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Effects of Consumption-Based Billing Depending on the Energy Qualities of Buildings in the EU

Potential assessment for member states

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Summary

The German study from January 2013 on the effects of consumption-based billing depending on building energy qualities is based on the findings of numerous studies on energy savings that result from consumption-based billing of heatings costs. The European Energy Efficiency Directive 2012/27/EU of 25/10/2012 now requires all end consumers to be fitted with meters to enable individual consumption registration (art. 9). The German experience shows that the introduction of consumption-based billing leads to permanent changes in consumer behaviour. As building occupants now have to pay for their individual consumption, overall consumption of heating energy has fallen by 20% compared to levels under the previously prevailing flat-rate billing basis. An extensive literature review of international studies will examine the transferability of this savings potential to other European countries.

Many years of experience of consumption-based billing in other countries has shown that the achievable savings in consumption in Europe are very much in line with the 20% typical in Germany. In France, Sweden, Poland and Italy, for example, it results in a total saving of 21,517 GWh per year, which would lead to an annual reduction of CO_2 emissions of 5.9 million tonnes. Comparing an estimation of typical costs for the implementation of consumption-based billing and with the expected financial savings from reduced consumption confirms the efficiency of Europe-wide consumption-based billing of heating costs.

1. Introduction

A study on the "Effects of Consumption-Based Billing Depending on Building Energy Qualities" has been available since January 2013. The basis of the research were the numerous projects and reports on established energy savings effects resulting from the introduction of consumption-based billing of heating costs in Germany. The European Energy Efficiency Directive 2012/27/EU of 25/10/2012 now requires all end consumers to be fitted with meters to enable individual consumption registration (art. 9). For the purposes of examining this, it is useful to see to what degree statements on the savings potential and effects of consumption-based billing can also be applied to other European countries or if these countries have had similar experiences. A comprehensive literature review of available studies mostly from European countries on the subject of consumption-based billing and consumption savings as a result of changed consumer behaviour in buildings will examine the transferability of the findings made to-date to other European countries. The collected studies and the statements that can be derived from them will be documented and systematically examined in the following paper. Any country-specific findings on the expected savings effects of consumption-based billing will be highlighted separately.

2. Analysis of European studies on the topic of consumption-based billing

2.1. Overview of the collected studies of relevant literature according to country and category

Table 1 lists all of the studies collected and evaluated that have a certain relevance to the subject of consumption-based billing. The sources are sorted according to country and the savings effects mentioned in the studies are listed separately. The table contains 24 studies with results from research from Germany as well as other European countries such as Switzerland, Denmark, Sweden, France and Austria.

The studies can be split into three categories according to the research method used:

- CAT A: Equipping buildings with meters, comparison of the heating period before and after installation of the meters or implementing consumption-based billing
- CAT B: Examination of several buildings of the same type or buildings in one residential area, of which only a part of the studied sample was fitted with metering technology. Afterwards the buildings were compared with one another with regard to consumption within the same heating period.
- CAT C: Theoretical examination of the subject of consumption savings due to heat cost allocators. References from literature reviews. The more recent studies of this category use building simulations to estimate the savings potential of modern buildings.

The allocation of the studies to the categories can also be seen in table 1. The appendix to this report gives brief summaries of the most important content and results of the individual studies.

Tab. 1: Studies of existing and accessible documents

Country	Author	Title	Saving	CAT
Germany	Loga, T.; Großklos, M.; Knissel, J.	Der Einfluss des Gebäudestandards und des Nutzerverhaltens auf die Heizkosten – Konsequenzen für die verbrauchsabhängige Heizkostenabrechnung. IWU Darmstadt, 2003	Existing property: 20% LEH: 30 – 40%	C
		Lohnt in Niedrigenergiehäusern die verbrauchsabhängige Heizkostenabrechnung? HLH vol. 56 (2005) No. 7 – July		C
	Kuppler, F.; Minol Messtechnik	Erste Heizkostenabrechnung nach Verbrauch in Chemnitz. Sonderausgabe des Heizungsjournals; 3. NT-Sonderausgabe, 1991	On average 20%	B
	Schiller, S.	Versuchsergebnisse mit Wärmemessern (Heizkostenverteilern) bei Zentralheizungen. HR, 12/1956	On average 23%	A
	Raiß, W.	Einsparung an Heizenergie durch wärmedichtes Bauen und Wärmeverbrauchsmessung. HLH 15, 12/1964	15%	C
	Kolar, J.	Fernwärme und End-Energie in Nürnberg. FWI, Issue 2/1978	15 – 20%	B
	Jacobi, E.	Vertretbare und erreichbare Heizungsbetriebskosten im Wohnungsbau. BBauBl, Issue 2/1962	15 – 25%	C
	Ackermann, F.; Reckel, G.	Erfahrungen mit einer Verbrauchsvariante der Fernwärmeabrechnung. FWI, Issue 5, Issue 3/1976	20%	A
	Oschatz, B.; Richter, W.	Heizkostenerfassung im Niedrigenergiehaus. Im Auftrag des BBR, Bonn 2004	Simulations on the basis of 20%, LEH: 30 – 36%	C
	GEWOS	Durchführung der verbrauchsabhängigen Heizkostenabrechnung und ihre Auswirkung auf den Energieverbrauch – Endbericht. Hamburg 4/1986	On average 13%	B
	Raschper, N.	Energieeinsparpotenziale bei Bestandsgebäuden – Teil 1: Zwischen Bedarfsberechnung und Verbrauchswerten. Die Wohnungswirtschaft, 08/2010	25 – 30%	C
		Energieeinsparpotenziale bei Bestandsgebäuden – Teil 2: Warum Verbrauchswerte und Bedarfsberechnungen voneinander abweichen. Die Wohnungswirtschaft, 11/2010		C
	Stumpf, M.	Verhaltensänderungen und organisatorisch-technische Optimierungen ein starkes Team bei der Energieeinsparung. Erfahrungen und Erkenntnisse aus psychologischen Studien zum Energienutzungsverhalten an Hochschulen. January 2014, University of Freiburg, Dissertation	9% heat 36% electricity (saving resulting from changes in consumer behaviour)	A
	Peruzzo, G.	Heizkostenabrechnung nach Verbrauch. Kommentar zur Verordnung über die verbrauchsabhängige Abrechnung der Heiz- und Warmwasserkosten. Kommentar und	15%	C

		Anleitung für die Praxis. 5., grundlegend überarb. und wesentl. erw. Aufl., Luchterhand Verlag GmbH, Neuwied, Kriftel, Berlin, 09/1996		
Switzerland	Goepfert, J.; Forster, R.	Herstellungs- und Betriebskosten sowie Art der Betriebskostenabrechnung von Zentralheizungen größerer Wohnblöcke und geschlossener Siedlungsgebiete. Sanitäre Technik, No. 2/1962	25 – 40%	C
Sweden	Adamson, B.; Reijner, E.	Wärmeverteilungszählung in Wohnhäusern. Gesundheits-Ingenieur, Issue 1/1958	10 – 25% (heating) 40 – 50% (hot water)	B
Denmark	Gullev, L.; Poulsen, M.	The installation of meters leads to permanent changes in consumer behavior. News from DBDH, 3/2006	15 – 17% Maximum 30%	A,B
Norway, Finland	Gölz, S.	Energiesparen im Haushalt durch Feedback des eigenen Verbrauchs. Workshop - Folien, Fraunhofer ISE, 12/2009	5 – 10% (electric energy) 13% (total energy consumption)	C
Scandinavia, NL, UK, Japan	Darby, S.	The effectiveness of feedback on energy consumption - a review for defra of the literature on metering, billing and direct displays. Environmental Change Institute, University of Oxford, 4/2006	3 – 20%	C
France	ADEME: Huze, M.-H.; Cyssau, R.	Maitrise de la demande d'énergie par les services d'individualisation du chauffage. Rapport final, 09/2006	20%	A
		Maitrise de la demande d'energie par les services d'individualisation du chauffage collectif. Paper		A
	Syndicat de la mesure	L'individualisation des frais de chauffage à l'épreuve des faits; Étude de l'impact des systems sur les consommations d'énergie en résidentiel collectif. Rapport final 12/2015	19,8%	A
Russia	Poetter, K.; Pahl, M.H.	Wasser- und Wärmeeinsparung in russischen Wohnhäusern. Ergebnisse des Dubna Projekts. 03/1999, Euroheat and Power, Issue 28, p. 29 - 35	23% heat 55% hot water	B
Austria	H. Juri, F. Adunka	Technische und psychosoziale Einflussfaktoren auf den Wärmeverbrauch von Wohngebäuden	15 – 20%	C
	Adunka, F.	Grundlagen der Heizkostenverteilung. Text of a presentation given in Haus der Technik, Essen, 2005	10 – 30%	C

Table 2 below gives a list of studies whose results regarding the savings effects of consumption-based billing are already known as they are referenced in the studies from table 1. Even though some of these studies are now between 30 and 85 years old, it can still be seen that the basic effect with regard to energy savings resulting from consumption behaviour after the introduction of heat cost allocators can be seen to have remained unchanged during this time. It has not been possible thus far to determine all of the respective primary sources of these studies. This includes 10 studies from Germany, the former Czechoslovakia and Austria. The savings listed are therefore based solely

on the statements in secondary sources and therefore there is a great deal of uncertainty with regard to the values specified.

Tab. 2: Studies (to-date without original documentation of primary source)

Country	**Author**	**Title**	**Saving**
Germany	Behrens, H.	Der Bau und Betrieb von Zentralheizungen; Nr. 17/1929, Reichsforschungsgesellschaft für Wirtschaftlichkeit im Bau- und Wohnungswesen	approx. 20%
	Neue Heimat	Heizungs- und Warmwasserkosten und ihre Abrechnung; Z 50-ka-115, April 1975	15 – 20%
	Kunde, W.	Energieeinsparung durch rationelle Wärmeerzeugung und objektbezogene Wärmeabrechnung, BGW-Schriftenreihe, Heft 7/1976, Hamburg	15 – 18%
	FAVORIT	Energieeinsparungen in Demonstrativbaumaßnahmen (Hagen) über 7 Jahre. Hamburg	20 – 30%
	Wohnbau Mainz GmbH	Energieeinsparungen in gesellschaftseigenen Wohnanlagen über 4 Jahre	15 – 30%
Czechoslovakia (now Czech Republic and Slovakia)	Navatil, L.	Versuche und Erfahrungen mit Wärmemessern in der CSSR. Energetika No. 5/1969	23 – 37%
Austria	Kraus, E.	Erfahrungen mit der Wärmemessung und -abrechnung auf Basis von Heizkostenverteilern im Bereich der Wohnungsanlagen der Stadt Wien. Lecture, Sept. 1975, Berlin	approx. 20%
	Heizbetriebe Wien GmbH	Energieeinsparung in fernwärmeversorgten Wohnanlagen. March 1984	25 – 40%
	K. Fantl	Einflüssen der Heizkostenverrechnung auf den Energieverbrauch. Beiträge zur regionalen Energiepolitik Österreichs, Vol. 2, 2nd Edition. Vienna, 1978	15 – 20%
	W. Riemer	Verbrauchsabhängige Heizkostenverrechnung. Articles and Reports for the Seminar of 16/02/1982, External Institute of the Technical University of Vienna (ed.), TU Vienna, Vienna, 1982, p. 13	10 – 30%

In addition the collection of studies currently contains around nine further relevant sources on the subject of consumption-based billing that pertain to the energy savings potential resulting from consumer behaviour and making active use of this potential. These studies do not name a particular energy savings potential and should be seen as supplementary literature. Short summaries of all of the studies can be found in the appendix.

2.2. Presentation of some studies sorted according to country

2.2.1. Situation in Germany

In Germany it is now regarded as generally acknowledged that savings of around 20% of consumed heating energy can be achieved through changes to consumer behaviour following the introduction of consumption-based billing when compared with flat-rate billing. The following section presents five studies related to this issue to back up this thesis.

It is noticeable that most German studies were either conducted several years before the German Heating Cost Regulation came into force in July 1981 (e.g. 1956[1]) or at around the time the regulation came into effect (e.g. 1976[2], 1978[3] and 1985[4]). Further studies were performed when the area the regulation covered was expanded to include the states of the former German Democratic Republic (e.g. 1991[5]). More recent publications mostly cite the results already known. The reason for this is the preference for performing research of this kind in the context of legislative amendments.

One study conducted in Berlin [1] examined four detached houses and 15 blocks of housing each with 81 consumer units. The buildings studied consisted of 42.1% of residential buildings, 36.9% of mixed-use buildings and 21% completely non-residential buildings. The billing-relevant consumer units were equipped with heat cost allocators using evaporation-based measurement principles. At the end of the study the fuel consumption of the buildings for the heating period of 1954/55 was compared to the respective earlier figures when flat-rate billing was used. An average reduction in fuel consumption of around 23% was determined in this study. However, the savings per building fluctuated from 5.8% to 37.2%.

Between the heating periods of 1973/74 and 1974/5, the switch was made from flat-rate billing to consumption-based billing for a housing estate with district heating in Wolfsburg [2]. For this purpose 1467 flats in the complex were fitted with evaporation heat cost allocators and the two heating periods were compared. A reduction in consumption of around 5998 MWh was determined in otherwise unchanged conditions. This corresponds to a saving of 20%. Table 3 shows an overview:

[1] Schiller, S: Versuchsergebnisse mit Wärmemessern (Heizkostenverteilern) bei Zentralheizungen. HR, 12/1956 [1]

[2] Ackermann, F.; Reckel, G.: Erfahrungen mit einer verbrauchsvariante der Fernwärmeabrechnung. FWI, Jg. 5, Issue 3/1976 [2]

[3] Kolar, J.: Fernwärme und End-Energie in Nürnberg. Fernwärme International, 7th Volume 5, Issue 2/1978 [3]

[4] GEWOS: Durchführung der verbrauchsabhängigen Heizkostenabrechnung und ihre Auswirkung auf den Energieverbrauch – Endbericht. Hamburg 4/1986 [4]

[5] Kuppler, F.; Minol Messtechnik: Erste Heizkostenabrechnung nach Verbrauch in Chemnitz. Sonderausgabe des Heizungsjournals; 3. NT-Sonderausgabe, 1991 [5]

Tab. 3: Results of a study in Wolfsburg [2]

Heating period	Housing estate consumption (weather-adjusted)
1973/74 (flat-rate billing)	29,606 MWh
1974/75 (consumption-related billing)	23,608 MWh

A more far-ranging study was undertaken between 1974 – 1977 in an area of Nuremberg with district heating [3]. 7200 of the 8100 flats in this supply area were equipped with evaporation heat cost allocators. This study was able to evaluate three full heating periods and compare the flats with consumption-based billing with the other flats for which billing was still conducted on a flat-rate basis. As table 4 shows, the additional consumption of the flats not fitted with heat cost allocators was between 18 and 26%.

Tab. 4: Results of a study in Nuremberg

Heating period	Residential units with heat cost allocators	Residential units with flat-rate billing	Additional consumption
1974/75	11,907 kWh/a	14,050 kWh/a	18%
1975/76	11,568 kWh/a	14,576 kWh/a	26%
1976/77	11,962 kWh/a	14,593 kWh/a	22%

In the years from 1981 to 1985, 110 buildings equipped with heat cost allocators in 6 locations in West Germany were compared with a control group [4]. This consisted of 95 buildings distributed throughout the Federal Republic of Germany in which flat-rate billing was still used. When the buildings were selected, attention was paid to ensuring that all other building characteristics and usage-related features were as evenly distributed as possible. Four heating periods were evaluated for both groups and the weather-adjusted consumption curves were determined for both groups. As a result, an average additional heating energy consumption of 13% was identified for the buildings with flat-rate billing. Due to the consumption pattern established over the individual heating periods, the study assumed that the savings effect from consumption-based billing would decline over time. The reason given for this was the general tendency among all citizens towards saving more.

A more recent study was conducted in Chemnitz for the heating period of 1990/91 [5]. For this study 46 flats were fitted with heat cost allocators as well as hot and cold water meters. As the Heating Cost Allocation Regulation was not yet applicable in the new German states at this time, the tenants were promised prizes to reward the 10 most economical residents. This was supplemented by information on correct heating and ventilation as well as on the function of the metering devices. At the end of the study, the respective consumption figures of the individual tenants for the heating period under examination were analysed. The buildings in question recorded an average of 25% lower heating energy consumption compared with other buildings of the control group with flat-rate billing in Chemnitz. A direct comparison of the tenants shows that 17% of

residents had an above average consumption, whereas all other consumption figures for residential units were less or only slightly above average.

2.2.2. Situation in other countries

Whereas the German studies date back many years, there are nevertheless many of them; other countries have little experience with regard to consumption-based billing. The following section presents a few important studies from Denmark[6], Sweden[7], France[8,9] and Russia[10].

In a major project in Albertslund/Denmark, the heat consumption for heating and hot water was investigated for a total of 2510 buildings [6]. These buildings were spread over seven residential areas. Over a period of 14 years from 1991 to 2005, the switch was made in each residential area from flat-rate to consumption-based billing. In parallel to the changed billing method, the tenants were informed as to how the measuring devices functioned and also about the billing modes. In extreme cases, household heat consumption fell by 30%. However, more realistic consumption reductions were between 15 and 17%. The recorded savings took effect within two years and continued for the entire period of the study.

In the heating period of 1953/54, a study was performed in a residential area in Stockholm of ten identical buildings each housing 10 flats [7]. 5 of these buildings were equipped with heat cost allocators and calorimeters. The occupants of these buildings were informed of their individual consumption by monthly readings. In comparison to the buildings where billing was conducted on a flat-rate basis, the flats equipped with heat consumption measuring devices had a lower consumption of 10 – 25% in terms of heat consumption energy and 40 – 50% with regard to hot water consumption.

A study in France observed 5 buildings with a total of 264 flats during the time when flat-rate billing was replaced with consumption-based billing. The buildings were in Paris (2), Reims (2) and Pantin (1). The composition of the consumption-based billing method was 40% according to basic costs and 60% according to individual consumption. In the years from 2004 to 2006 one heating period with flat-rate billing and one period with consumption-based distribution of the heating costs were examined. The results showed an average saving of 20% when compared to flat-rate billing. A most recent study shows on a very broad basis with 75 buildings all over France a similar result with average energy savings of 19,8% [9].

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[6] Gullev, L.; Poulsen, M.: The installation of meters leads to permanent changes in consumer behavior. News from DBDH, 03/2006 [6]

[7] Adamson, B.; Reijner, E.: Wärmeverteilungszählung in Wohnhäusern. GI, Issue 1/1958 [7]

[8] Ademe; Huze, M.-H.; Cyssau, R.: Maitrise de la demande d'energie par les sevices d'individualisation du chauffage. Rapport final, 09/2006 [8]

[9] Syndicat de la mesure: L'individualisation des frais de chauffage à l'épreuve des faits; Étude de l'impact des systems sur les consommations d'énergie en résidentiel collectif. Rapport final 12/2015 [9]

[10] Pötter, K.; Pahl, M. H.: Wasser- und Wärmeeinsparung in russischen Wohnhäusern. Ergebnisse des Dubna Projekts. Euroheat and Power, 3/1999, Issue. 28 [10]

In the small Russian town of Dubna [10] 72 flats were fitted with individual water meters, heat cost allocators and thermostatic valves. The flats were located in two structurally identical housing units of a nine-storey brick building. Two other housing units were used to compare the real water and heating consumption figures. The first consumption-based heating cost bills were issued for the 72 flats fitted with metering devices in May 1998. The evaluation of the 1997/1998 heating period showed that the flats billed in a consumption-based manner had a reduced heat consumption of 23% compared with the control group. Hot water consumption fell by 55%.

2.2.3. Comparison of the results and Europeanisation

Table 5 shows the savings observed in the studies presented thus far in various European countries. The savings effects in the countries in question are of similar dimensions — between 13 and 25%. When examining the results it must be remembered that experience of consumption-based billing in other countries has not been studied and reported upon to the same degree as in Germany. Some studies showed that particularly high savings could be attained by making information available to the tenants on either a one-off or regular basis.

Tab. 5: Savings observed in different countries

Country	**Observed saving**
Germany	13 – 25%
Austria	10 – 30%
Denmark	15 – 17%
Sweden	10 – 25%
France	20%
Russia	23%

It can be seen in the table above that the attainable average consumption savings resulting from consumption-based billing in Europe are also around the 20% typical in Germany. Deviations from this value are probable in individual cases especially when the structural circumstances and the usage of the building are taken into account, however the tendency is that both greater savings as well as lesser savings will result. Therefore for further potential savings estimates and simplified economic efficiency analyses an average consumption reduction of 20% will be used.

In the context of the introduction of consumption-based billing of heating costs as required in the EU directive, it is recommended that the abovementioned savings effects are verified with a before/after comparison.

3. Potential estimate and economic efficiency consideration

Now the aim is to derive statements on absolute savings and potential emissions reductions in Europe with the aid of the relative energy savings resulting from consumption-based heating cost allocation determined previously. The proportion of apartment buildings relevant for consumption-based billing in terms of the total residential building stock and therefore the billing market differs widely within Europe as the following diagram illustrates.

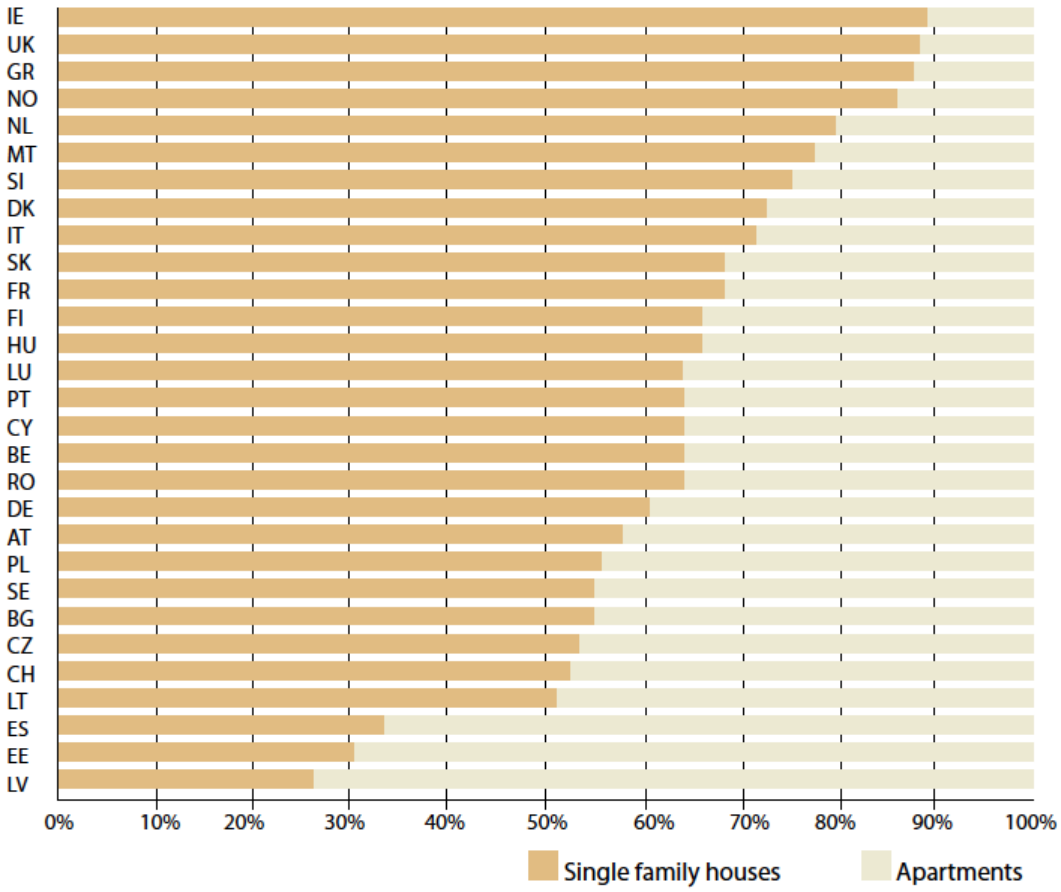

Fig. 1: Proportion of residential living area of single family and apartment buildings in European countries[11]

It therefore makes sense to restrict further consideration of the savings potential to selected European countries. The selection of the countries at this point will be made to take account of the building stock relevant for heating cost billing in individual countries as well as the levels of meters fitted already. Data is available for this, as can be seen in figure 2.

[11] Europe´s buildings under the microscope. A country-by-country review of the energy performance of buildings. BPIE 2011

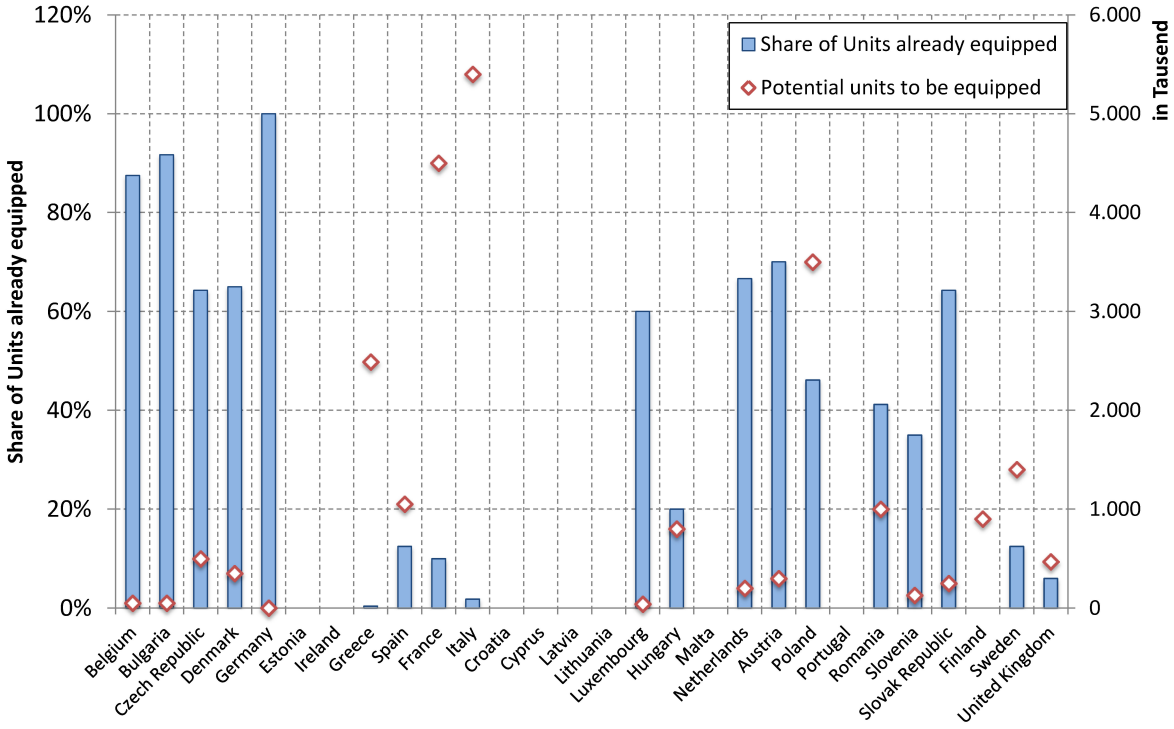

Fig. 2: Number of relevant accommodation units and levels of heat cost allocator equipment in Europe[12]

France, Italy, Poland and Sweden are among the European countries with the greatest number of flats still to be fitted with heating cost allocation systems. Therefore it is useful to conduct the potential savings estimate for these countries. The following section contains economic considerations on heating cost allocation as well as calculations of the annual CO_2 emissions including the emissions reductions resulting from heating cost allocation. The statistical building data for the individual countries required for the estimations has been taken from freely available building databases – as far as this is available[13] [14]. For the CO_2 emissions factors, the values stated in [15] are applicable. All calculations relate to room heating (without domestic hot water generation). The economic efficiency calculation has the aim of compensating the costs necessary for providing the technical equipment (including servicing) for heating cost allocation with the attainable heating cost savings. The heating cost saving due to heat cost distribution is 20% in accordance with the estimate made above. The costs of heating cost allocation are country-specific values.

[12] E.V.V.E 2011

[13] http://www.episcope.eu/building-typology/

[14] http://www.buildingsdata.eu;

[15] http://www.eumayors.eu/IMG/pdf/technical_annex_en.pdf

France

In France there are about 5 million accommodation units in apartment buildings that are relevant in terms of heating cost allocation. This corresponds to a total residential surface area of around 304.1 million m^2. The typical flat size used as the basis for the efficiency calculation is 68 m^2. Figure 3 shows that the economic conditions for the use of heating cost allocation are given for all building age categories. This effectively involves the entire stock of apartment buildings under consideration here.

In France, currently around 10% of the accommodation units falling into the heating cost allocation application area are equipped with heat consumption recording equipment or heat cost allocators. In older accommodation units, it is mostly gas that is used for heat generation (63%) whereas more modern buildings mostly use electricity as an energy source (48%). The buildings heated with electricity will not be considered here as it is assumed that decentralised heating is used here. The current annual CO_2 emissions in apartment buildings – taking the existing equipment level for heat cost allocators into consideration – are an estimated 6.6 million tonnes. If all units were fitted with allocators, an annual saving of 1.2 million tonnes could be achieved. Figure 4 shows a summary of CO_2 emissions where the heat cost allocators are completely missing (equipment level: 0%), the current level of equipment (10%) and a 100% equipment level of all relevant accommodation units. In addition the annual emissions reduction potential from heating cost allocation that is achieved or attainable is shown (right axis). Table 6 contains detailed information on the calculation of CO^2 emissions.

Tab. 6: Calculation of CO_2 emissions for France

Energy source	**Emissions factor in kg/kWh**	**ACTUAL emissions in million tonnes CO_2/p.a.**	**Emissions with 100% HCA in million tonnes CO_2/p.a.**
District heating	0.25	0.9	0.74
Natural gas	0.202	5.0	4.1
LPG[16]	0.2	0	0
Heating oil	0.279	0.6	0.5
Total		**6.5**	**5.3**

[16] Liquefied Petroleum Gas

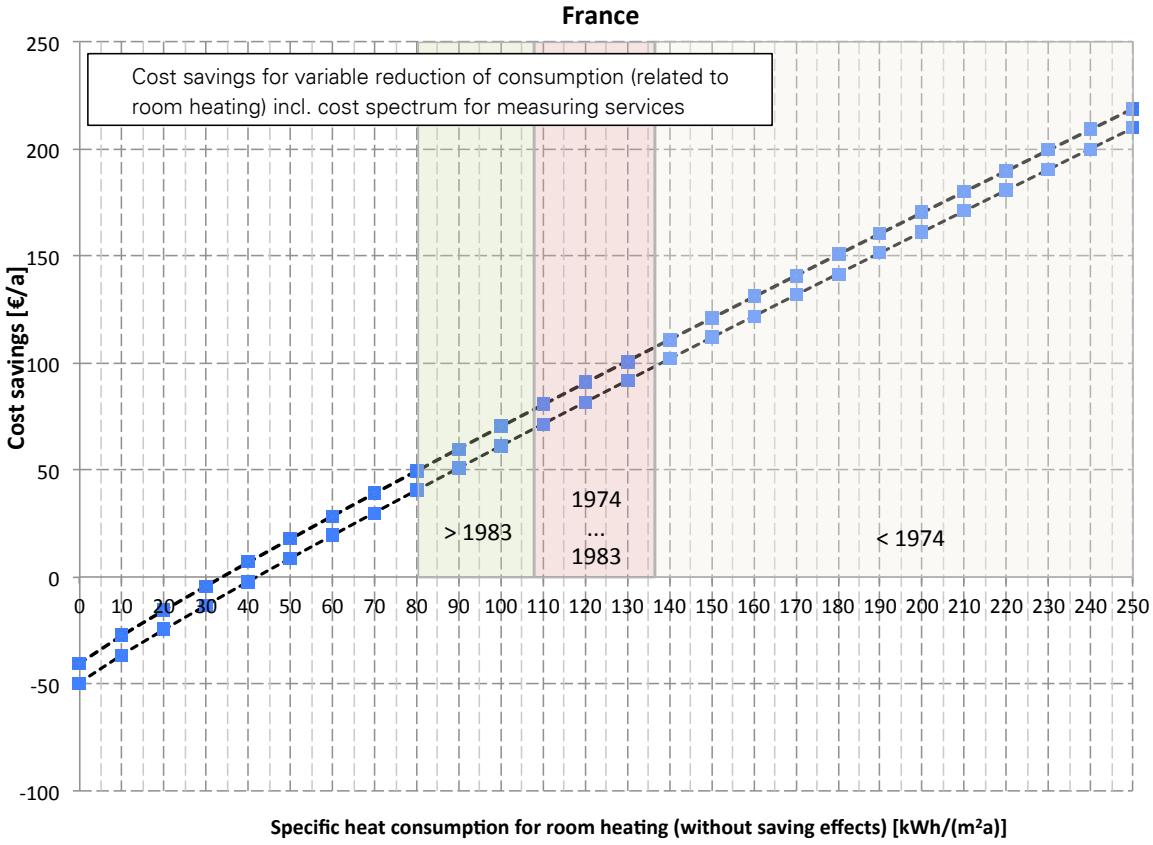

Fig. 3: Cost savings with heating cost recording (France)

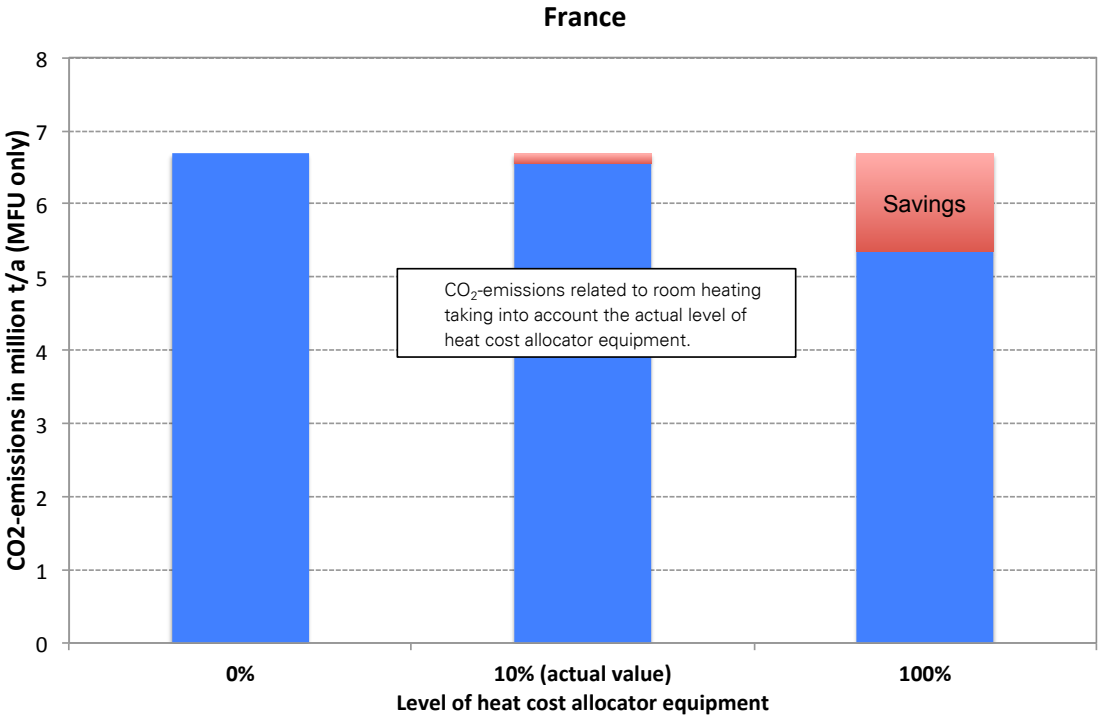

Fig. 4: CO_2 emissions with heating cost recording (France)

Italy

In Italy there are about 5.5 million accommodation units in apartment buildings that are relevant in terms of heating cost allocation. This corresponds to a total residential surface area of around 513.1 million m^2. The typical flat size used as the basis for the efficiency calculation is 80 m^2. Figure 5 shows that the economic conditions for the use of heating cost allocation are given for all building age categories. This effectively involves the entire stock of apartment buildings under consideration here. Consumption data of residential buildings in Italy was taken from the ENTRANZE project[17].

In Italy, currently around 2% of the accommodation units falling into the heating cost allocation application area are equipped with heat consumption recording equipment or heat cost allocators. The buildings are largely supplied with gas for heat generation (proportion 77...93%). District heating is not relevant here. The current annual CO_2 emissions in apartment buildings – taking the existing equipment level for heat cost allocators into consideration – are an estimated 10.8 million tonnes. If all units were fitted with allocators an annual saving of 2.1 million tonnes could be achieved. Figure 6 shows a summary of CO_2 emissions where the heat cost allocators are completely missing (equipment level: 0%), the current level of equipment (2%) and a 100% equipment level of all relevant accommodation units. In addition the annual emissions reduction potential from heating cost allocation that is achieved or attainable is shown (right axis). Table 7 contains detailed information on the calculation of CO^2 emissions.

Tab. 7: Calculation of CO_2 emissions for Italy

Energy source	**Emissions factor in kg/kWh**	**ACTUAL emissions in million tonnes CO_2/p.a.**	**Emissions with 100% HCA in million tonnes CO_2/p.a.**
District heating	-	0	0
Natural gas + LPG	0.202	10.6	8.55
Heating oil	0.279	0.2	0.15
Total		**10.8**	**8.7**

[17] The challenges, dynamics and activities in the building sector and its energy demand in Italy. D2.1 of WP2 from Entranze Project; http://www.entranze.eu

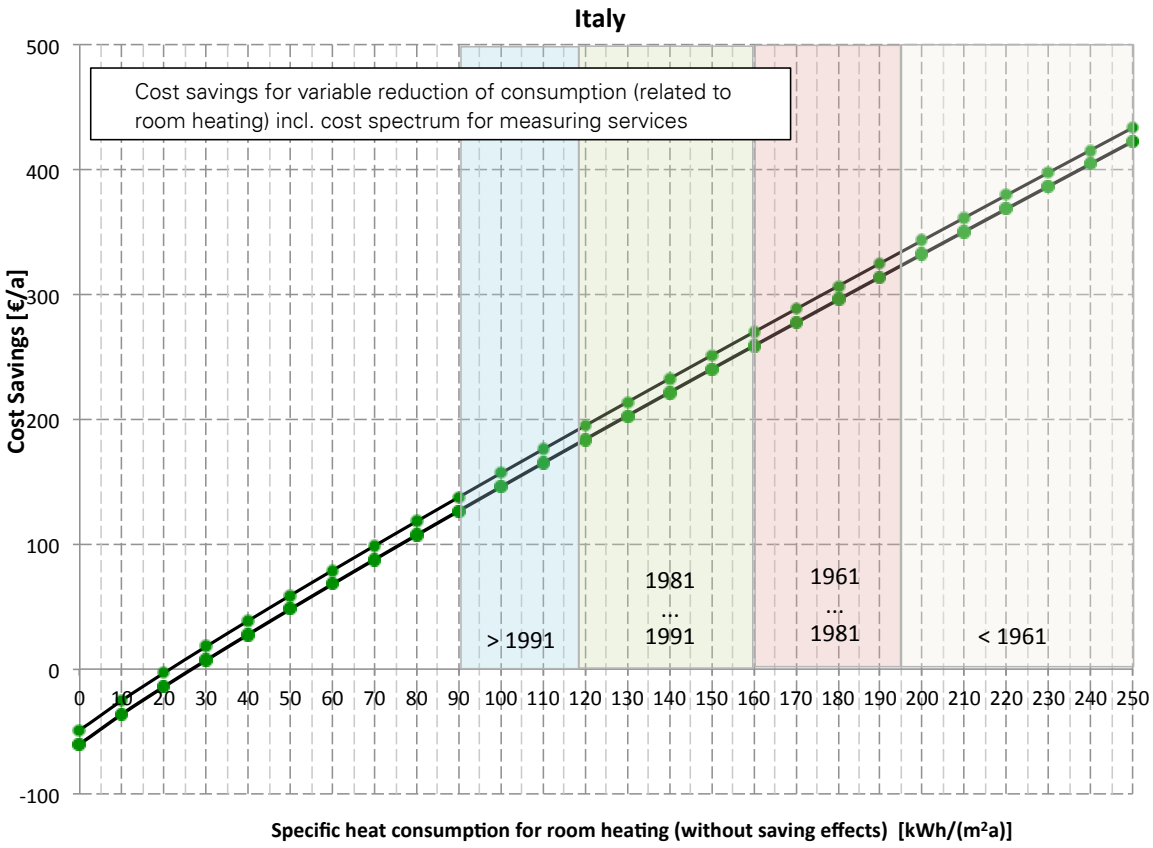

Fig. 5: Cost savings with heating cost recording (Italy)

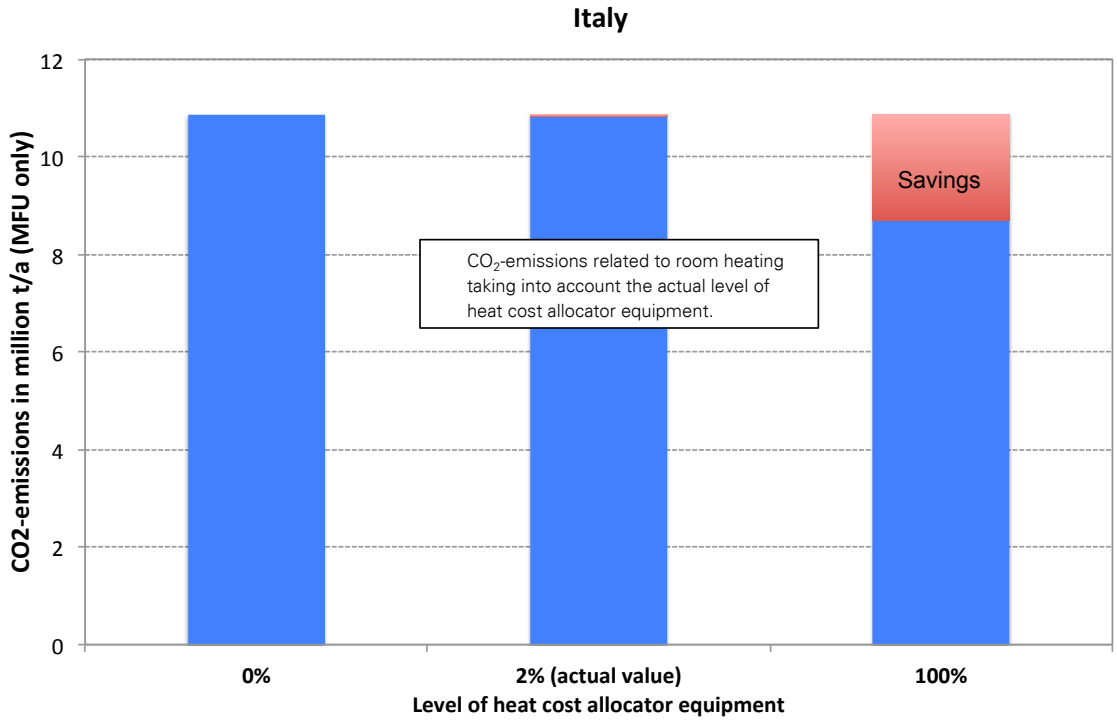

Fig. 6: CO_2 emissions with heating cost recording (Italy)

Poland

In Poland there are about 6.5 million accommodation units in apartment buildings that are relevant in terms of heating cost allocation. This corresponds to a total residential surface area of around 343.8 million m^2. The typical flat size used as the basis for the efficiency calculation is 50 m^2. Figure 7 shows that the economic conditions for the use of heating cost allocation are given for all building age categories. This effectively involves the entire stock of apartment buildings under consideration here.

In Poland, currently around 46% of the accommodation units falling into the heating cost allocation application area are equipped with heat consumption recording equipment or heat cost allocators. All conventional energy sources such as district heating (estimated proportion 30% gas, approx. 46.60% oil and coal) are in use. District heating in Poland has a relatively poor average CO_2 emissions factor of 100.5 t/TJ [18]. The current annual CO_2 emissions in apartment buildings – taking the existing equipment level for heat cost allocators into consideration – are an estimated 11.1 million tonnes. If all units were fitted with allocators an annual saving of 1.3 million tonnes could be achieved. Figure 8 shows a summary of CO_2 emissions where the heat cost allocators are completely missing (equipment level: 0%), the current level of equipment (46%) and a 100% equipment level of all relevant accommodation units. In addition the annual emissions reduction potential from heating cost allocation that is achieved or attainable is shown (right axis). Table 8 contains detailed information on the calculation of CO^2 emissions.

Tab. 8: Calculation of CO_2 emissions for Poland

Energy source	**Emissions factor in kg/kWh**	**ACTUAL emissions in million tonnes CO_2/p.a.**	**Emissions with 100% HCA in million tonnes CO_2/p.a.**
District heating	0.36	5.1	4.5
Natural gas	0.202	5.3	4.7
LPG	0.2	0	0
Heating oil	0.279	0.75	0.7
Total		**11.1**	**9.8**

[18] "Fernwärme in Polen", information from the Chamber of Commerce Polish District Heating

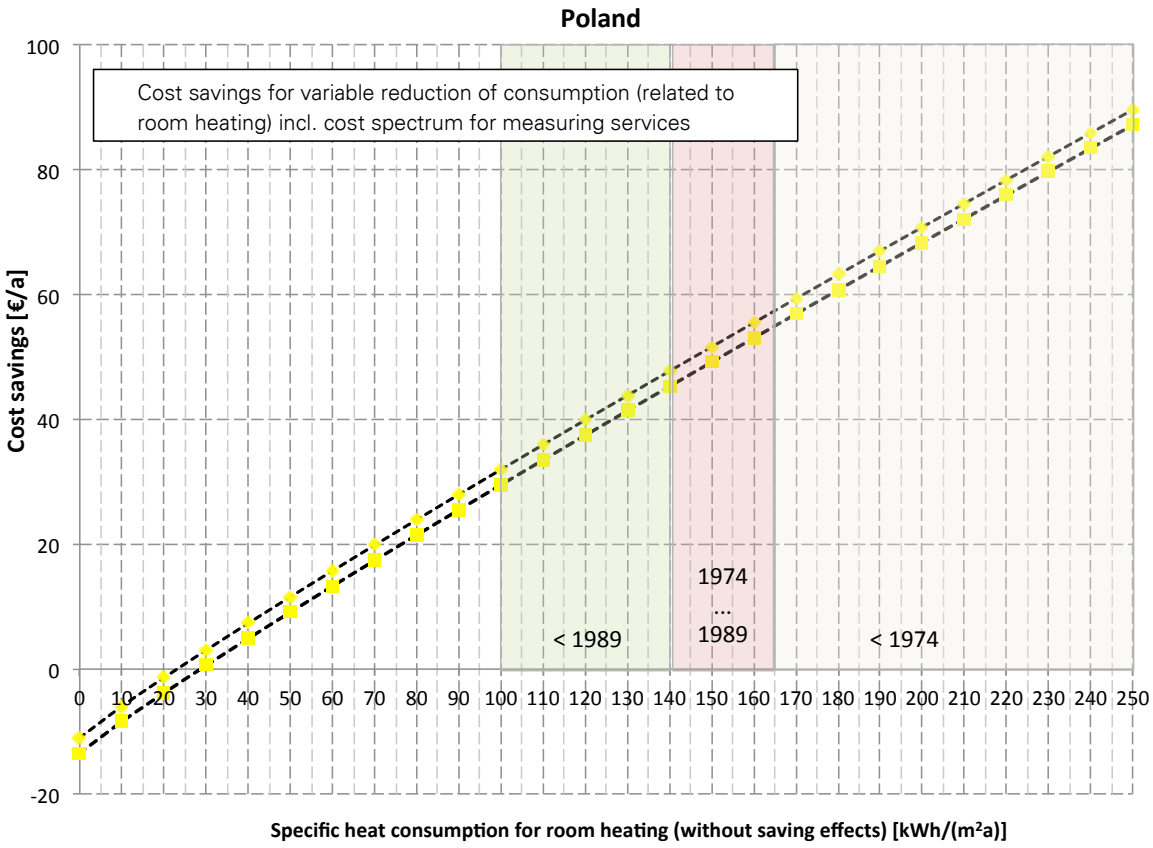

Fig. 7: Cost savings with heating cost recording (Poland)

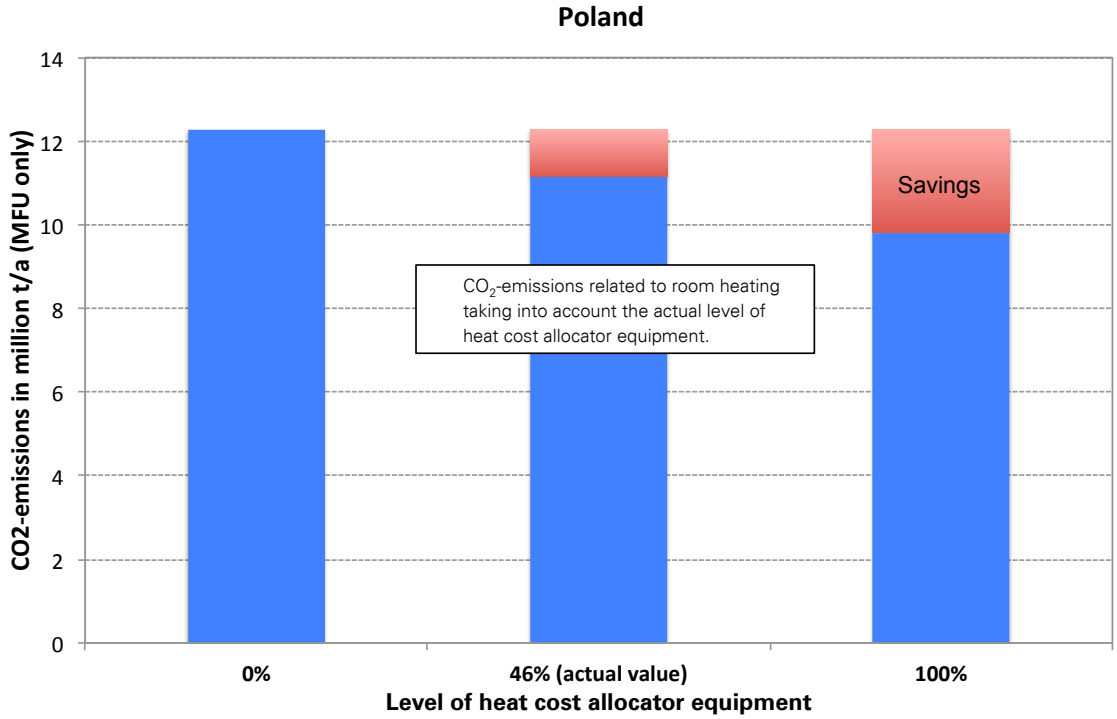

Fig. 8: CO_2 emissions with heating cost recording (Poland)

Sweden

In Sweden there are about 1.6 million accommodation units in apartment buildings that are relevant in terms of heating cost allocation. This corresponds to a total residential surface area of around 158.1 million m^2. The typical flat size used as the basis for the efficiency calculation is 70 m^2. Figure 9 shows that the economic conditions for the use of heating cost allocation are given for all building age categories. This effectively involves the entire stock of apartment buildings under consideration here. The necessary consumption data for estimating heat consumption have been taken from a special Swedish statistical report[19].

In Sweden, currently around 13% of the accommodation units falling into the heating cost allocation application area are equipped with heat consumption recording equipment or heat cost allocators. The heating supply of the buildings is largely by means of district heating (proportion 80%). The CO_2 emissions linked with district heating supply in Sweden are relatively low and amount to only around 50 kg/MW[20]. The current annual CO_2 emissions in apartment buildings – taking the existing equipment level for heat cost allocators into consideration – are therefore just around 0.98 million tonnes. If all units were fitted with allocators an annual saving of 0.18 million tonnes could be achieved. Figure 10 shows a summary of CO_2 emissions where the heat cost allocators are completely missing (equipment level: 0%), the current level of equipment (10%) and a 100% equipment level of all relevant accommodation units. In addition the annual emissions reduction potential from heating cost allocation that is achieved or attainable is shown (right axis). Table 9 contains detailed information on the calculation of CO^2 emissions.

Tab. 9: Calculation of CO_2 emissions for Sweden

Energy source	**Emissions factor in kg/kWh**	**ACTUAL emissions in million tonnes CO_2/p.a.**	**Emissions with 100% HCA in million tonnes CO_2/p.a.**
District heating	0.05	0.92	0.75
Natural gas	0.202	0	0
LPG	0.2	0	0
Heating oil	0.279	0.06	0.05
Total		**0.98**	**0.81**

[19] http://www.scb.se (Swedish statistics)

[20] „Low Carbon District Heating in Sweden" by Sven Werner Halmstad University, 2010

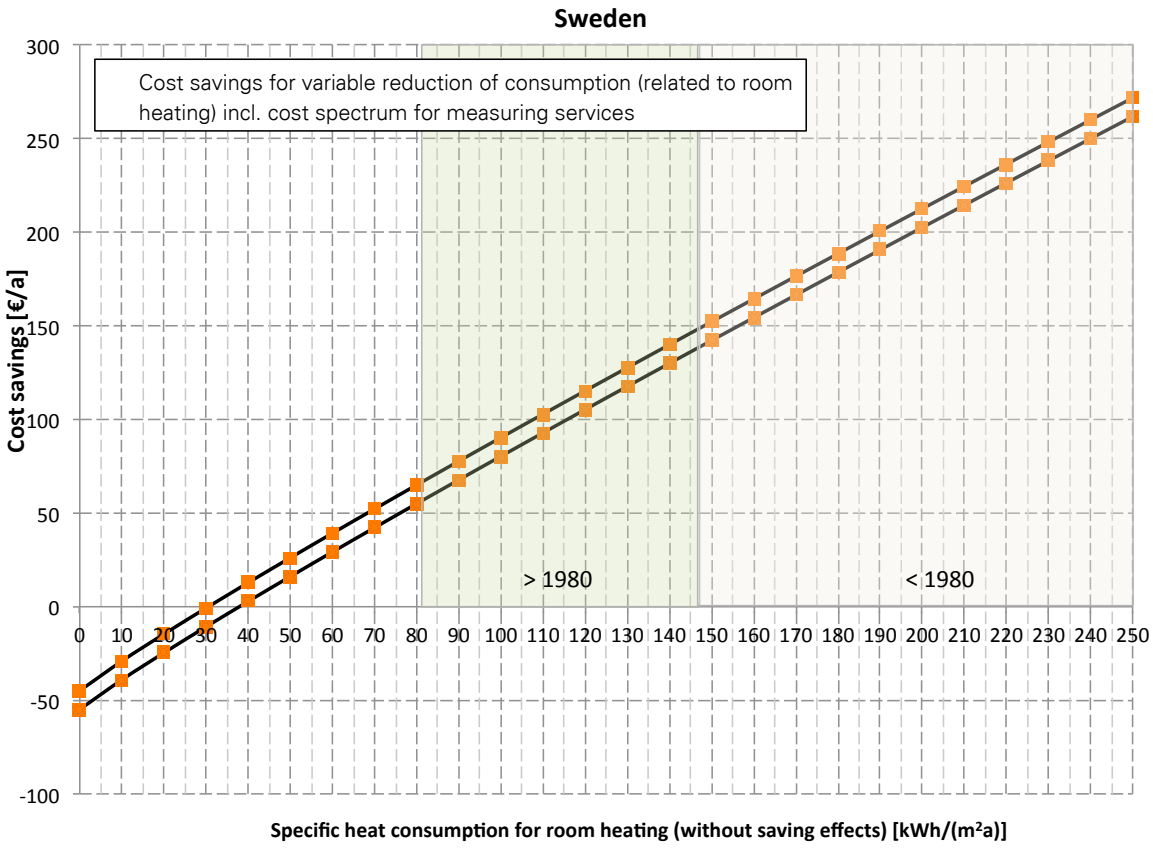

Fig. 9: Cost savings with heating cost recording (Sweden)

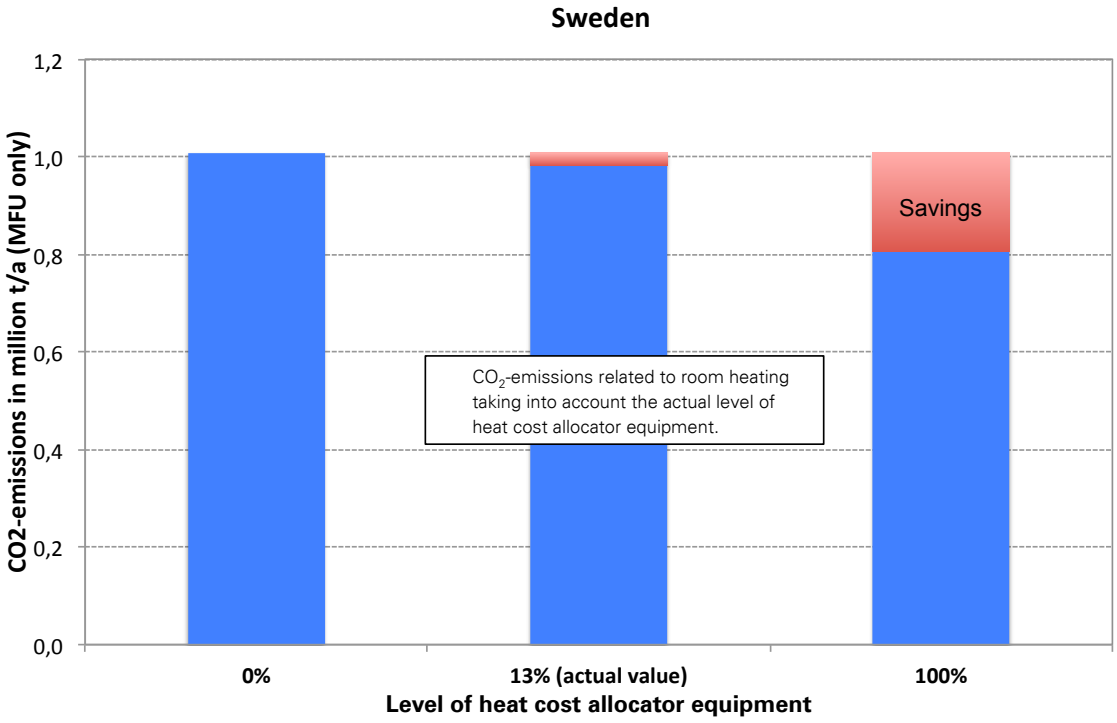

Fig. 10: CO_2 emissions with heating cost recording (Sweden)

Table 10 gives a summary of the most important key figures for the four countries under consideration. The table shows the number of accommodation units still relevant in terms of further equipping, the corresponding total residential area in the countries, the minimum required heat consumption for room heating for heating cost allocation to be economical under the currently prevailing conditions and the savings in terms of CO_2 emissions that can be expected if all units were equipped with the corresponding technology.

Tab. 10: Overview of the countries under consideration

Country	**Number of relevant accommodation units**	**Respective heated area in million m²**	**Heating consumption as cost limit for economic efficiency in kWh/m²a**	**Avoidable CO_2 emissions in million t/a**
France	4.5 million	273.6	34	1.2
Italy	5.4 million	503.8	21	2.1
Poland	3.5 million	186.3	23	1.3
Sweden	1.4 million	138.4	30	0.2
Total	**14.8 million**	**1,102.1**		**4.8**

On the basis of these figures, in the four countries under consideration alone the use of consumption based heating cost allocation, assuming a corresponding consumption reduction of 20% per annum, an estimated output of 4.8 million tonnes of CO_2 emissions could be avoided.

The economic efficiency of the measures is guaranteed in the four countries for the entire stock of apartment buildings as the heating consumption shown in the statistics is greater than the calculated threshold value for economic efficiency. If the results of the German study are taken into consideration when evaluating the economic efficiency of the introduction of consumption-based heating cost allocation, it must also be taken into account that the calculated surface-related energy requirement values considerably underestimate actual energy consumption in some cases[21].

[21] Kähler, A.; Klein, J.: Vorsicht bei Amortisationsrechnung - Energiekennwertestudie zeigt massive Verbrauchsspreizungen und deutliche Abweichungen zwischen Bedarf und Verbrauch. IKZ-Fachplaner, 9-2014

http://www.ikz.de/nc/ikz-fachplaner/artikel/article/vorsicht-bei-amortisationsrechnungbr-energieken-0054075.html

Appendix

The following list provides short summaries of the studies examined. All of the studies have a certain relevance to the topics of consumption-based billing or energy savings as a result of changed user behaviour. First, literature sources are listed that directly refer to percentage energy savings in buildings which are the result of user behaviour arising from consumption-based billing. This collection encompasses 24 studies with results from research from Germany as well as other European countries such as Switzerland, Denmark, Sweden, France and Austria.

In addition, the research for this study has also taken in studies, which do not specifically state a savings potential, but which can be regarded as supplementary literature. These additional nine studies will be presented in the section following this one.

Studies examined with brief summaries

D-01: Loga, Tobias; Großklos, Marc; Knissel, Jens: Der Einfluss des Gebäudestandards und des Nutzerverhaltens auf die Heizkosten – Konsequenzen für die verbrauchsabhängige Heizkostenabrechnung. Institut Wohnen und Umwelt GmbH Darmstadt, 15 July 2003

The project examines the economic efficiency of consumption-orientated heating cost billing. The first aim was to identify the achievable savings resulting from consumption-based billing. The possible savings were examined with regard to their relationship to user behaviour and different building energy standards. This was conducted in four stages:

- Description of energy behaviour in buildings (identification of the parameters that can be influenced by the users)
- Evaluation of measuring projects (quantification of usage parameters)
- Creation of a user model (typical values for economic, wasteful and average behaviour)
- Determination of the comparative costs as a function of the building standard

On the basis of the evaluation of the measurement results of different studies, an "average user" as well as comparative "savers" and "wasters" were defined. These groups of user differ according to target room temperature, lowering temperatures at night, partial heating and ventilation. As reference values for the cost comparisons, the average heating costs were calculated using the average usage for different building energy standards (existing multi-family units, German Energy Saving Regulation of 2002, LEH and passive-energy house standard) Firstly the savings due to consumption-based billing were examined. A reduction of 20% of heating consumption was empirically proven for existing buildings. On the basis of the user models, savings of 30 to 40% were calculated for LEHs. For the examination of user influence on individual consumption, the previously created user model (wasteful, average, sparing) were used.

D-02: Loga, Tobias; Großklos, Marc: Lohnt in Niedrigenergiehäusern die verbrauchsabhängige Heizkostenabrechnung? HLH vol. 56 (2005) No. 7 – July

This article summarises the findings of a study ("Der Einfluss des Gebäudestandards und des Nutzerverhaltens auf die Heizkosten – Konsequenzen für die verbrauchsabhängige Heizkostenabrechnung" [The Influence of Building Standards and User Behaviour on Heating Costs – Consequences of Consumption-Based Heating Cost Billing] IWU, Darmstadt 2003) that was commissioned by Viterra Energy Services AG (ista Deutschland GmbH). This study looks at whether energy can also be saved in low energy houses with consumption-based heating cost billing. Even though heating energy consumption at average usage levels largely depends on the energy qualities of the building, the user can exercise a great influence on consumption with either particularly sparing or wasteful behaviour. The article estimates this influence to be a ± 50% change in consumption compared to the average user of the building examined. The study focussed particularly on low energy housing. These buildings have a low transmission heat loss of 30 – 50% under the threshold value set down in the German Energy Saving Regulation. Consumption-based billing is lucrative for the user if the costs for conducting this type of billing are lower than the financial savings compared to the average household.

D-03: Minol Messtechnik: Erste Heizkostenabrechnung nach Verbrauch in Chemnitz. Sonderausgabe des Heizungsjournals; 3rd Special Issue "Niedertemperaturheizung", Nov./Dec.1991

This article reports on the investigation of the effects of consumption-based heating cost billing on energy consumption using the example of a pilot project in the Sonnenstraße in Chemnitz. The experiment was intended to prove that billing on the basis of individual consumption would result in heating and water cost savings within a short period without additional investment. 46 flats were equipped with heat cost distributors as well as hot and cold water meters. As the Heating Cost Allocation Regulation was not yet applicable during the affected heating period of 1990/91, the 10 most sparing users were promised rewards. They were informed ahead of the project about heating correctly as well as how the measuring devices functioned. After the evaluation of the first heating period, it was established that savings of 5.20 DM/m^2 annually in heating costs or a 25% reduction in heating energy consumption could be attained compared to comparable buildings in Chemnitz without consumption-based billing. An analysis of the individual consumption values of the occupants showed that the users behaved in very different ways. Whereas 83% of the flats examined had lower or only marginally higher than average heating consumption, 17% had an above-average consumption. In the sense of billing fairness, this seems to prove that heating cost allocation on the basis of individual consumption is a justified means.

D-04: Schiller, Siegfried: Versuchsergebnisse mit Wärmemessern (Heizkostenverteilern) bei Zentralheizungen. Haustechnische Rundschau, Issue 12, December 1956

The article investigates the experiences of landlords and tenants of centrally heated buildings with consumption-based heating cost allocation. The study examines non-residential buildings as well as purely residential buildings of differing sizes as well as mixed-used buildings. In the run-up to the study, surveys of tenants and landlords were conducted and the benefits of heating cost allocation were presented. The investigation yielded results showing savings of fuel consumption of between 5.8 to 37.8%. The average saving was 23%. A survey conducted after the switch to consumption-based billing showed the 91% of tenants and nearly 100% of landlords were convinced that billing was now fairer than previously. Tenants began to reduce their heating consumption with savings measures. These measures were largely turning off radiators in secondary rooms and in the bedroom.

D-05: Raiß, W.: Einsparung an Heizenergie durch wärmedichtes Bauen und Wärmeverbrauchsmessung. HLH 15, No. 12, December 1964

The article is a summary of the report given by Prof W. Raiß at the World Power Conference of 1964 in Lausanne. The opportunities for saving energy in buildings were named as the structure of the building and local, requirements-orientated regulation of the power to heating surfaces. The section covering heat consumption measurement first names the general difficulties that result from consumption-based billing:

- How is the necessary stand-by heating to be billed?
- How are the differences in geographical orientation of the flats in terms of heating requirement to be handled?
- How can the transmission of heat from heated flats into unheated or lesser heated flats or secondary rooms of other flats be taken into account?

After this section, the general procedure for determining the correct consumption of heating costs was explained.

Specialist literature from the pre-war years had shown that savings of between 20 to 30% were possible compared to flat-rate billing, without taking individual consumption into account. The reason given for this was that there was no incentive to make savings with flat-rate billing. This would result in bedrooms and secondary rooms being fully heated and a general overheating of all rooms. The author assumes that the introduction of heat meters would result in savings of 15% and more if the rooms were overheated previously. Otherwise the savings would be around 10%.

D-06: Kolar, J.: Fernwärme und End-Energie in Nürnberg. Fernwärme International, 7th Volume, Issue 2, April 1978

This article is the publication of investigations commissioned by EWAG (Energie- und Wasserversorgung Aktiengesellschaft, known today as: N-ERGIE). Firstly the city of Nuremberg is presented in detail as a city in the middle Franconian agglomeration. A list of various statistics shows the energy consumption as well as the heating and energy source structure of households in Nuremberg in 1975. Afterwards the areas of Nuremberg supplied with district heating are examined in closer detail and various studies are presented that look at the development of district heating supply in Nuremberg. In the last section the author looks at heat cost allocators as the "optimum means for saving energy". EWAG introduced evaporation heat cost allocators as early as 1968. An evaluation of the heating periods 1974/75, 1975/76 and 1976/77 with heating cost allocation compared the consumption of flats equipped with heat cost allocators with the consumption of similar flats without heat cost allocators. The additional consumption of the flats not fitted with heat cost allocators was between 18 and 26%.

D-07: Jacobi, E.: Vertretbare und erreichbare Heizungsbetriebskosten im Wohnungsbau. BBauBl, Issue 2, 15 February 1962

This article takes a closer look at various aspects of heating costs in residential buildings. To make new flats competitive on the free market, their operating costs were to be reduced to a minimum. In the opinion of the author, good heating insulation and a modern heating system are particularly necessary. The article starts by presenting the average heating requirement values for flats in a building with good heat insulation. These are presented in the context of the location of the consumer unit in the building. Afterwards the additional costs for retrofitting good heat insulation are presented and suggestions are made for financing these costs. In addition, the individual costs of installing central heating and the operating costs of this system are explained in detail. Subsequently the annual usage hours of the heating system with average heat insulation of the building with flat-rate billing are compared to those with measured billing. According to this, in three-room flats mostly occupied by families, a 15 to 20% reduction in annual usage costs was observed with measured billing; in smaller flats occupied by employed persons, the reduction was between 20 and 25%.

The savings of measured billing compared to flat-rate billing have to be balanced with the extra cost of conducting measurements and creating these bills. The article shows the annual financial expenditure for devices, installation, services etc. depending on the size of the flat. Whereas a measurement with the aid of a water meter and multiple sensor device, depending on the average operating costs, 20 to 27% of the annual heat consumption occurring under flat-rate billing would have to be saved, with measurement using heat cost allocators, 8 to 10% of consumption would have to be saved to make measured billing economical. The article summarises the advantages and disadvantages of the billing modes, with the author coming down in favour of flat-rate billing.

D-08: Ackermann, F.; Reckel, G.: Erfahrungen mit einer Verbrauchsvariante der Fernwärmeabrechnung. FWI, Edition 5, Issue 3/1976

1467 flats of a housing estate with district heating were examined during the period in which the switch was made from flat-rate billing to consumption-based heating cost billing using evaporation measuring devices. For the purposes of the study the heating energy consumption of the housing estate, the heating period of 1973/74 (flat-rate billing) was compared with the subsequent period of 1974/75 (consumption-based billing). After adjustment for differing weather conditions, it was seen that tenants reduced their consumption by 20% and made a financial saving of 11.9% or DM 1.18/m2. The financial savings resulted from the tariff structures of the Wolfsburg public utilities company applicable at the time. The calculation also takes the billing costs into account.

D-09: Oschatz, B.; Richter, W.: Heizkostenerfassung im Niedrigenergiehaus. Forschungen im Auftrag des BBR, Issue 118, Bonn 2004

The study focussed on the question of whether the implementation of consumption-based billing is also economical in modern buildings with constantly decreasing heat requirements, e.g. in low energy housing. The study first gives an overview of the prevailing standards and regulations for heating cost allocation as well as the legal basis established by the German Energy Saving Regulation. This is followed by a brief summary of the regulations on heating cost calculation in other European countries. Afterwards the study looks at the issue of the degree to which user behaviour can influence the heat consumption of a building. Studying different residential buildings (detached houses, terraced housing, 12-apartment buildings) with different insulation standards, an investigation was conducted of the effects of behavioural changes on the part of the user (increasing room temperature, air exchange) on heating consumption using the calculation established in DIN V 4108-6. This shows that the energy-related effect on the building of temperatures changed by the user and/or air exchange depends on the heat insulation. The better the energy qualities of the building structure, the lower the additional heating requirement when user demand increases. On the other hand the relative effects rise significantly due to the lower basic heating requirements in highly heat insulated buildings. The savings potential of consumption-based billing established in the literature were adjusted to the conditions in low energy houses for the purposes of examining economic efficiency. The calculations showed a heating requirement savings potential of 30 – 36% for low energy houses. In addition end energy demand values were calculated from the heat requirement values using flat-rate building expenditure figures. These calculations show that without consumption-based billing there is an average additional energy requirement of 26...27 kWh/m^{2}a in low energy houses with condensing and district heating. With gas and oil low temperature heated low energy houses an additional energy requirement of 29...30 kWh/m^{2}a is to be expected. This is followed by a discourse on the state of heat cost allocator technology and the market situation in Germany at the time the study was conducted (e.g. proportions of different heat cost allocators in use). In addition to the literature review, housing associations were also surveyed.

D-10: GEWOS: Durchführung der verbrauchsabhängigen Heizkostenabrechnung und ihre Auswirkung auf den Energieverbrauch – Endbericht. Hamburg 4/1986

The assessment was intended to clarify the degree to which consumption-based heating cost calculation results in changes to user behaviour and therefore contributes to energy savings. For the purposes of the study, 110 buildings spread over six locations throughout Germany were selected. At the time of the study, they had all been equipped with heat cost allocators for three to four heating periods. The energy consumption of these buildings and other building data were determined. There was also a control group of 95 buildings in which either no heat cost allocators were installed or in which they had been installed only recently. Weather-adjusted energy consumption curves were calculated for both groups over a period between 1981 and 1985. In addition, a survey of tenants and owners or housing associations was conducted across Germany. The results proved that heat consumption in residential buildings without consumption-based billing was on average 13% higher. The largest savings were observed in the transitional months in spring and autumn. The consideration of economic aspects in the assessment was orientated to the current tariff structures at that time. It was established that tenants had to save between 4 and 7% of heating energy (evaporation meters vs. electronic heat cost allocators) in order not to incur financial losses due to the implementation of consumption-based billing. The investigations also show that the savings effect of consumption-based billing reduces over time. The reason given for this is the generally stronger savings pattern of citizens even in the few buildings in which consumption-based billing is not used. This has obviously resulted from the considerable promotion of using heat energy in an economical manner. Thus the assessment assumes that the higher savings potential of around 20% proven in the studies conducted in the 70s was justified.

D-11: Raschper, N.: Energieesinsparpotenziale bei Bestandsgebäuden – zwischen Bedarfsberechnung und Verbrauchswerten.

and

D-12: Raschper, N.: Energieeinsparpotenziale bei Bestandsgebäuden – Teil 2: Warum Verbrauchswerte und Bedarfsberechnungen voneinander abweichen. Die Wohnungswirtschaft, 11/2010

A research project examined the energy consumption values of around 60,000 flats in existing buildings in Hamburg in 2009. In addition an exhibition of requirements and consumption certificates of 42 representative buildings was held and an analysis of the resulting differences was performed. The basis allowed the difference between assumed and actual tenant behaviour to be determined. Thus it was possible to justify the lesser consumption of non-renovated old buildings (in a range of 40 – 60 kWh/m^{2}a) and the increased consumption after comprehensive modernisation work (approx. 20 – 30 kWh/m^{2}a) with consumption-based billing. These findings enable a more practice-related

estimation of the energy savings potential of existing buildings, e.g. after renovation work. It must be noted that the German Energy Saving Regulation (EnEV) permits many simplifications in the calculation of the energy requirements of residential buildings that are used in most cases by the authorities issuing energy performance certificates due to pricing pressure. This is principally related to the simplification of the German Energy Saving Regulation in the following areas:

- calculation of the usable space
- flat-rate heat demand for hot water
- flat-rate assumption of thermal bridges
- determination of external and window surface areas
- estimation of the energetic quality of existing components and systems technology and
- ventilation heat loss

The further examination of literature and data enabled the identification of an average consumption of 145 kWh/(m^2a) for heating and hot water in residential buildings in West Germany. Only approx. 5 – 10% of the existing buildings examined fall into the category of high consumption buildings with consumption of over 200 kWh/(m^2a). It has been proven that user behaviour has a decisive influence on actual consumption in renovated buildings. Thus it was possible to show greater consumption of up to 25 – 30%. Due to non-altered tenant behaviour, the real heating energy consumption after modernisation can frequently only be lowered by 60 – 90 kWh/(m^2a). The actual attainable savings potential of the flats in Hamburg under investigation was estimated by the author at 30 kWh/(m^2a). User behaviour mostly comes into play with regard to the selection of room temperature and air exchange rate. An increase/decrease of room temperature of around 2 K results in an increase/decrease in energy requirement of approx. 15%. Some publications show considerably higher ranges in the choice of room temperature. However, the greatest effect is the option of air exchange rate. A reduction of the standard rate of 0.7 h^{-1} to the hygienic minimum air exchange requirement of 0.3 h^{-1} results in a calculated 25% lower energy requirement, whereas doubling the air exchange rate means an increased requirement of around 50%.

D-13: Stumpf, M.: Verhaltensänderungen und organisatorisch-technische Optimierungen – ein starkes Team bei der Energieeinsparung. Erfahrungen und Erkenntnisse aus psychologischen Studien zum Energienutzungsverhalten an Hochschulen. January 2014, Berlin, Dissertation

This study examines the possibilities of energy savings in university buildings. Universities are not only expected to adhere to applicable legal regulations but also to take on a leading role or act as a role model. Implementing behavioural changes is complicated by the high degree of heterogeneity of university members as well as the high degree of fluctuation of temporary employees. The existing energy savings potential is divided into a technology-related and behaviour-related parts. The author particularly highlights that

in addition to technical optimisations, user behaviour or individual methods of handling the building have a very significant influence on the eventual energy consumption of the building. The user-related energy savings potential is estimated to be around 5 – 20%. Energy-relevant behaviour is influenced by the most widely differing factors. The author starts with a comprehensive literature review of previous research results on the possibilities of promoting environmentally responsible or sustainable mindsets and behaviour. The following interventions are named in descending order according to their usefulness:

- Removal of hindrances for action (situational simplification)
- Justification of certain behavioural patterns
- Prompts / appeals
- Feedback
- Information / instructions
- Role models / social models

The so-called "behaviour-orientated interventions" are analysed by the author and applied and evaluated in a case study conducted at the University of Freiburg. The aim was to establish the following four behavioural patterns:

- Switching off PCs and peripheral devices at the end of the working day
- Avoiding stand-by losses (use of socket strips with power switches)
- Optimisation of ventilation (avoiding keeping windows constantly in a tilted position in winter)
- Sensible setting of thermostatic valves or turning them down during absence

The prototype project – "Nachhaltige Energieeffizienz" [Sustainable Energy Efficiency] presented in this study was founded by a working group at the University of Freiburg (Institute of Psychology). The focus was on measures requiring low investment and a combination of technical optimisation and changing behaviour. In the years from 2003 to 2005, a mean value for the electricity and heating consumption of the Institute of Psychology's main building (mostly used as office space) and the lecture theatre building (mostly used for teaching) was calculated and this was compared with the consumption attained by the project from 2006. There are only a few intervention possibilities for users in the lecture theatre building. The savings measures are restricted here largely to technical optimisations and user-orientated operation. In the main building technical, organisational and behaviour-related strategies were used. During the project, in 2012, 24% of electricity and 16% of heat were saved compared to the reference value. In the lecture theatre building 20% of electricity and 55% of heat were saved. It must be assumed here that the proportion of savings as a result of individual behaviour of employees amounts to 9% of heat and 36% of electricity. In the study, this is followed by a chapter that presents various studies with a psychological background that examine the subject of energy savings at universities. The analysis of these studies is used to derive a guideline for integrated energy savings projects.

D-14: Peruzzo, G.: Heizkostenabrechnung nach Verbrauch. Kommentar zur Verordnung über die verbrauchsabhängige Abrechnung der Heiz- und Warmwasserkosten. Kommentar und Anleitung für die Praxis. 5., grundlegend überarbeitete und wesentlich erweiterte Auflage, Luchterhand Verlag GmbH, Neuwied, Kriftel, Berlin, November 1996

This work explains regulations of the Heating Cost Allocation Regulation with regard to legal aspects and provides legal advice for numerous individual issues relating to the practical implementation of legal requirements on the basis of court decisions. To achieve this, the study firstly cites the individual paragraphs of the Heating Cost Allocation Regulation and then presents them in a manner that is understandable for a wider audience using examples. The study also includes two sample invoices that are used to illustrate to the reader the procedure for the consumption-based allocation of heating costs to individual tenants. This is rounded off by information on correct heating and ventilation as well as the position of the Heating Cost Allocation Regulation in the legal regulations that accompany it. In his introduction, the author quotes "empirically proven studies" that show a reduction of energy consumption in a building of 15% as a result of the implementation of the Heating Cost Allocation Regulation.

CH-01: Jacobi, E.; Neubert, H.; Goepfert, J.; Forster; Henselmann; Strempel: Herstellungs- und Betriebskosten sowie Art der Betriebskostenabrechnung von Zentralheizungen größerer Wohnblöcke und geschlossener Siedlungsgebiete. Sanitäre Technik, 27th Issue, 1962

This article presents a summary of the talks given by various speakers on 15 November 1961 at the Haus der Technik in Essen. The talks were given at the 17th Congress on Heating, Ventilation and Air-Conditioning Technology. The individual sections are devoted to the respective presentations and their subjects.

- Herstellungs- und Betriebskosten vom Standpunkt des Verbrauchers [Manufacturing and Operating Costs from the Point of View of the Consumer] (Jacobi, E.): Operating cost savings are particularly possible during the 32-week heating period in the 15 weeks with warmer weather and the eight weeks of mild weather. Tenants are not prepared to make savings in the remaining nine weeks of cold weather (and at weekends). This means that savings are possible on 60% of all heating days, lowering the room temperature by 1 K results in 6% lower consumption, therefore a reduction of 3 K would result in savings of between 18 to 20%. This results in a saving of 12% over the entire heating period. Mr Jacobi criticises the heat emissions that inevitably results between heated and unheated rooms during partial heating. On the basis of this he reckons with an increase in annual heat consumption of around 10 to 20% on the basis of consumption-based billing.
- Herstellungs- und Betriebskosten vom Standpunkt des Bauherrn [Manufacturing and Operating Costs from the Point of View of the Building Owner] (Neubert, H.): The financing of the conversion of the heating system and improvements to the heat insulation of residential buildings is conducted in different ways in every federal state. For

this reason the costs are not affordable in some locations. Mr Neubert demands the promotion of renovation measures.

- Vor- und Nachteile der Wärmemessung [Advantages and Disadvantages of Heat Metering] (Goepfert, J.): Mr Goepfert criticises the lack of suitable measuring devices for consumption-based operating cost billing. Further to this, some studies have shown that the installation of these devices is too expensive to justify any later consumption savings. On the basis of this, he suggests foregoing the measurements and instead undertaking a more suitable regulation of the heating systems. According to this procedure, where district heating is in use, the flow temperatures should be regulated at least for each building and the water quantities for each flat. Despite this, Mr Goepfert states that studies conducted after the introduction of heat metering, heat consumption in rented flats fell by around 30% and in detached houses by 50%. He emphasises that the measuring devices are to be seen as a means for reducing wastage and should not be seen as a reason for leaving flats unheated.
- Betriebskosten bei der Zentralheizung [Central Heating Operating Costs] (Forster): The operating costs of central heating should be affordable. For this reason, simple or inexpensive means should be used to tackle senseless waste of heat. He is therefore a proponent of usage-related billing of operating costs. This will make tenants immediately aware and interested in saving consumption. Dr Forster highlights the evaporation principle measuring method that had already resulted in fuel savings of 25 to 40% in Switzerland.

S-01: Adamson, B.; Reijner, E.: Wärmeverteilungszählung in Wohnhäusern. Gesundheits-Ingenieur, Issue 1/1958

This article presents the results of a study conducted in Sweden on the subject of heating cost allocation metering in residential buildings. The intention was to examine the accuracy of the evaporation meters in use and the reduction in heat consumption caused by the change to user behaviour after the implementation of consumption metering. The study looked at a housing estate with 10 identical buildings each with 10 flats. 5 of the buildings were fitted with evaporation meters of a particular kind. Additional meters of a different kind were installed in one of these 5 buildings in order to be able to identify differences between the models with regard to their accuracy. The tenants were regularly reminded to make savings with information from the measuring service company and by monthly readings that were conducted by the property manager. The savings that resulted from the use of evaporation meters were in a range of 10 to 25% depending on the quality of the heating system adjustment beforehand. In addition a reduction of heat consumption for hot water provision of around 40 to 50% was also recorded.

DK-01: Gullev, L.; Poulsen, M.: The installation of meters leads to permanent changes in consumer behavior. News from DBDH, March 2006, Denmark

This article is an updated version of an article of the same name from 1999. It describes observations made after switching from flat-rate billing to consumption-based billing in Denmark. According to this study, a reduction of heat consumption in households of up to 30% in extreme cases was recorded. The realistic consumption reduction is stated as around 15 to 17%. In the opinion of the author, this saving took effect relatively quickly after around 2 years and was sustained in the following years. In parallel to the switch of billing methods, the consumers were given detailed information on the manner in which the measurements were performed in order to motivate them to adopt a more responsible attitude to energy use. After the oil crisis of 1973/74 the prices for raw materials rose threefold. This had a dramatic effect on Denmark, where energy consumption at this time relied to 92% on imported oil.

N-01: Gölz, S.: Energiesparen im Haushalt durch Feedback des eigenen Verbrauchs. Workshop – Slides, Fraunhofer ISE, 12/2009

The slides were created for a presentation for the Environment Day at the Institute of Psychology in Freiburg at the start of December 2009. Firstly the slides give an overview of the role of the Fraunhofer Institute for Solar Energy Systems in research work in the context of Smart Metering. Afterwards the presenter discusses current technology and the political background. A review of feedback research shows a summary of previous findings from different countries. E.g. in Norway, where in the first year after meters were installed, energy savings of 8% were recorded. In the second year this rose to 10.4%. A generally improved understanding for the relationship between individual behaviour and consumption was observed; this resulted in conscious changes in behaviour, e.g. when selecting the heating temperature. This resulted in a pedagogical effect that resulted in a saving of 13%. In Finland a small saving of 4.9% was achieved. A US study goes into more detail as to what information on the invoice could be used to a greater extent by the customer. In this context, a comparison of monthly consumption with the same month of the previous year (weather-adjusted) seems to be of interest. In addition a constant consumption feedback process triggered by the actual invoice and also the comparison made in social situations with corresponding household groups are popular tools for customers for estimating consumption correctly.

Afterwards the respective properties of measuring technology that are relevant and necessary for customers are explained. The study then presents a summary of the results of earlier studies on consumer acceptance and energy-efficient consumption. This section is followed by feedback from the INTELLIEKON project are explained. This project was a cooperation between the Fraunhofer ISE and various energy providers and took place from 2008 to 2011. The aim of the project was to make a closer investigation of the effect of feedback on household behaviour, the resulting energy savings and the ecological effect of this. The study shows that ultimately it is not the meter in itself that is relevant for the customer but the expanded range of services (feedback, billing and tariffs).

UK-01: Darby, Sarah: The effectiveness of feedback on energy consumption - a review for defra of the literature on metering, billing and direct displays. Environmental Change Institute, University of Oxford, April 2006

A summary of various studies pertaining to the effectiveness of feedback on energy consumption in households. All of the studies examined regard feedback (regardless of the type and manner) as being fundamentally useful for the user in terms of improving control of individual consumption. Studies from the USA, Canada, Scandinavia, the Netherlands and the UK were evaluated. The level of the observed savings potential depends on the type of feedback:

- Direct (e.g. display or measuring device on the wall): 5 – 15%
- Indirect (e.g. supplier invoice): 0 – 10% (saving varies depending on the additional information provided, e.g. comparison with consumption in the previous year, etc.).
- Pay-as-you-go systems: 10 – 20% (North America), 3% (Northern Ireland)

A comparison of various feedback systems allows the following conclusions to be drawn:

- Standard gas and electricity meter: Although these are not usually located in the occupier's environment, there are diligent tenants who read these meters regularly to check their bills. In combination with information on saving energy and with suitable instructions, motivated participants were able to reduce their energy consumption by 10 to 20%.
- Key/keypad meters: Credit was bought in advance from a local provider. The credit was redeemed by entering a code in the metering device which was located in a room in the household chosen by the occupant. In addition to current consumption, other information such as tariff changes are displayed on the device. In Northern Ireland in 2006, around 25% of consumers used this type of energy meter (electricity and gas) and were able to save around 3% of their consumption. A similar method was tested in various cities in Ontario ("pay as you go" systems). According to the energy supplier (Woodstock Hydro), users of these systems were able to reduce their energy consumption by 15 – 20%. The study assumes that these savings are the result of consumers becoming conscious of their energy consumption due to the metering device display. The considerable difference between the savings in Northern Ireland and those in North America is possibly the result of different information being made available via the display unit or differing display forms.
- Additional display units to supplement the actual metering device: Most studies investigate electricity consumption using the displays. However, one study examines a model in which the gas consumption of the previous day is compared with a weather-adjusted target value. This feedback method yielded an energy consumption saving of up to 10%.
- Display on the television or computer monitor: An interactive online platform was developed and tested in Japan. The service included the following: display of consumption history, daily and 10-day costs, living space temperatures and comparisons with other flats. Within a nine-month test phase involving 10 households, electricity con-

sumption was reduced by 18% and gas consumption by 9%. A similar project in the Netherlands saw energy consumption savings of 8.5% attained.

- Informative billing: The annual consumption bill was supplemented with additional information. This included distribution of the heating load throughout the year, consumption changes in different periods compared to the previous year's figures, comparison with similar households, average energy distribution to end consumers in normal households (vacuum cleaners, kettles, etc.). Savings of 0 – 12% were recorded.

F-01: ADEME: Huze, M.-H.; Cyssau, R.: Maîtrise de la demande d'énergie par les services d'individualisation du chauffage. Rapport final, 09/2006

and

F-02: ADEME: Huze, M.-H.; Cyssau, R.: Maîtrise de la demande d'energie par les services d'individualisation du chauffage collectif. Paper

For this French study, five buildings with a total of 264 flats were observed during the time when flat-rate billing was replaced with consumption-based billing. Two of the buildings investigated were in Paris with another two in Reims and one in Pantin. The composition of the consumption-based billing method was 40% according to basic costs and 60% according to individual consumption. In the years from 2004 to 2006 one heating period with flat-rate billing and one period with consumption-based distribution of the heating costs were examined. The results showed an average saving of 20% when compared to flat-rate billing.

RUS-01: Pötter, K.; Pahl, M. H.: Wasser- und Wärmeeinsparung in russischen Wohnhäusern. Ergebnisse des Dubna Projekts. Euroheat and Power, 3/1999, Edition 28

In the small Russian town of Dubna, 72 flats were fitted with water meters, heat cost allocators and thermostatic valves. The flats were located in two structurally identical housing units of a nine-storey brick building. Two other housing units were used to compare the real water and heating consumption figures. The first consumption-based heating cost bills were issued for the 72 flats fitted with metering devices in May 1998. The article describes the project measures and experiment conditions as well as the political framework in Russia, where 50% of water and heat supply was still subsidised in 1999. Starting from 2003, this subsidy was to be reduced in stages to 0%. It was expected that the socio-economic problems already prevalent at the time would become even worse with the reduction of the subsidy. To avoid this problem, the installation of building transmission stations and individual water meters for individual flats in new buildings was prescribed by law. The evaluation of the 1997/1998 heating period showed that the flats billed in a consumption-based manner had a reduced heat consumption of 23% compared with the control group. Hot water consumption fell by 55%.

A-01: H. Juri, F. Adunka: Technische und psychosoziale Einflussfaktoren auf den Wärmeverbrauch von Wohngebäuden, gww 49 (1995) 6, P. 217-224

The article covers the results of a research project investigating the influence of individual user behaviour on heat consumption in flats with district heating. The study used the measurement data of Viennese district heating in cooperation with the Bundesamt für Eich- und Vermessungswesen [Federal Office for Calibration and Measuring Technology]. This data originated from a major experiment in a state-owned residential complex with 48 accommodation units in the Vienna Arsenal district from 1985 to 1988. Findings on individual heating habits were derived from the typical operating conditions of the heating system. In addition a survey was conducted in summer 1994 with the aim of identifying the motivations behind the heating patterns of individual tenants. Three heating periods were examined:

- 1985/86: Improvement of the thermal building shell, resulting in a saving of 23.1% compared with the previous heating period.
- 1986/87: Installation of a smaller circulation pump and hydraulic system adjustment, resulting in a further saving of 7.7%.
- 1987/88: Installation of thermostatic valves on all radiators resulting in increased consumption of 2.8%.

An examination of the behaviour patterns showed that the rise in consumption in the last heating period was due to incorrect ventilation on the part of the tenants. In general, in some cases considerable fluctuations in consumptions were established between the individual flats:

- 10 accommodation units deviated from the mean value (deviation ± 10%)
- 6 accommodation units registered a consumption of up to 20% above the average
- There were no anomalies with the other 26 accommodation units (deviation ± 5%)

These heavy fluctuations could not have been caused by the differing locations of the flats within the building. The investigation of the temperature differences and flows of the individual heating circuits as well as the tenant survey show that the occupants did not adjust their heating behaviour to the new conditions (heating with district heating instead of with coal ovens/individual room heating as previously, use of thermostatic valves). Often, only individual rooms were heated and this was kept at a constant level during the day. Mostly, no reduction was made at night and no reduction or switching off of heating power was performed during ventilation. There were even some tenants who did not adjust the setting of the thermostatic valves throughout the entire heating period. In the heating period of 1992/93, heat consumption of the building was 10% higher than in 1987/88. This shows that correct user behaviour could yield a further savings potential. Therefore tenants should be comprehensively informed of the functions of the heating system and the thermostatic valves as soon as they move in.

A-02: Adunka, F.: Grundlagen der Heizkostenverteilung, text of a presentation given in Haus der Technik, Essen, 2005

In central Europe, around 40% of final energy consumption is used for heating and domestic hot water generation (data as of 1994). This article looks at reducing this proportion as a contribution to solving climate problems. Measures are sought to promote energy savings in households. Two common methods are presented.

- Improvement of heat insulation in buildings
- Comfort reduction (lowering the mean room air temperature)

Controlled consumption measurement is regarded as essential for supporting comfort reductions. The author cites several sources that name a reduction of between 10 – 30% in heat consumption as a result of consumption-based billing. The article goes on to discuss the advantages and disadvantages of consumption-based billing as well as the challenges arising from its implementation. This is followed by an examination of the influences on heating cost allocation. A distinction is made between physical, structural effects (position of the flat, external wall proportion, heat insulation) and the influence of the user (room temperature setting, ventilation behaviour). The article goes on to evaluate a survey of tenants of the Viennese Arsenal residential building complex with regard to their heating behaviour, preferred temperatures and heating control and ventilation behaviour. In the conclusion, the author provides notes on the information on correct heating and ventilation behaviour that should be made available to new tenants.

Overview of supplementary literature sources

D-15: Gertis, K.; Hauser, G.: Energieeinsparung durch instationäres Heizen in Wohnungen. HLH 26, 5/1975

The article discusses the possibilities and consequences resulting from intermittent heating. The various effects on room temperature of unsteady heating are investigated with the aim of determining the actual savings potential of this. These include the building type (light/heavy, insulated interior building components), the level of the internal thermal masses, the intensity of window air exchange and the outdoor temperatures (design temperature for the heating compared to average outdoor temperatures during the heating period). The investigations show that the sluggishness of the heat transmission processes resulting from the building's thermal mass restricts the energy saving to be expected. In principle, the following applies: The slower the reaction of the building construction to changes in thermal output, the lower the potential energy savings from intermittent heat operation. The amount of energy that can be saved due to unsteady heating ultimately depends on a combinations of different factors. In addition to the building type of the flat, the behaviour of the neighbours also plays a role. The greatest energy savings occur when all of the occupants of a multi-family unit all heat intermittently in a synchronised manner.

D-16: Behr, I.; Enseling, A.; Großklos, M.; Hacke, U.; Müller, K.: Heizkosten im Passivhaus – Warmmiete oder Flatrate-Modell – Praxiserfahrungen. IWU- Institut Wohnen und Umwelt GmbH, Darmstadt, 31 March 2010, Commissioned by the Hessian Ministry for the Environment, Energy, Agriculture and Consumer Protection

The studies looks at practical examples in which the exemption clause of the Heating Cost Allocation Regulation (§11) is applicable. This principally involves passive-energy buildings which, in addition to consumption-based billing, can also optionally be invoiced according to heating cost fixed rates, flat-rates, distribution according to living area proportion and rent including heating. Four different passive-energy buildings with different heating cost billing methods were examined in the study. The exceptions given in the Heating Cost Allocation Regulation are analysed thoroughly. The following procedure was selected:

- Explanation of the exception clause and the conditions to be adhered to in order to claim such an exception
- Description of the possibilities for heating cost billing permissible under tenancy law
- Illustration of the case examples
- Illustration of the additional costs of the passive-energy building standard in the construction of tenant buildings as well as funding opportunities using the state of Hesse as an example
- Analysis of rent including heating as a market stimulus

- Examinations of the user's influence on hot water consumption

The study initially criticises the insufficient accuracy of §11 of the Heating Cost Allocation Regulation and the problems arising from this in its practical implementation. Suggestions are made for tightening up the paragraph. In addition, the study calls for a separate examination of the supply of hot water and heat as it has been proven that user behaviour with regard to room heat does not necessarily correspond to user behaviour with regard to hot water consumption. Further to this, the study comes to the conclusion that in a passive-energy building with a limited output, no significant effects of user behaviour on hot water consumption are to be expected. For buildings with a higher heat requirement, in addition to checking the economic efficiency of the billing type, an investigation should also be conducted into the extent to which a lack of consumption-based billing affects user behaviour and therefore energy consumption.

D-17: Schahn, J.: Projekt Energiemanagement am Psychologischen Institut der Universität Heidelberg: Ein erfolgreicher Fehlschlag. Umweltpsychologie, 11th Edition, Issue 2, 2007, P. 138 – 163

This article reports on the results of a pilot project conducted from 2001 to 2003 at the Institute of Psychology at the University of Heidelberg. Saving electrical, heating and cooling energy was achieved by taking into account the behaviour of people who consume energy on-site. For this purpose a series of technical and psychological measures were introduced. The psychological, behaviour-forming interventions included providing information (on sensible savings measures) as well as feedback (on consumption and savings) and rewards in the form of financial savings passed on to the affected persons. The measures used could be split into four categories of actions to be performed: one-off vs. repeat measures and central (one person) vs. decentral (every person in the building). Due to the complexity of measuring the energy saving potential of every single measure/intervention, the annual total saving of all applied measures during the years of the project and a subsequent survey (2004 to 2006) was specified with regard to a zero line (mean, weather-adjusted consumption of the years from 1997 to 2000). On average 6.5% of electricity consumption and 12.4% of district heating consumption could be saved annually during the project period. At least with regard to district heating, the savings continued into the subsequent surveyed period and even increased by an average of 3% during this time.

D-18: Matthies, E.: Gewohnheiten wechseln. Verbundprojekt „Change" zum Energienutzungsverhalten im öffentlichen Dienst. 2010

In addition to the physical, structural and technical equipment of the buildings, the level of energy saving depends very much on everyday user behaviour. The North Rhine-Westphalian energy agency estimates user potential in public institutions as being between 5 and 20%. In a joint project of several universities that was sponsored by the BMBF [Federal Ministry of Education and Research], environmental psychologists and engineers worked together from 2008 to 2010 to establish how great the savings po-

tential from user behaviour actually is and how it can be activated most efficiently. For this aim, strategies, which had been proven to be effective over the course of 30 years of environmental psychology research, were applied in various universities in Germany. These most efficient methods included:

- Voluntary agreements
- Targets
- Use of media to demonstrate model behaviour
- Differentiated individual advice
- Feedback techniques

By contrast, the provision of information only seems to be effective in combination with other measures. In general, user behaviour strongly depends on habit and is only to be influenced by measures that capture a high degree of attention. During the course of the project, a comprehensive package of measures was developed and tested. Four universities (Dortmund, Münster, Siegen and Bonn) with a total of 15 buildings took part in the first project phase. A simulation conducted earlier estimated the attainable savings potential as 18% for electricity and 9% for heat consumption. However the actual potential realised by the campaign was 7.7% for electricity and 0.7% for heat.

D-19: Hansmeier, N.; Matthies, E.: Energiebewusste RUB – Richtig Heizen und Lüften. Ergebnisse einer umweltpsychologischen Intervention zur Förderung energieeffizienten Verhaltens an der Ruhr-Universität Bochum. Unpublished project report, Ruhr University Bochum, Psychology faculty, 2007

Due to insufficient scope of action for constructional and technical renovations and against the background of rising energy prices, a study was undertaken at the Ruhr University Bochum (RUB) with the aim of utilising the previously unused energy savings potential of energy awareness. As the costs of investment for interventions in the area of user behaviour are considerably lower than those for constructional measures, it was expected that the interventions would pay for themselves within the implementation period. This allows financial gains to be made from saving energy in the short-term. With the aid of findings from the field of environmental psychology, suitable interventions were to be developed and practiced and evaluated in the winter semester of 2006/07. The weather-adjusted consumption data in the years from 2000 to 2005 was used as a comparison. After comprehensive potential and target group analysis, the target behavioural patterns to be promoted were defined. E.g. in offices:

- Opening the window wide for shock ventilation instead of tilting the window
- Turning off the heating in the event of longer absence periods
- Moving furniture 30 cm away from radiators and readjusting the thermostatic valves
- Keeping doors to unheated/differently heated rooms closed
- Not using hot air fans/heaters

If the potential was completely utilised, i.e. thanks to 100% participation of all RUB employees, the energy savings potential of the behaviour recommendations is between 10 – 25%. The realistic expectation was utilisation of the potential from behavioural changes of 50% which would result in a 5 – 8% saving of heat consumption. To motivate employees to take part, an intervention programme was developed on the basis of different environmental psychology techniques and target group-specific distribution methods (campaign week, spreading active knowledge using flyers and brochures, self-obligation using questionnaires, incentives, posters, website, articles in the university newspaper). At the end of the study, 6% of heat consumption had been saved.

NL-01: Van Raaij, W. F.; Verhallen, Th. M. M.: A behavioral model of residential energy use. Journal of economic psychology, 03/1983, North-Holland Publishing Company

Around 30% of the total energy consumption of the Netherlands can be allocated to the residential building sector. Of this, 75% can be assigned to room heating, 15% to domestic hot water generation and 10% for supply of electrical energy. The greatest savings potential are therefore in the area of room heating. This article examines the question as to which factors can motivate persons in the household to save energy and looks at the obstacles for implementing behavioural changes with the aim of saving energy in the household. A model is presented for the evaluation of the various influences. This model connects personal as well as environmental and behaviour-specific factors of household energy consumption with each other. The most important aspects here are social and demographic factors, family lifestyle, energy prices, environmental awareness, cost-benefit considerations, feedback on energy consumption, the level of information and building characteristics. These factors and the possible approaches derived from this for future energy saving campaigns and further research are discussed in the sections that follow.

NL-02: Staats, H.; van Leeuwen, E.; Wit, A.: A longitudinal study of informational interventions to save energy in an office building. Journal of applied behavior analysis, 2000, p. 101 – 104, Leiden University, Netherlands

This article reports on an investigation conducted in an office building in the Netherlands. The effects of behaviour-forming measures for developing energy saving habits were examined. A building with 384 offices was selected for the purpose. Each office had two to three radiators that were equipped with six-stage (0 – 5) thermostatic valves. The two target behaviour patterns were:

- Keeping windowsills clear
- Selecting the same setting for all radiator thermostatic valves of one office room by employees

The measures deployed also including handing out information brochures on the hoped-for behaviour for reducing heating consumption as well as weekly feedback on current consumption on notice boards in the building lifts. In addition the employees were given individual feedback and reminded of the correct thermostat settings and not to use win-

dowsills as bookshelves. The programme was conducted over a period of two years. The changes to employee behaviour meant that gas consumption for heating the building fell by 6%.

USA-01: Carrico, A. R.; Riemer, M.: Motivating energy conservation in the workplace: An evaluation of the use of group-level feedback and peer education. Journal of Environmental Psychology 31, P. 1 – 13, 2011

This article gives an account of an investigation of 24 buildings of a medium-sized, private university in the south of the USA: The buildings were mainly used for office rooms, research and teaching. There was a campaign aimed at all employees with the aim of imparting essential information on energy consumption and energy saving measures (switching off lights, thermostatic valve settings). Further to this, four test groups were formed. 25% of all participants only received information from the campaign (control group). A second group of another 25% were also trained by a colleague who had volunteered for the task and who was specially trained for these duties in advance of the project. The third group received regular feedback on their energy consumption in addition to the information made available in the campaign. The fourth group received a combination of all three behaviour-forming measures (campaign, colleague support and feedback). All measures were performed simultaneously over a period of four months. The data was recorded over a period of eight months, four months before the start of the project measures and the four months during which they were implemented. In addition historical consumption data of the same eight-month period of the previous two years was used for comparison. The electric energy consumption was measured. Surveys were also conducted in addition to the data recording and analysis of consumption data. As expected, the group subjected to the combined measures attained the highest savings of 8%. The group which received regular feedback on their consumption was able to reduce 7% of their power consumption.

Int-01: Hacke, U.: Save@Work4Homes – Supporting European Housing Tenants In Optimising Resource Consumption. Intelligent energy executive agency, 10/2007

The SAVE project had the aim of significantly reducing energy consumption in private households throughout Europe. This was to be achieved by constantly informing the tenants (Internet portals, displays in flats, magazines, etc.) about their current and previous consumption and the relationship between behaviour and consumption. The author first examines the different variables that influence heat energy consumption in private households. These include building characteristics (insulation standard/ glazing, surface-area-to-volume, system technology, etc.), climactic conditions and the users. A differentiation must be made here between user influence (e.g. household size, presence, lifestyle, etc.) and user behaviour (room temperature selection and air exchange). It is only by using all these variables that user behaviour can be changed thanks to information on personal energy consumption.