Decomposing final energy use for hot water in the residential sector in Austria

Editor: Angela Holzmann
Kurt Kratena (Austrian Institute of Economic Research)

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Mariahilfer Straße 136, A-1150 Wien; Tel. +43 (1) 586 15 24, Fax +43 (1) 586 15 24 - 340;
E-Mail: office@energyagency.at, Internet: http://www.energyagency.at

Editor-in-chief: Peter Traupmann, CEO

Project management: Angela Holzmann

Proofreading: Margaretha Bannert

Layout: Marion Katzenschlager

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1 Introduction

Figure 1 shows the final energy consumption of Austria by economic sectors and end-use categories for the years 1993 and 2009. Besides the agricultural sector, energy consumption has grown in all economic sectors between 1993 and 2009. The transport sector experienced the greatest increase and had by far the largest share in energy demand in 2009, followed by the industrial sector. In view of the increases in transport and industrial energy consumption, the final energy use of the residential sector declined in relative terms. While accounting for the largest share in energy consumption in 1993, residential energy consumption remained almost constant in absolute terms, resulting in the third largest share in final energy consumption in 2009. However, data show that apart from transport, residential heating was by far the biggest energy end-use category in Austria in 2009, causing three quarters of private households' energy use and 18% of total final energy use.

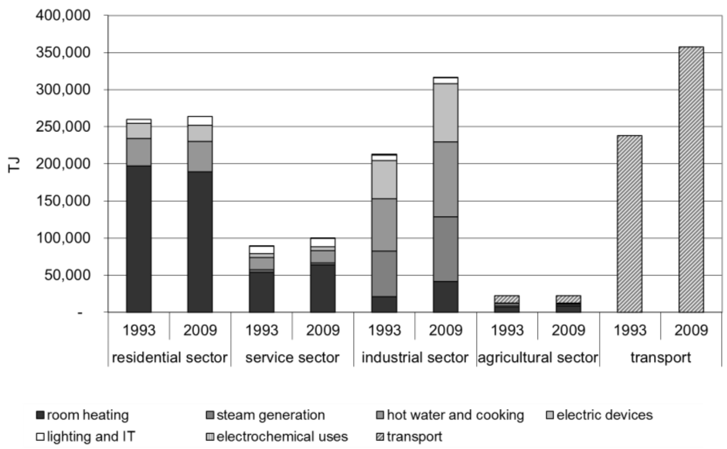

Figure 1: Final energy use by end-use categories and economic sectors in Austria, in 1993 and 2009, source: Statistics Austria (2011)

Figure 2 shows the annual development of residential final energy demand for hot water which slightly increases from 1993 to 2009 (+6%).

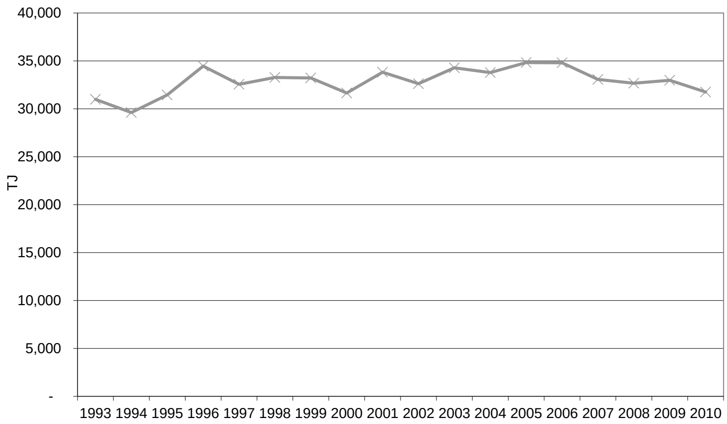

Figure 2: Final energy use for hot water and cooking in the residential sector in Austria, 1993–2009, source: Statistics Austria (2011)

Considering that, on the one hand, in Austria quite a number of measures have been implemented to reduce final energy demand for heating so far, and that, on the other hand, final energy demand for heating has not been reduced in the expected way, the authors carried out an extensive analysis of the influence factors on final energy demand for heating in Austria's private households, see Holzmann et al. (2013). We have applied the Logarithmic Mean Divisia Index (LMDI I) method to a dataset compiled from different sources and covering the period from 1993 to 2009. The impact of eight different factors on final energy use for heating in Austria's private households has been analysed.

To complement the results obtained, we now have a closer look at final energy demand for ***hot water generation***. The main factors influencing final energy use for hot water are identified as well as their impacts on energy demand by applying the Logarithmic Mean Divisia Index (LMDI I) method. The main factors are population, intensity, fuel share and efficiency and will be defined in the methodology approach.

The article is organized as follows: Section 2 describes the methodological approach, specifies the analysed effects and provides an overview on relevant data sources. Section 3 presents results and discussion.

For an extensive literature review on studies applying the LMDI method on residential energy consumption and for details on Index Decomposition Analysis and the development of the LMDI-approach see Holzmann et al. (2013).

2 Methodology and data

2.1 Methodology

The LMDI analysis can be done on a time series basis as well as on a period-wise basis (Ma and Stern, 2006). Contrary to the analysis of the influence factors on heating demand (Holzmann et al., 2012), we decided to perform a period-wise decomposition analysis for the years 1993 and 2009 in the case of final energy use for hot water.

Final energy use for hot water generation is expressed as the product of the following factors:

$$FE^{observed,HW} = \sum_f \left[P \times \frac{UE}{P} \times \frac{UE_f}{UE} \times \frac{FE_f^{observed,HW}}{UE_f} \right] \quad (1)$$

where $FE^{observed,HW}$ represents observed final energy use of private households for hot water, UE represents useful energy use, and P stands for population. For ease of presentation the following terms are introduced to represent the terms on the right hand side of equation (1):

$$FE^{observed,HW} = \sum_f \left[P \times I \times F_f \times E_f \right] \quad (2)$$

Changes in final energy use for hot water, $FE^{observed,HW}$, are thus explained by the following effects:

(1) The population effect P shows the impact of growing population numbers on final energy use for hot water;

(2) The intensity effect I ($I = \frac{UE}{P}$) describes the impact of unit energy consumption, expressed as useful energy consumption per person, on final energy use for hot water generation;

(3) The fuel share effect F_f ($F_f = \frac{UE_f}{UE}$) shows the effect of a shift in fuel shares, given by the quotient of useful energy demand per fuel and total useful energy demand (UE); f represents coal, oil, gas, electricity, district heating, biomass and ambient heat;

(4) The efficiency effect E_f ($E_f = \frac{FE_f^{observed,HW}}{UE_f}$) accounts for the impact of changes in system efficiency on final energy use for hot water generation, expressed as the quotient of final energy use (FE) per fuel and useful energy demand (UE) per fuel.

Applying LMDI methodology to equation (2) results in equation (3) (for details of the derivation of the formula see Holzmann and Kratena (2013)).

$$\Delta FE_{t,t-1}^{observed,HW} = FE_{t}^{observed,HW} - FE_{t-1}^{observed,HW} = \sum_{i} \Delta FE_{i,t,t-1}^{observed,HW} =$$
$$\sum_{f} \tilde{FE}_{f,t,t-1}^{observed,HW} \times \ln\left(\frac{P_t}{P_{t-1}}\right) + \sum_{f} \tilde{FE}_{f,t,t-1}^{observed,HW} \times \ln\left(\frac{I_t}{I_{t-1}}\right) +$$
$$\sum_{f} \tilde{FE}_{f,t,t-1}^{observed,HW} \times \ln\left(\frac{F_t}{F_{t-1}}\right) + \sum_{f} \tilde{FE}_{f,t,t-1}^{observed,HW} \times \ln\left(\frac{E_t}{E_{t-1}}\right) \tag{3}$$

where $i_t \in \{P, I, F_f, E_f\}$

and $t \in \{1993, 2009\}$ represent annual time steps.

Equation (4) shows the influence on the change in energy demand of factor i:

$$\Delta FE_{i,t,t-1}^{observed.HW} = \sum_{f} \tilde{FE}_{f,t,t-1}^{observed} \times \ln\left(\frac{i_t}{i_{t-1}}\right) \tag{4}$$

where $\tilde{FE}$ is the logarithmic average of final energy use at time t and t-1 as shown in equation (5):

$$L\left(FE_{f,t}^{observed,HW}, FE_{t-1}^{observed,HW}\right) = \frac{\left(FE_{f,t}^{observed,HW} - FE_{f,t-1}^{observed,HW}\right)}{\left(\ln FE_{f,t}^{observed,HW} - \ln FE_{f,t-1}^{observed,HW}\right)} = \tilde{FE}_{f,t,t-1}^{observed,HW} \tag{5}$$

2.2 Data

Final energy use for hot water generation in private households in Austria has been published by Statistics Austria (2011) from 2005 onwards. Up to 2005, Statistics Austria provides combined figures of final energy use for hot water and cooking. In order to analyse the long-term development of final energy use for hot water, the published final energy use for hot water and cooking from 1993 to 2004 has been adjusted for cooking based on the published data from 2005 to 2010. Final energy use for hot water (and cooking) is published according to fourteen energy carriers which have been subsumed to coal, oil, gas, electricity, district heating, biomass, and ambient heat.

Data on population numbers are also published by Statistics Austria (2010).

Hot water can be produced by heating systems (combined systems) or by separated systems (hot water systems). In order to estimate the efficiency of these systems, information on the stock of existing systems is required. As there is no consistent data available, age and efficiency of current and former systems for heating and hot water have been estimated based on a literature review: Data concerning combined systems are based on literature review done in Holzmann et al. (2012); efficiencies of hot water systems are based on Diefenbach (2002).

A recently conducted survey on heating behaviour among 1,000 Austrian households gives information on shares of combined and separated systems per fuel (Holzmann and Kratena, 2013). Table 1 shows the results of the survey. Hot water generation using oil, coal, biomass, and district heating generally works in combined systems. Systems using electricity, gas or ambient heat (heating pumps or solar heating systems) can be either combined or separated systems.

Table 1: Generation of hot water by fuel and generation system, source: telephone survey, prepared by the authors

	Combined systems	**Separated hot water systems**
Oil	100%	
Coal	100%	
District Heating	100%	
Biomass	100%	
Electricity	9%	91%
Heating pump	22%	78%
Solar plants	5%	95%
Gas	81%	19%

3 Results and discussion

Table 1 and Fig. 1 present aggregate results of the decomposition analysis.

In total, final energy use for hot water increased by 1,994 TJ or 6% from 1993 to 2009; this means an average increase of 0.39% per year.

The results show that changes in the fuel share mix and changes in system efficiency have a decreasing effect on final energy use for hot water. However, changes in population numbers, and changes in the unit consumption per person more than offset these energy savings.

Table 1: Aggregate decomposition of final energy use for hotwater 1993–2009

Contribution to change in final energy use	Total	ΔFE_P	ΔFE_I	ΔFE_F	ΔFE_E
Absolute contribution in TJ	1,994	1,868	14,117	-9,741	-4,249
Relative contribution (in terms of final energy use 1993)	6%	6%	46%	-31%	-14%

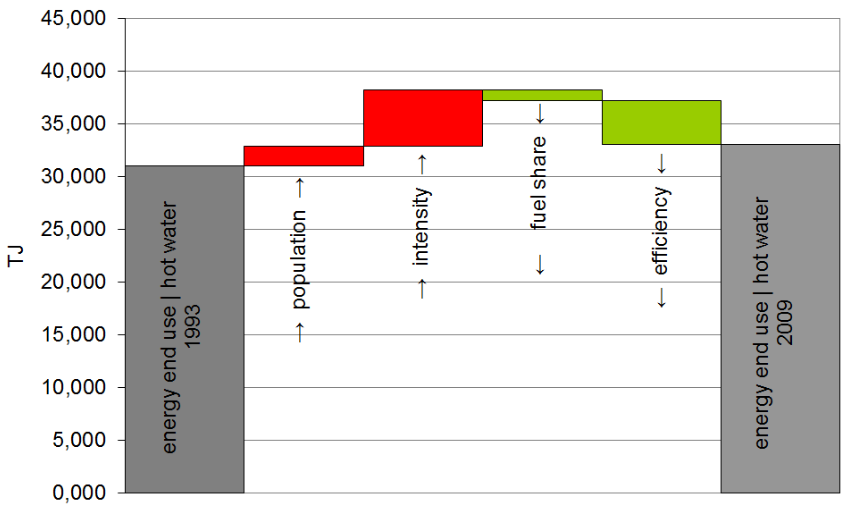

Fig. 1: Aggregate decomposition of final energy use for hot water 1993–2009, without consideration of weather. Source: prepared by the authors

Growing population numbers have an increasing effect on final energy use for hot water. Austria's population grew by 6% from 1993 to 2009, which means an average annual increase of 0.4%. Compared to the other analysed effects, population growth has the smallest influence on energy demand for hot water. In total, it caused a rise in final energy use for hot water of 1,868 TJ or 6% compared to 1993.

The intensity effect combines various effects. While the other analysed effects are calculated based on data from both official statistics and literature research, the intensity effect is obtained as residual. The most important interpretation of the intensity effect is that it is a convenience effect, thus showing changes in consumer behaviour. These changes can be due to changes in the daily hygiene habits, changes in the age structure of the population, technical improvements in sanitary systems and so on. Furthermore, as residual effect, this effect could also include inaccurate assumptions regarding collected data, which, despite all accuracy, cannot be ruled out completely. On the one hand, system efficiencies are based on a literature review and a telephone survey. On the other hand, statistical data concerning hot water is at least partially based on estimations and calculations. Total correspondence of the data with reality is therefore unlikely.

The intensity effect is the major effect found in the decomposition analysis. It accounts for 14,117 TJ of final energy use increase from 1993 to 2009 and increases final energy use by 46% compared to 1993.

Changing fuel shares have a decreasing effect on final energy use for hot water. In total, the fuel share effect caused a fall in final energy use for hot water of 9,741 TJ or 31% compared to 1993.

The system efficiency effect represents changes in hot water system efficiencies. These changes are explained by (1) changes in the age, and (2) the efficiency of the technology. Data on boilers do not allow showing both effects separately. The heating system efficiency effect accounts for 4,249 TJ of final energy use decrease from 1993 to 2009. This means a reduction of 14% of the final energy use compared to 1993.

References

Diefenbach, N., Loga, T., Born, R., Großklos, M., Herbert, C., 2002. Energetische Kenngrößen für Heizungsanlagen im Bestand. Institut für Wohnen und Umwelt GmbH.
Holzmann, A., Adensam, H., Kratena, K., Schmid, E., 2012. Decomposing final energy use for heating in the residential sector in Austria. Energy Policy, submitted.
Holzmann, A., Kratena, K., 2013. Telefonumfrage zum Thema Heizen und Warmwasser in Österreichs privaten Haushalten
Ma, C., Stern, D.I., 2006. China´s Changing Energy Intensity Trend: A Decomposition Analysis. Rensselaer, Working Papers in Economics.
Statistics Austria, 2010. Population Statistics, 19.05.2010.
Statistics Austria, 2011. Useful energy analysis 2009, "Nutzenergieanalyse 2009".

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ÖSTERREICHISCHE ENERGIEAGENTUR – AUSTRIAN ENERGY AGENCY
A-1150 Vienna, Mariahilfer Straße 136 | Phone +43-1-586 15 24 | Fax +43-1-5861524-340
office@energyagency.at | www.energyagency.at