7.1	3.4	2.6	1.5	9.7	3.8
Firewood	182.8	8.2	25.0	2.5	207.7	8.6
Wood Chips, Briquettes	8.0	3.1	1.4	0.9	9.4	3.2
Wood Pellets	—	—	—	—	9.8	2.0
Heat Pump	—	—	—	—	31.6	5.1
Solar Heating	—	—	—	—	5.8	0.4
Total	2 119.5	35.6	442.0	13.4	2 608.8	38.7
Car Usage	1 349.3	26.9	249.5	6.3	1 598.8	27.7
Total	3 468.8	46.9	691.5	15.7	4 207.5	50.5

Sample results exhibit statistical uncertainty

It bears noting that any analysis based on **a sample exhibits a certain amount of statistical uncertainty**. Since a survey can capture only a subsample of the total population, there is a chance that the sampled results might randomly deviate from the underlying true population values. To account for this inherent uncertainty, Table 2 shows the standard errors associated with each parameter, from which confidence intervals can be constructed. **Reporting standard errors and confidence intervals is a standard procedure in the scientific community**, for a twofold purpose. First, it limits the range of values in which the true popu-

lation parameter rests. Second, the confidence intervals are essential for comparing the obtained results with other data sources. [1]

Energy audits have limited effects

A further issue addressed by the survey was the energy efficiency of dwellings. Home owners were questioned about whether renovations were undertaken and whether they received an energy audit. The results show that the majority of the audits (71 %) took place between 2002 and 2007 and almost two-thirds of the respective households paid for the audit themselves – despite the existence of various financial supports. **The comparison of audited households with a non-audited control group gives striking results**: a received audit barely improves the probability of undertaking a renovation, depending on the considered renovation measure. However, the small number of audited household limits somewhat the ability for definitive conclusions.

High data quality of the sample

Finally, a quality revision of the surveyed consumption data was carried out. Data on the consumed amount of electricity and district heating was collected for a subsample of the forsa.omninet-panel from the household's utility company. Comparing the utility data with the data surveyed from the households gives an impression of the accuracy of the obtained consumption figures. **The analysis shows that only in a very few cases are substantial deviations between utility and household survey data evident**. It is even more encouraging that these few cases were - without exception - **recognized and eliminated by the revision process** that was specifically developed for this household survey and is applied to the survey data before extrapolating the survey results to the national level. This leads to the conclusion that the data in the survey is of excellent quality.

[1] "[T]o reject a hypothesis because the data show `large´ departures from the prediction requires a quantitative criterion of what is to be considered a large departure (Jeffreys 1967, 384)", in Ziliak, McCloskey (2004:331), "Size Matters: The Standard Error of Regressions in the *American Economic Review*", Economics in Practice, *Econ Journal Watch* 1(2):331-358. Translated into the actual context: Standard errors and conficence intervals are essential decision aids whether the obtained results depart by chance or in a systematic matter from other data sources.

Conclusion and Recommendation

Panel surveys provide a powerful data-foundation for answering a broad range of empirical questions. The repeated survey of the forsa.omninet-households marked the first time in Germany that a panel was used for focussing on residential energy usage. Apart from the high validity of the obtained results, such a panel approach endows the researcher with a comprehensive knowledge about the participating households. As many household characteristics are stable or adjust only slowly over time (e.g. renovations), their attributes need not be recorded with each panel wave. Hence, repeatedly interviewing the same households leaves space for a detailed analysis of more variable aspects in different survey years while not overburdening the questionnaire. Ideally, the analysis period would be expanded to three years, as this would allow surveying the households at the beginning and at the end of the year of interest. This opportunity is especially of interest for quantifying the consumption of storable fuels.

Panel survey allows state-of – he-art policy evaluation

Beyond its benefits for questionnaire design, a panel approach enables the researcher to make use of state of the art evaluation methods to **evaluate the effects of energy and environmental policy measures**. For instance, the household's energy consumption might be measured before and after an implemented retrofit measure, thereby allowing quantification of **the effectiveness of** the measure and, along these lines, of the effectiveness of **an underlying policy program**. Such an evaluation does not rely exclusively on technical estimates but additionally considers behavioural information to measure changes in energy consumption after a renovation. Rigorous evaluation techniques are, incidentally, a compulsory standard in the USA for the quantification of energy savings due to demand-side management programs.

Estimates of efficiency improvements become more exact

It is advisable to continue with the chosen panel approach, especially as the European directive on end-use efficiency requires elaborated evaluation techniques to quantify the achieved energy savings. In light of these requirements, **perpetuating the survey**

with respect to the sample households and the questionnaire design has the major advantage of **decreasing the amount of statistical error** compared to independent cross-sectional samples, and **leading to more precise estimates of energy consumption and efficiency improvements**. Hence, any decrease in observed energy consumption is likely to reflect an actual improvement in energy efficiency rather than a chance event.

Another issue addressed by this research project was to develop a procedure that interpolates the residential energy consumption for years without a survey wave. However, the experience of the current survey confirms the necessity of inquiring multi-period billing data for aims of calculating reliable consumption figures, at least for storable fuels. It is only a small step ahead to expand the energy consumption survey to multiple periods for all fuels. Moreover, **because actual data are available, it seems unwise to rely on interpolated, less exact data**.

In order to ensure participation rates of as much as 70 % among the forsa.omninet-households, a rather long inquiry period is necessary. The experience of both the German residential energy consumption survey in 2005 and in 2003 should be taken into consideration in future surveys. One possibility to scoop out as much as possible from an existing household sample is to omit certain topics from the questionnaire. For example, one might **poll consumption data for renewable energy solely from an extended telephone survey**, a path partially taken in this survey.

To conclude, it is useful to recall a passage from the new IEA study „Energy Use in the New Millenium: Trend in IEA Countries" (IEA 2007), which analyses the trends in energy consumption of affiliated member states between 1990 and 2004. The new IEA-chairman, Nobuo Tanaka, criticized that only half of the member states supply data about their sectoral energy consumption. As **detailed information about consumption patterns is the essential condition for an adequate energy policy**, he encourages the member states to spend more efforts in developing an accurate stock of data. In the future, this demand will become increasingly important, especially in light of the requirement of the European directive on energy end-use efficiency.

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