THE ICT PSP METHODOLOGY FOR ENERGY SAVING MEASUREMENT

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A COMMON DELIVERABLE FROM PROJECTS OF ICT FOR SUSTAINABLE GROWTH IN THE RESIDENTIAL SECTOR

eSESH

Saving Energy in Social Housing with ICT

(Version 2 – September 2011)

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Dissemination Level		
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REVISION HISTORY AND STATEMENT OF ORIGINALITY

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1	May 2011	Günter Lohmann	IWU	Revision of chapter "Methodology for energy efficiency measurement"
2	July 2011	Gregor Heilmann	empirica	Restructuring of version 1 (Introduction)
3	July 2011	Ulrike Hacke	IWU	Revision of chapter "Methodology for impact assessment" Restructuring, formatting of chapter "Methodology for energy efficiency measurement"
4	August 2011	Simon Robinson	empirica	Integration of impact assessment and methodology for measurement of energy savings
5	September 2011	Ulrike Hacke	IWU	Final edit
6	September 2011	Gregor Heilmann	empirica	Final edit and submission

Statement of originality

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

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1 Introduction

1.1 Purpose of this document

In response to the Third Call for Proposals under the ICT PSP Work Programme 2009, Objective 4.1 – "ICT for energy efficiency in social housing", three projects have been selected:

- 3e-HOUSES: Energy Efficient e-HOUSES
- E3SOHO: Energy Efficiency in European Social Housing
- eSESH: Saving Energy in Social Housing with ICT

The three consortia were asked to work on the development of a methodology for energy saving measurement – the current status is presented in this document. The 1st version of this document has been completed by 3e-HOUSES[1] in September 2010.

This document contains the updated version of this document and uses all information provided in the first version. In this version it has been tried to concentrate on information directly related to energy saving measurement which means that information provided in the previous version regarding 3e-HOUSES pilots has been partly removed. Information about all three projects is publicly available on the project websites.[2]

1.2 Document structure

The document is structured as follows:

Chapter 1.3 includes a brief summary of the IPMVP protocol and its options as the basis for the methodology described in chapter 2.

Chapter 2 contains "The ICT PSP methodology for the measurement of energy savings and emission reduction". It asses the different IPMVP options and outlines the foundations of the ICT PSP approach for energy saving and peak demand reduction.

Chapter 3 contains project specific examples from eSESH as well as from 3e-Houses and chapter 4 lists sources for further information.

1.3 The measurement protocol IPMVP

The original basis for savings calculations within the ICT-PSP projects was a modified version of the EVO International Performance Measurement & Verification Protocol (IPMVP).

The IPMVP was originally developed by the U.S. Department of Energy, was first published in 1996 under the name NEMVP and is now owned by an international not-for-profit organisation EVO. According to the EVO site (www.evo-world.org) the protocol is the leading international standard in measurement and verification protocols. The IPMVP is defined in three volumes[3]:

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1 http://www.3ehouses.eu/sites/default/files/3e-HOUSES_Deliv_1-2_Definition_of_Methodologies.pdf
2 www.eSESH.eu - www.3ehouses.eu - www.e3soho.eu
3 All documents are available after a short registration at www.evo-world.org

- Concepts and Options for Determining Energy and Water Savings, Volume 1, (September 2010)
- Concepts and Practices for Improved Indoor Environmental Quality, Volume 2, (March 2002)
- Concepts and Practices for Determining Energy Savings in New Construction, Volume 3/I (January 2006)
- Concepts and Practices for Determining Energy Savings in Renewable Energy Technologies Applications, Volume 3/II, (August 2003)

The IPMVP was designed to reduce risk for investors in energy performance contracting by providing an agreed method for estimating energy savings to be shared between contractual partners. The protocol is designed explicitly for so-called “big energy efficiency projects” in the industrial sector, i.e. those with annual consumption levels of over 1,000,000 kWh.

The current methodological proposal for ICT PSP projects in the residential sector sets out from the IPMVP and adapts its provisions to the very much smaller scale of energy consumption in the residential sector and to the different purpose of providing feedback on the success of attempts to save energy in that sector.

One early adaptation of IPMVP to ICT PSP was to attempt to reduce costs of measurement in line with the dramatically lower scale of energy consumption by suggesting the use of larger time intervals for measurement and the use of less sub- metering. It was found that the IPMVP approach is in parts applicable to the residential sector, in particular, notions of baseline and methods of calculating savings.

However, there are parameters such as demand response and avoided CO_2 emissions which are not taken into account in the IPMVP protocol and where extensions are required[4]. To calculate the CO_2 emission savings from energy use savings, the overall consumption of electricity and of particular fuels for heating can be converted to CO_2 using standard combustion coefficients for fuels and a coefficient for CO_2 emission per kWh electricity generated based on the national mix of generation sources. The calculation of CO_2 emission savings is of course quite different in the case of successful “peak-shaving” (see chapter 2.4).

The IPMVP measurement and verification plan (M&V Plan) includes the following 13 topics (IPMVP, vol. 1, page 39 ff.):

1. **Intent of energy conservation measures (ECM):** Description of the planned services, conditions and intended results
2. **Selection of option and measurement boundary:** IPMVP differentiates between four options to specify determinations of savings (IPMVP, vol. 1, p21f and fig. 3, p37)
3. **Definition of baseline:** Period, energy data and conditions (independent variables such as outdoor temperature; static factors such as building characteristics or equipment inventory)
4. **Definition of reporting Period:** Period after intervention, e.g. installation of EAS or EMS

[4] **Ernest Orlando Lawrence: Berkeley National Laboratory: Estimating Demand Response Load Impacts**

5. **Definition of basis for adjustment:** Description of a set of conditions to which all energy measurements will be adjusted (e.g. temperature adjustments)
6. **Specification of analysis procedure:** Used statistical data analysis procedures
7. **Specification of energy prices:** Prices that will be used to value the savings (of importance in cases of adjustment needs because of prices changes)
8. **Meter specifications:** Description of metering points and periods (of importance in cases of not continuous energy consumption metering)
9. **Assignment of monitoring responsibilities:** Definition of responsibilities for recording and reporting of energy data
10. **Evaluation of expected accuracy:** Statistical accuracy of the measurement
11. **Definition of budget required for savings determination:** Initial set-up costs and ongoing costs throughout the reporting period
12. **Specification of report format:** Description of how result will be reported and documented
13. **Specification of quality assurance:** Description of quality assurance procedures

In summary an M&V Plan mainly focuses on meter installation, calibration and maintenance; data gathering and screening; development of computation methods and – if necessary – acceptable estimates; computation of measured data and reporting, quality assurance and third-party-verification of reports.

1.4 IPMVP measurement options

In IPMVP, four options A-D are given for measurement and verification.

OPTION A. Partially Measured Retrofit Isolation:
Savings are determined by field measurement of the key performance parameter(s) which define the *energy* use of the implemented Energy Efficiency Measures (EEMs) in the affected system(s) and/or the success of the project. The parameters which are not selected for field measurement are estimated. These estimates can be based on historical data, manufacturer's specification, or engineering judgment. A documentation of the source or justification of the estimated parameters is required. The plausible savings error arising from estimation rather than measurement is evaluated. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the measured parameter, and the length of the *reporting period*. Using Option A only partial measurements will be carried out in the parts which are affected by the implementation of the energy efficiency solution with some parameters stipulated rather than measured. The stipulations can be done only, if it is sure that there is no impact on overall reported savings from these parameters. To isolate the energy use of the EEM-system affected equipment from the rest of the facility, measurement equipment shall be used. This equipment works as a boundary between affected and non-affected equipment. As said, stipulations are partly allowed under Option A, but great care has to be taken to review the engineering design and installation to ensure that all stipulations are realistic and achievable. With

the use of stipulations of different parameters certain insecurity is created. Only very realistic estimations should be done (e.g. a reduction of operating hours of the lighting with using of the same equipment) in order to calculate the savings.

This option could be chosen to calculate energy savings if there are changes of lamps, appliances, thermal equipment or changes of operating times.

Example of application: A lighting retrofit where power draw is the key performance parameter that is measured periodically. Estimate operating hours of the lights based on building schedules and occupant behaviour.

How Savings are calculated:

Savings = Base year – Post-Retrofit ± Adjustments

It is necessary to calculate the *baseline* and *reporting period energy* consumption from:

- short-term or continuous measurements of key operating parameter(s)
- *estimated* values
- Sub-metering ECM affected systems.

Routine and non-routine adjustments are required.

OPTION B. Retrofit Isolation: All Parameter Measurement

The savings determination techniques of Option B are identical of those of Option A except that no stipulations of parameters are allowed under Option B. This means that full measurement is required, which makes this option a more expensive solution for measurements in energy consumption and determination of energy savings. On the other hand more accurate and reliability of results are obtained with this option.

Savings are determined by field measurement of the *energy* use of the *EEM*-affected system.

The measurement frequency ranges vary from short-term to continuous, depending on the expected variations in the *savings* and the length of the *reporting period*.

There are short-term or continuous measurements in *baseline* and *reporting period energy*. Routine and non-routine adjustments are required.

The savings created by most types of EEMs can be determined with Option B, but it is to consider that the costs associated with the verification increase as well as metering complexity increases too.

Examples of application: Application of a variable speed drive and controls to a motor to adjust pump flow; measure electric power with a kW meter installed on the electrical supply to the motor which reads the power every minute. In the *baseline period* this meter is in place for a week to verify *constant* loading. The meter is in place throughout the *reporting period* to track variations in power use.

OPTION C. Whole Facility

Option C involves the use of utility meters, whole building meters or sub meters to assess the energy performance of a total building. All the EEM systems savings are to be assessed with this option, so it will include all consumptions and savings of different EEMs, so preferably this option is suitable for one type of EEM. If different EEMs are applied the collective savings will be estimated from the energy meter of the whole facility and therefore cannot be distinguished.

Savings are determined by measuring energy use at the whole *facility* or sub-*facility* level. Continuous measurements of the entire *facility's energy* use are taken throughout the *reporting period*.

The whole *facility baseline* and *reporting period* (utility) meter data will be analysed. *Routine adjustments* are required, using techniques such as simple comparison or regression analysis. *Non-routine adjustments* are required.

Examples of application: Multifaceted energy management program affecting many systems in a *facility*. The energy use with the gas and electric utility meters for a twelve month *baseline period* and throughout the *reporting period* will be measured.

Option C should be used if there are many types of EEMs in one building/housing and if the energy performance of the whole building/housing is to be assessed.

This option is indicated for energy efficiency measurements application with total energy savings potential higher 10%.

OPTION D. Calibrated Simulation

Savings are determined through simulation of the *energy* use of the whole *facility,* or of a sub-*facility*. Simulation routines are demonstrated to adequately model actual *energy* performance measured in the *facility*. This Option usually requires considerable skill in calibrated simulation.

Energy use simulation, calibrated with hourly or monthly utility billing data. (Energy end use metering may be used to help refine input data.)

Examples of application: Multifunctional energy management program affecting many systems in a facility but where no meter existed in the *baseline* period. Energy use measurements, after installation of gas and electric meters, are used to calibrate a simulation. *Baseline* energy use, determined using the calibrated simulation, is compared to a simulation of *reporting period* energy use.

2 The ICT PSP methodology for the measurement of energy savings and emission reduction

2.1 Introduction

2.1.1 Savings measurements are based on estimation of non-intervention consumption

Energy savings due to an Energy Saving Intervention (ESI) cannot be measured directly, as they represent the difference between energy actually consumed after the intervention and that which would have been consumed ***had the intervention not been carried out***. For policy in an ICT PSP context it is also important to anticipate the impact should the intervention be applied more widely, that is for example, what the overall energy saving would be if the ICT applications developed and applied in the pilot were applied to all residential buildings in Europe.

Because energy saving cannot be measured directly, any measurement is in fact based on assumptions of a possible parallel development – the development of energy use without the intervention: "non-intervention consumption".

2.1.2 Assessment of IPMVP options in the context of ICT PSP

Constant demand – IPMVP Options A and B

The simplest assumption of how demand in a building would develop without the intervention is that demand for energy in a building is constant. If demand is constant, the intervention would reap savings perhaps by making the conversion of primary energy into the heat / coolness / cooked meal / well-lit rooms more efficient.

The energy saving measurement methodology for this case is simplicity itself. Energy savings can simply be measured by the change in energy consumption before and after the intervention. Given 24/7 constant demand with no stochastic variability, only one measurement would be needed. More measurements and some averaging might be needed if the measurement apparatus exhibits error - or because the energy conversion efficiency of the ICT application varies over time (warm-up phase for lamps etc.).

In the industrial settings addressed by IPMVP there may be examples of constant demand, e.g. a pump operates continuously at the same load while production plant is in operation; the hallway lighting is on 24/7 etc.

In cases of constant demand it may not even be necessary to make any measurement in situ. IPMVP Option A captures this allowing that the manufacturer's specified efficiency improvement in a light is used for the savings calculation and that this is acceptable to the ESCO contracting partners.

Even in IPMVP, however, situations of varying demand have a central role. Production processes may not run at the same capacity all the time, may be shut down etc. A pumping operation may take place at regular intervals, not continuously. Measurement of savings from an intervention which involves installing a more efficient pump may need only one measurement, but this needs to take place at a point where demand is known to be equal to the comparison value from before the intervention – the "constant loading" mentioned in Option B.

This mode of thought led to the development of the options A and B in IPMVP. A corollary to Options A and B is that any energy saving intervention planned or executed would be in no need of an ICT PSP pilot to prove the saving level in a statistically representative sample.

Options A and B therefore seem to be uninteresting in the context of ICT PSP.

Modelling variable demand – Option D

IPMVP also deals with less simple cases, where demand varies in a less predictable way, where there is no repeated pumping cycle in which a point of equal demand can be identified. For example, even when production is running at the same capacity, flows of raw materials or heating processes may vary in demand due to variation in input temperatures of the raw materials, their specific weight, consistency etc. This demand variability is a major cause of the complexity of methodology proposed under IPMVP.

In a machine production environment, the factors causing variability of demand are often accessible and even measurable. Where the processes under consideration are well understood, one solution is to model the variability. However, if an accurate model can be set up, this must contain parameters encapsulating the energy saving, and once set up, no additional measurements would be needed, certainly not over a 12 month operation period.

Again, Option D seems to be uninteresting in the context of ICT PSP pilot.

Variable demand as a result of the ICT application – Option C

In the residential sector, an assumption of constant demand (Option A) or cyclically predictable demand (Option B) or another demand structure which can be fully modelled (Option D) cannot usually be made. In particular, none of these assumptions applies to projects aiming to change the resident behaviour – i.e. change demand – as a key way in which the intervention takes effect, such as many interventions being piloted in the ICT PSP projects.[5]

In the ESCO contracting situation, the ESCO will not implement interventions which change demand; responsibility for changing levels of demand will be contractually assigned to the user organisation and the commercial impact as well. If energy consumption rises not because of poor performance by the solution provider but because of increased demand, the ESCO will typically want this corrected – adjustments have to be made to correct the demand and the energy saving to what it would have been under constant (or contractually agreed) demand. Thus IPMVP, supplying solutions into this contractual relationship, bases all options on the usual separation of demand (user organisation responsibility) and supply (ESCO responsibility).

Nevertheless, the approach offered in IPMVP as Option C is certainly applicable in an ICT PSP context. This option does not assume constant energy demand or that energy demand variation can be accurately modelled. Option C is a before-after comparison. The IPMVP approach in Option C still

[5] e.g. the piloted Energy Awareness Services for tenants in eSESH or the Resource use Awareness Services for tenants in BECA

carries the notion of fully repeated cyclical variation in demand. This is exposed in the notion of an "operating cycle", (IPMVP, Vol. 1, p15), however, with some adjustments the approach is still applicable to ICT PSP pilots. The ICT PSP methodology presented here also allows for a control group approach, not defined in IPMVP (and likely to be inappropriate in ESCO contracting).

2.2 Foundations of the ICT PSP approach

2.2.1 Independent and dependent variables

Before introducing the ICT PSP methodology, it is important to introduce an understanding of key terms such as dependent and (relevant) independent variables, and, for the before-after approach, the idea of baseline and reporting period.

Independent and dependent variables are understood as follows:

- **Independent Variable:** Characteristics of a building, its environment or use which affect energy consumption: weather (temperature, humidity), occupancy, dwelling size, heating system, etc. When reference is made to an independent variable, the implication is that it has an impact on demand. Some such variables can be easily measured – e.g. ambient temperature – others may be more difficult to measure.
- **Dependent Variable:** Characteristics of a building or its use which is the target of an intervention. Here the main focus is (reduction in) energy consumption, which can be related to the scale of the intervention as number of tenants (kWh per person) or the size of the dwellings (kWh per square meter).

In before-after comparison, the actual energy saving caused by an Energy Saving Intervention (ESI) is estimated from the difference between consumption after the intervention (ESI) and the consumption which would have taken place under the same demand conditions without the ESI.

To estimate what consumption would have been without the ESI, consumption data prior the intervention is used. This is known as **baseline data**. An *extended baseline* is the projection of consumption before the intervention into the period after the intervention.

Figure 2-1 shows the progress of energy consumption. To the left of the arrow the energy consumption without the ESI is shown. With this data it is possible to create the baseline. To the right of the arrow the consumption after the ESI is shown.

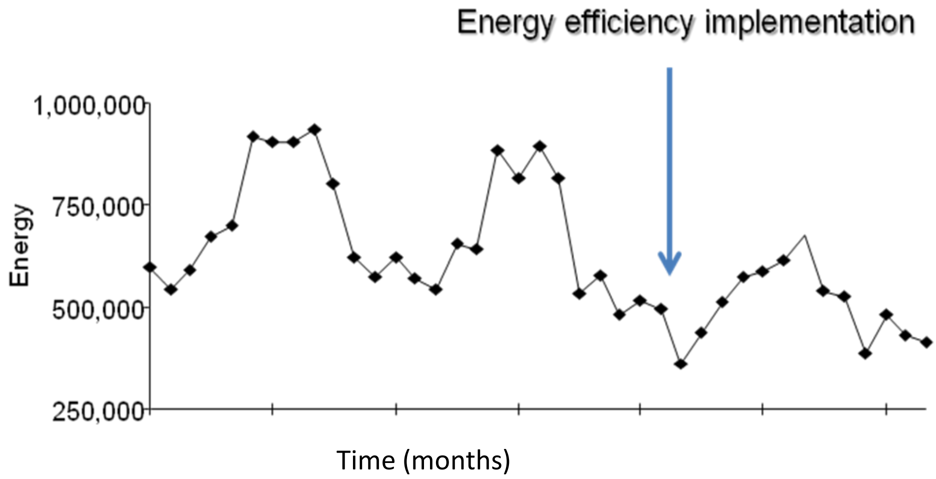

Figure 2-1 – Progress of energy consumption

Until the shown point (arrow) in Figure 2-2 the consumption is needed to create the baseline. The continuation of the baseline, the extended baseline, shows the expected consumption without the ESI, however, if the ESI is implemented this continuation does not take place and cannot be measured directly. The period after the intervention during which measurement of saving takes place is referred to as the **reporting period.**

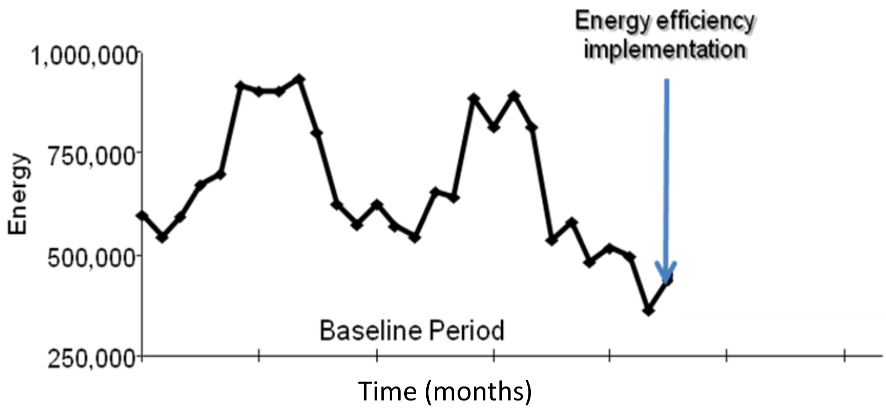

Figure 2-2 – Baseline before ESI implementation

The arrow in Figure 2- 3 divides both parts in the “baseline period” and the “reporting period”

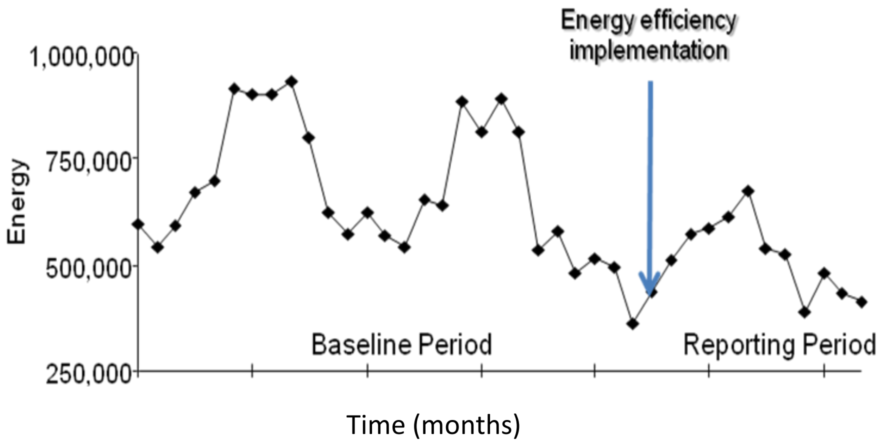

Figure 2-3 – Baseline before ESI and progress of energy consumption

After the ESI has been implemented (reporting period), the consumption is expected to be lower than it would be had the baseline continued. For better understanding, the following Figure 2-4 shows the energy savings after the implementation:

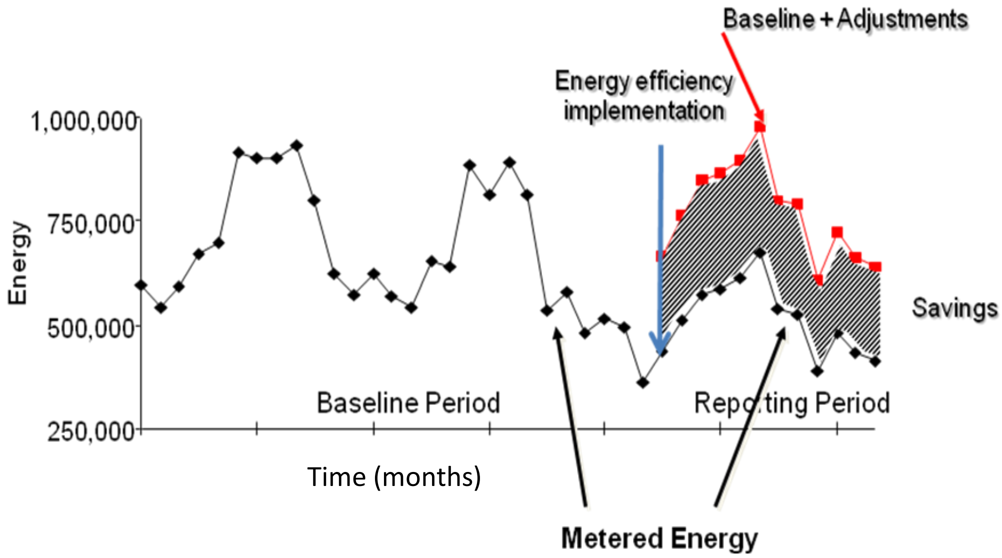

Figure 2-4 – Energy savings

2.2.2 Intervention (treatment)

Another important concept is that of the *intervention*: the action from outside which has been undertaken to reduce energy consumption in a particular domain. There are other terms used for intervention. For example, when evaluating the behaviour-related effects of consumption feedback services, the empirical social research terms that service as treatment. The term is originated from psychological experiments which are used to establish cause and effect of measures, instruments, etc. The main characteristic of experiments is the availability of two (tenant) groups – the experimental or treatment group which receives the treatment and the control group which receives no treatment. Control group approaches are discussed below.

2.2.3 Dependent variables and their units (ratios)

To make figures on energy saving comparable despite different sizes of dwelling, times of year, number of occupants etc., specific units can be used in presentation which set levels of energy consumption or energy saving in relation to the size of the unit considered. Specific units can be useful to show the dependency of energy savings on independent variables such as floor area, occupancy or ambient temperature, or to remove the influence of these variables when comparing two savings measures. Which units are appropriate depend to some extent on the type of energy use in question.

Also, as pointed out above, there is not a direct relationship between the energy saved in the final energy form (using kWh as primary unit) in the form of primary energy (using kWh_{PE} as primary unit) and CO_2 emission savings (e.g. using tonnes of CO_2 as primary unit). Which primary unit is being used must be made clear. Some examples of appropriate specific units by function are:

Heating:

- Energy consumption (saving) per dwelling (kWh/dwelling p.a.)
- Energy consumption (saving) per person (kWh/person p.a.)
- Energy consumption (saving) per square meter (kWh/m^2 p.a.)
- Energy consumption (saving) per degree-day KWh/HDD p.a. (Heating Degree Days)
- Primary Energy consumption (saving) per square meter (kWh_{PE}/m^2 p.a.)
- Share of renewable energy (%)

Cooling:

- Energy consumption (saving) per dwelling (kWh/dwelling p.a.)
- Energy consumption (saving) per person (kWh/person p.a.)
- Energy consumption (saving) per square meter (kWh/m^2 p.a.)
- Energy consumption (saving) per degree-day KWh/CDD p.a. (Cooling Degree Days)
- Primary Energy consumption (saving) per square meter (kWh_{PE}/m^2 p.a.)
- Share of renewable energy (%)

Electricity:

- Energy consumption (saving) per dwelling (kWh/dwelling p.a.)
- Energy consumption (saving) per person (kWh/person p.a.)
- Energy consumption (saving) per square meter (kWh/m^2 p.a.)
- Primary Energy consumption (saving) per square meter (kWh_{PE}/m^2 p.a.)
- Share of renewable energy (%)

Domestic Hot Water (DHW):

- Energy consumption (saving) per dwelling (kWh/dwelling p.a.)
- Energy consumption (saving) per person (kWh/person p.a.)

- Primary Energy consumption (saving) per person (kWh_{PE}/person p.a.)
- Share of renewable energy (%)

Cold water

- Water consumption (saving) per person (litre /person p.a.)

Avoided CO_2 emissions

- CO_2 avoided emissions ($kgCO_2$/a) = energy savings (kWh/a) * emission factor ($kgCO_2$/kWh)

The emission factor depends on the type of energy saved, for example:

- Electricity: depending on the composition of the electricity generation mix of each country in each moment.
- Natural gas: 0,201 (kg CO2/kWh)
- Diesel: 0,287 (kg CO2/kWh)

Before moving to an economic view, it is important to note that for residents in particular, energy savings are not the only relevant output of an ESI. An important additional output variable for HVAC functions is the subjective "comfort" experienced by residents, which is partly captured by objectively measurable values such as room temperature and relative humidity in the dwelling. The impact of humidity and a range of gaseous or fibrous particles like CO, Radon, Ozone, fibers, etc. on Indoor Environmental Quality (IEQ) is addressed in IPMVP Volume 2. High relative humidity may contribute the growth of fungi and bacteria dangerous to health. The additional relevant units here are:

- Room air temperature (degrees C)
- Relative humidity (%)

From an economic perspective, energy savings may represent the return on an economic investment. The return on this investment can be illustrated by setting savings in relation to size of investment in different ways. Key variables here are the conversion of consumption figures in kWh and litres of cold water into EURO, using market prices:

- Cost of consumption (saving) per dwelling (€/dwelling)
- Cost of consumption (saving) per person (€/person)
- Cost of consumption (saving) per square metre (€/m^2)

Particularly where the investor and/or recipient of energy bills is a private person, issues of affordability – proportion of disposable income – may play a role, such that cost might be expressed as a proportion of per capita (disposable) income:

- Cost of consumption (saving) as proportion of per capita income (%)

Looking at the return on investment, key ways of expressing investment success are:

- Net present value of the investment per square metre (€ / m^2)
- Return on investment (ROI) (%).

Finally, for reasons of assessing the likelihood of further exploitation of results it may be important to report the level of public funding:

- Public funding [%]: Share of public funding in the energy saving investment.

2.3 The ICT PSP approach – energy saving

2.3.1 Pre-post comparison

As outlined above, measuring energy savings requires estimation of consumption which would have taken place had the intervention not been carried out, the "non-intervention consumption". Estimates of non-intervention consumption can be based on extrapolation of consumption in a period before the intervention. The result of an energy saving intervention is estimated through comparison of measured energy consumption data before (baseline period) and after the intervention starts (reporting period).

Ideally a model has been built which shows how energy use varies under the influence of independent variables, such as outside temperature, occupancy, household size etc.

If no independent variables can be measured, the selection of a baseline period is critical. This period should be such that all known but unmeasured independent variables exhibit a full range of variation during the baseline period.

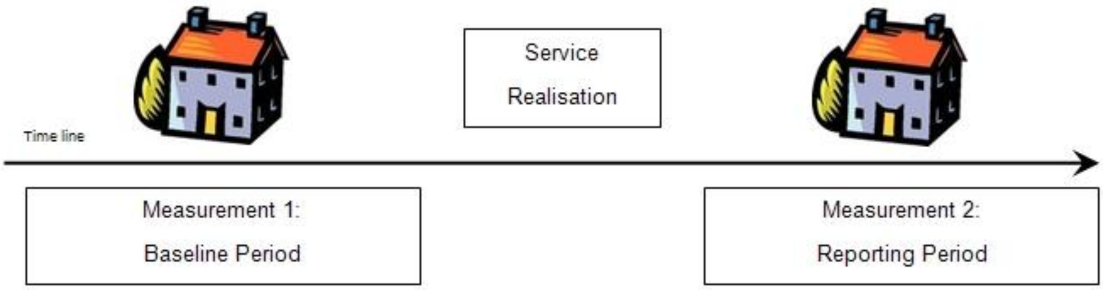

Figure 2-5 – Before-after-analysis of one building

If for example demand varied month by month during the year but was the same for the same month of each year, it would be important either to ensure the baseline covers a full year, or to ensure baseline and reporting period cover the same months in different years. Of course this does not fully reflect key residential patterns – holidays are not just taken in different months but also for different periods, and for heating bills years are not the same on average nor are months directly comparable.

Measuring baseline data is a costly exercise, and the quality of the decisions can impact on the accuracy and validity of conclusions on energy savings. Decisions on length and timing of baseline measurement are therefore very important. Depending on the independent variables affecting the consumption which is targeted, different decisions will be taken about the appropriate length of baseline – day, week, month or year.

If it can be assumed that domestic hot water consumption is quite similar from day to day during the whole year, baseline data from one day would be enough. If mild variation is expected, this might be extended to a week. This of course raises the question as to why a 6 or even 12 month operation period would be needed for the reporting period data. Similar considerations might apply to cold water consumption, however, it is even clearer here that garden-watering and swimming-pool use is seasonal, and weather-dependent, so that longer periods of monitoring would be advisable – or the building of a statistical model based on multiple independent variables.

The recommended approach is to develop regression models that reproduce the energy consumption based on values of the independent variables.

Climatic changes are the main reason of variability in residential consumption profiles. Average temperature or heating degree days (HDD) and cooling degree days (CDD) can be used.

Whereas in the industrial production plant targeted by IPMVP there may be repeated periods of energy use making up something which can be referred to as an energy use cycle, this is not the case in domestic energy consumption. Therefore, no suggestion for linking particular baseline periods to particular energy uses – a week for hot water, a year for heating - is given in the methodology.

For regression models an adequate accuracy of modelling of the variation in the dependent variable is necessary to accurately estimate the extended baseline – the no-intervention consumption - in the reporting period.

One metric for goodness of fit is the squared multiple correlation coefficient R^2, which reflects the proportion of variance explained in the model. If R^2 is low, further independent variables must be found to improve predictions. If R^2 remains low, only very large savings of energy will be reliably detected.

The IPMVP suggestion to include only months with more than 50 degree days in the analysis[6] is appropriate only if the cost of data gathering can be reduced this way, and the energy savings in warmer months is insignificant in the impact of the intervention as a whole.

	Baseline (kWh)	**HDD**
January	3.746,80	299
February	3.033,87	189
March	2.666,27	206
April	1.778,29	118
May	1.396,91	62
June	471,53	19
July	366,56	3
August	109,28	5
September	571,41	18
October	1.269,90	80
November	2.158,28	249
December	4.066,22	318
	21.635	**1.566**

Figure 2-6 – Baseline consumption and baseline degree days

[6] IPMVP, vol. 1, p. 83.

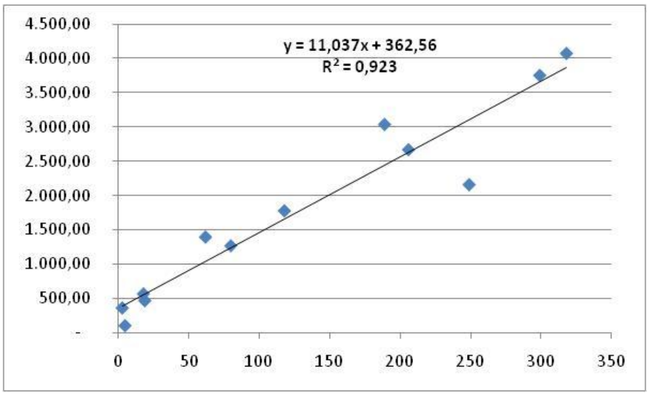

Figure 2-7 – Table and graph of energy consumption related to HDD

Figure 2-7 shows a regression line reflecting a correlation between monthly consumption and HDD. More than 90% of variance is explained, which suggests that accuracy of estimation is very good. In fact, a model such as this, of energy consumption for heating of a building in regular use, built with an independent variable reflecting ambient temperature such as degree days and using data for an entire year, will normally have a high R^2. The high value reflects the very high variability of the dependent variable, heating consumption over the year, rather than showing the model is adequate for detecting energy savings due to an intervention. This variability must be reduced to show the impact of even the most effective intervention.

2.3.2 Outside temperature as independent variable

Within the EU a number of calculation models are in use to reflect outside temperature changes over time. Examples are given from Germany, France and Belgium.

In Germany there are a number of different standards for heating degree days, based on different heating limit temperatures (heating degree days and of degree-day numbers – HDD, outdoor temperature 15°C or less)[7]:

$HDD_{Heizgradtage/heating\ degree\ days}$ = Heating limit temperature $_{(10,\ 12,\ 15)}$ – Daily average outside temperature

[This formula is used for a climate adjustment.]

$HDD_{Gradtagszahl/degree\text{-}day\ numbers}$ = Inside temperature $_{(20)}$ – Daily average outside temperature.

[This formula is used if solar and internal gains should be taken into account too.]

Specific energy consumption figures (kWh/m^2) can be divided by $DD_{Heizgradtage}$ resp. $DD_{Gradtagszahl}$. The quotient is a figure in kWh/(m^2*Kelvin-days) (or *24/1000 in m^2*Kilo Kelvin Hours).

In France the heating limit temperature (external temperature baseline) amounts 18°C. The degree day correction is divergent as well and is calculated as follows:

[7] Passive house standard 10°C, 50°F; low energy standard 12°C, 53,6°F; all the rest of buildings (building stock)15°C, 59°F. The use of equal heating limit temperatures in order to determine the number of degree days in both baseline and reporting period is obligatory.

$$DD = 18°C - \frac{Highest\ temperature - lowest\ temperature}{2}$$

[Calculation of heating degree days: Average between maximum and minimum outside temperature]

The calculation of the degree days in Belgium is the same as the calculation of $DD_{heating\ degree\ day}$ in Germany. In Belgian the tradition is to use a heating limit temperature of 16, 5°C.

For purposes where the consumption over a short period is to be corrected or compared, Belgian practice is to take account of the delay effect / thermal inertia of buildings by using 'equivalent degree days' to take account of energy saved in building structure from previous days, as follows:

DDequiv = 0.6 x DD (today) + 0.3 x DD (yesterday) + 0.1 x DD (day before yesterday).

For purposes such as the issuing of energy performance certificates of buildings it is customary in Germany to use long-term averages from weather data over a period of 30 to 40 years. Given this or another appropriate standard for outside temperature, e.g. the average number of heating degree days over a long period, measured data – baseline or reporting period - can be converted to energy consumption in a "standard" year.

$$C_{adj} = C_{met} * \frac{DD_{stand}}{DD_{met}}$$

Legend	
C_{adj}	consumption data temperature adjusted
C_{met}	consumption data in the metering period
DD_{stand}	number of degree days of a standard period
DD_{met}	number of degree days in the metering period

Figure 2-8 – Degree day correction with temperatures of a standard period

This method can be used not only to correct baseline data to a standard year, but also to correct the reporting period data to a standard year. When the temperature adjusted consumption data of the reporting period is subtracted from the consumption data of the baseline period this represents the saving which would have been achieved in a standard year.

One minor point to be taken into account here is that if reporting period figures are also adjusted to a standard year, then for transparency the saving figure calculated must be reported as "energy saved in a standard year", and not presented as the amount of energy saved in the specific ICT PSP pilot. And yet more minor is the point that given long-term global temperature trends, the value of standard years may be seen as diminishing, to be replaced by a projection of expected temperature over the investment pay-off period.

A much more important issue is the effectiveness of this approach for the purpose of evaluating ICT PSP pilots.

Given the powerful influence of outside temperature on energy consumption for heating, it is effectively being assumed that the only independent variable to be considered is outside temperature, and that this simple correction to differences in average outside temperature can be performed to show the energy saving. The effect of the independent variable is removed.

If this were indeed the only independent variable, the level of consumption, measured in kWh/Kelvin-days, would be constant during the baseline, and during the reporting period. The value of R^2 would be 1.0, showing that all variance had been explained. Given this constancy, the measurement period for baseline and reporting period could be shortened to any single day, radically reducing the costs of piloting in ICT PSP. This assumption is of course far from reality.

Multiple factors affect the level of energy consumption for heating apart from outside temperature. A simple example is the setting of thermostatic valves in radiator systems. If this setting is changed, the linear relationship between outside temperature and kW of energy lost through building walls shifts up or down in response. The setting of the valve is an independent variable – it does affect energy consumption.

This behaviour-related effect is important in the choice of baseline and reporting period, not the physical effect of ambient temperature on conduction processes through building walls.

If the valve is used by the resident to shut down the heating during a winter holiday, and the baseline period falls during this holiday, it will be difficult to show any energy saving from a subsequent intervention. The opposite is true where the reporting period falls in the holiday period. Here a simple degree day correction is inappropriate.

Looking at different energy uses makes this point more forcibly. To detect a change in the use of energy for the purposes of running household electric appliances, caused by a specific energy saving intervention, simply applying a "degree day correction" to baseline and reporting period would be obviously unacceptable.

Such considerations, and not the influence of climatic variables on which accurate data is available, are the reason both for extending measurement periods and using statistical techniques such as regression.

In the case of energy use for heating, degree days could be used in an initial conversion of raw energy data to a new statistic in kWh/Kelvin-day which is then taken ahead in statistical analysis to detect the reduction in energy use due to the energy saving intervention. However, as the following considerations show, it may not be appropriate to use degree days in this way, or even as independent variable in regression analysis.

There are multiple metrics for outside temperature variation. Degree days may be calculated using 10, 12, 15, 16.5 or 18 degrees Centigrade as cut-off (compare above). Data on average daily temperatures is available from networks of meteorological stations, and dedicated measurement could be used from the buildings in the pilot to provide hourly or even more frequent temperature values.

For the purposes of estimating real energy savings in ICT PSP pilots, the choice of an outside temperature metric is not guided by normative considerations such as is the case in certification. Instead, the metric should be as accurate a reflection as possible of the linear influence of changes in outside temperature on the loss of heat from a heated building, so that the real behaviour of heating systems controlled by residents can be modelled. Where residents are able and do set their heating system to provide inside temperature of over 20 degrees, most degree day statistics lose predictive power. The error is likely to be minor, however. The small value at the regression line intercept in Figure 2-9 probably reflects an error due to this discrepancy.

Unlike the German and Belgian degree days, with their normative assumptions of appropriate levels of temperature inside heated buildings, the “energy signature” customary in France is based on outdoor temperature without coding into degree days.

Figure 2-9 represent the energy signature of a building, showing the use of outdoor temperature in the regression equation. In the region to the right where the outside temperature is above the 18 degrees room temperature applied to social housing in France, the residual energy consumption represents the consumption of domestic hot water.

The energy signature, i.e. the complete plot of consumption against temperature, is predominantly used in France to analyse energy requirements and operating costs of a building. Its relevance here is to show that direct use of outside temperature metrics in statistical analysis without conversion into degree days is feasible.

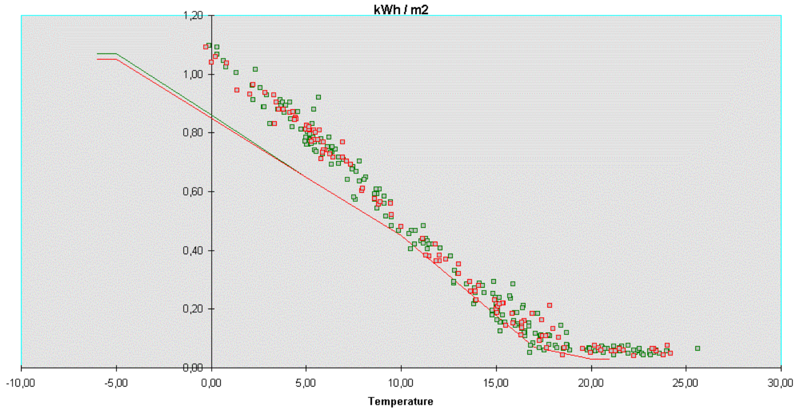

Figure 2-9 – Example of an Energy signature

2.3.3 Selection of reporting period

After the ESI and a following period with improvements/adjustments, the energy savings should remain stabilised for a certain period of time in the case where tenants are involved. To monitor the persistence (increase or decrease) of energy savings in the time it is necessary to roll out the following steps:

- In the short term, it is possible to compare each week to analyse if the energy savings are continuous over time after the energy saving intervention, especially if the savings depend on social behaviour.
- For equipment renovations it is very important to verify in the long-term too.

2.3.4 Summary of steps for estimation from baseline

In the before-after comparison approach, six steps are necessary:

1. Nominate a time period for the baseline which captures all variation of immeasurable independent variables and can yield an average which can reasonably be expected to be repeated in the future;
2. Gather data for the energy consumption (dependent variable) and for all accessible independent variables (baseline period);
3. Perform a regression analysis to establish the coefficients for each independent variable;
4. Nominate a time period for the reporting period which is again long enough to capture all variation of immeasurable independent variables[8];
5. Gather data for the energy consumption (dependent variable) and for all accessible independent variables (reporting period);
6. Apply the coefficients estimated in the baseline to the reporting period, yielding the result: energy saving as the difference between estimated and measured consumption.

2.3.5 Applying control group techniques

As stated above, energy savings due to an ESI cannot be measured directly, as they represent the difference between energy actually consumed after the intervention and that which would have been consumed ***had the intervention not been carried out***. Any measurement is in fact based on assumptions of a possible parallel development – the development of energy use without the intervention: “non-intervention consumption”.

There is no alternative but to *estimate* non-intervention consumption. Without this estimation there is no energy saving “measure”. Estimation can be based on prior consumption patterns or on patterns of consumption in comparable settings unaffected by the intervention – “control buildings” – or on both.

Up until now we have dealt with using prior consumption for estimation, using baseline energy consumption to estimate regression coefficients in order to re-applying these in the reporting period to gain an estimate.

An additional or alternative source of estimation is a control group or control building approach. Where no baseline energy consumption data are available – for example in case of new construction, the control group approach would be the only alternative.[9]

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[8] E.g. the ICT PSP Work Programme refers to a 12 months period

[9] Beyond the control group approach there are several different possibilities in order to get a baseline. But the control group design is the recommended best option. For further information see IPMVP, vol. 3/1.

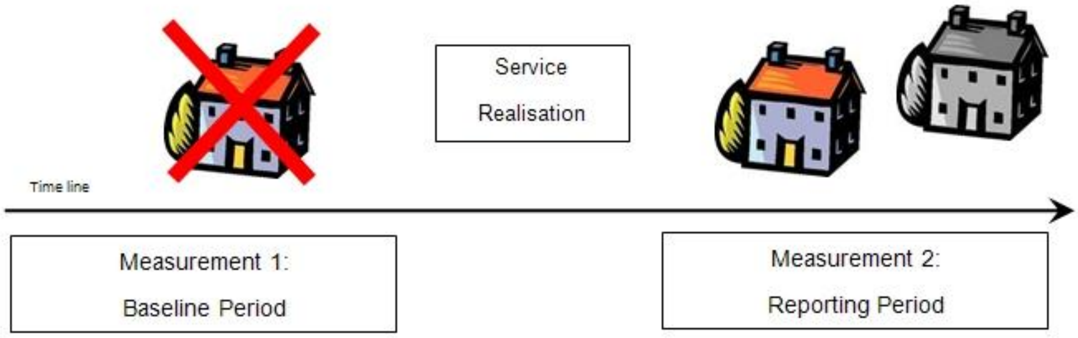

Figure 2-10 – Control building design

A control building is a building which matches the characteristics of the experimental building in all important respects, i.e. along all known independent variables. These can include for the building itself:

- kind of building,
- location,
- energy equipment,
- insulation,
- heating system

and for the building's residents:

- family structure,
- proportion of families with young children,
- proportion of employed and unemployed,
- absence / holiday behaviour patterns,
- use of building for occupational work,
- etc.

If there are differences between the experimental buildings and control buildings or their residents, these differences reduce the effectiveness of the control building approach. Differences open any results to challenge using rival hypotheses for non-intervention consumption estimates, hypothesised impacts of the differences. Despite the use of the word "hypothesis" here, the undermining of results is real: the "hypotheses" stand alongside "estimates", and have therefore close to equally strong claims to be heard.

In the best of cases the only difference between experimental and control building is the presence or absence of the ESI, for example tenants in the experimental building all have access to and regularly use consumption feedback via a web portal whereas the tenants of the control building have no access at all.

Practical considerations will usually prevent application of safeguards common in other domains, where subjects are blinded to their inclusion in one group or another – it is not to be ignored that the tenants of a control building, if they gained knowledge of the project and its purpose and their role in the experiment, might change their energy-related behaviour, invalidating the "no-intervention" status – or where individuals are randomly assigned to experimental and control group – it is not to be ignored that a pilot manager, wishing to show clear energy savings, might choose the most advantageous buildings to be in the experimental group.

The advantage of a control building design is that data is collected over the same period in time, therefore both control and experimental group experience other influences on their behaviour such as a tightening credit crunch or a lengthening of school holidays. In the before-after approach, such "history" influences would invalidate the comparison if they took place once some time after the start of baseline and before data collection in the reporting period finished.

Using control buildings, there is the additional option of pairing buildings between experimental and control group. In this case each pair must exhibit all the above similarities.

Implementing an evaluation using control buildings involves the following steps:

1. Select a group of buildings representative of the future exploitation potential of the energy saving intervention (ICT application)
2. Divide the pilot buildings into 2 groups: treatment /experimental and control.
3. (Optionally) establish pairs of analogues cases from both groups.
4. (Optionally) measure dependent and independent variables during the baseline period in each group
5. Implement the ESI in the treatment group
6. Measure dependent and independent variables during the reporting period
7. Use appropriate statistical techniques to estimate non-intervention consumption in the treatment group during the reporting period based on baseline model and control group model. Or use matched-pair statistical techniques to estimate the energy saving.
8. Calculate energy saving as difference between the estimated non-intervention consumption and the measured energy consumption in the treatment group in the reporting period. Or use matched-pair statistical techniques to estimate the energy saving.

2.3.6 Control group approach to behavioural changes

Where the intervention or treatment is the provision of an information service, a control group approach can be applied. In the best of cases tenants can be assigned to control or experimental group on a random basis. That means that all pilot tenants have the same probability to be part of the control or the experimental group. In doing so, to both tenant groups nearly apply the same conditions beside the relevant object of investigation (e.g. tenant portal). Ideally the control group match the characteristics of the experimental group concerning living situation, household size, average age, ecological awareness or the like. If there are behavioural or attitudinal changes in the experimental group obvious, but not in the control group, then those changes can be interpreted as a result of the treatment.

In some cases a control group approach is not appropriate because of the absence of comparable buildings, too small sample sizes or a combination of both. In such cases other comparisons between user groups can be considered. In the given context we can roughly differentiate three tenant groups:

- Experimental or treatment group with
    - active users with full access and a regular use of services,
    - passive users with possible access to services but without willingness to use,
- Control-group without access to services.

When comparing active users and passive users only, systematic bias has to be taken into account. Behavioural or attitudinal changes in the group of active users but not in the group of passive users must be interpreted with caution. The passive users are not a randomly assigned control group. It has to be taken into account that passive users seem to be not interested in the services at all or are not able to use the service. That can be caused by several reasons which should be captured in the data gathering and properly analysed.

Where a true control group cannot be built, it is expected to be helpful to differentiate not just passive and active users but different levels of service use. For example, it may be helpful to differentiate those who only use the service once or twice at the beginning from those who regularly use the service. Which subdivision of type of service use is appropriate depends on the content of the service, in particular the added information which can be gained by regular use compared to one-off use.

2.3.7 Measurement of independent variables by user survey

The primary dependent variable, consumption of energy, is ideally measured by devices such as smart meters, which once installed capture data continually and accurately. This is state-of-the art for electricity, and increasingly for gas.

Some independent variables such as outside temperature can also be measured automatically and reliably. This allows their inclusion in non-intervention consumption estimation without difficulty. Others, such as the presence of children among residents, or periods of absence for work or holiday, require the use of different techniques to “measure”, and as personal data are subject to data protection legislation.

Energy-related behaviour and attitudes represent a large set of such independent variables. Several ICT PSP projects have the common objective to develop ICT-based services to enable social housing tenants to optimise their energy consumption behaviour. Key topics of the services are approaches which deliver consumption feedback to the tenants for periods for less than a year which offer possibilities of an energy monitoring and energy management and/or contain interactive components like self-assessment-tools, benchmarking or alert systems. Differences can be found in the specific design of the services, the sample sizes of pilot users, etc.

Where interventions target user behaviour, and user variables are to be included as independent variables in the overall method, survey techniques can be used. When using surveys to measure behaviour and other person-related factors or other factors relevant to energy consumption, it is important to decide whether to use a cross-sectional study with one measuring point only or a longitudinal study with multiple stages.

To capture behavioural and attitudinal change due to an intervention at a single measurement point requires the use of questions referring to a previous time period, asking for instance if the resident used to pay more or less attention to closing windows at night, turning thermostat down, not over-filling a pan to be boiled or other behaviour affecting energy consumption.

The validity of answers to such retrospective techniques can be questioned, pointing to memory constraints and distortions due to grasping the purpose of the survey – to show improvements in energy behaviour.

Therefore longitudinal studies are to be preferred, in which attitudes and behaviour of the current time or immediate past are addressed.

When planning a survey of building residents, e.g. social housing tenants, the following three topics are particularly relevant:

- The questioning technique: Which type of tenant survey is appropriate?
- The willingness of tenants: How to motivate tenants to participate in a survey?
- The content of questionnaires: How to operationalise the aspects of interest?

The definition and operationalisation of evaluation items depends on several local issues. Examples from eSESH and 3e-Houses are given in the section further below.

2.4 The ICT PSP approach – peak demand reduction

2.4.1 Interventions to reduce peak demand

Whereas interventions aimed at energy savings target overall energy use, e.g. over a month, year or longer, the intervention in this case involves incentives provided to the customers to achieve a reduction in a certain period of time, when demand from all customers peaks. Demand Response (or Demand Side Management) applies to electricity consumption only.

Figure 2-12 represents hourly real low voltage consumption data (household sector) over 24 hours in winter and in summer time in Spain. In both cases the peak demand is between 22:00 and 24:00 p.m..[10]

[10] Source: CNE (Spanish Energy Regulator)

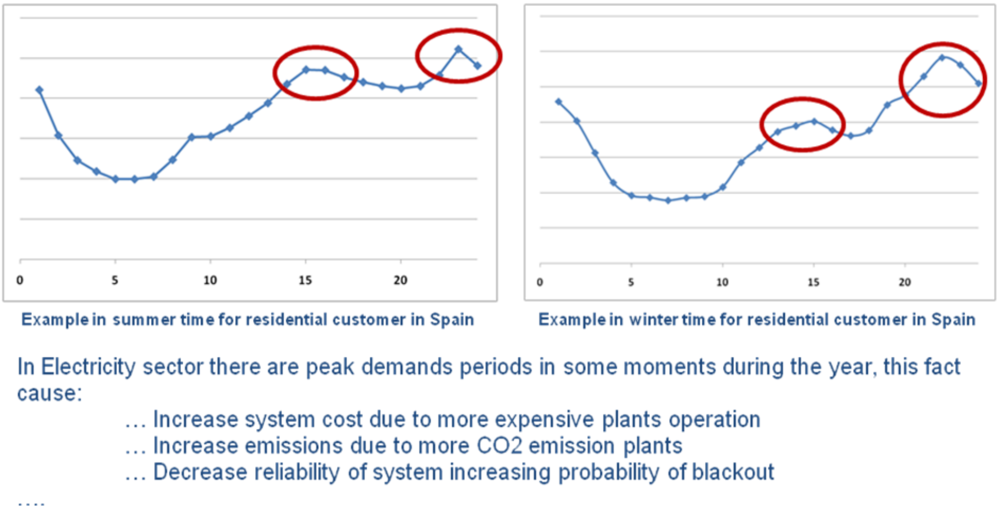

Figure 2-11 – Demand response needs in the household sector in Spain

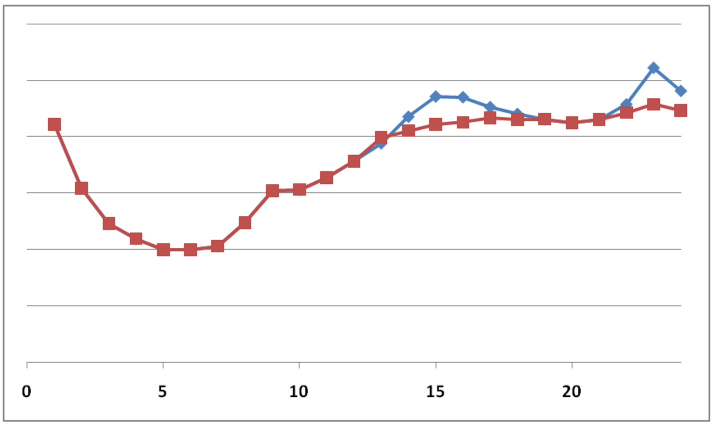

Figure 2-12 – Example for peak shaving[11]

Four different methods are discussed below for estimating the degree of peak shaving achieved, summarised in Figure 2-14.

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[11] Peak shaving doesn't implicitly result in power savings, but in shifting demand in load valleys.

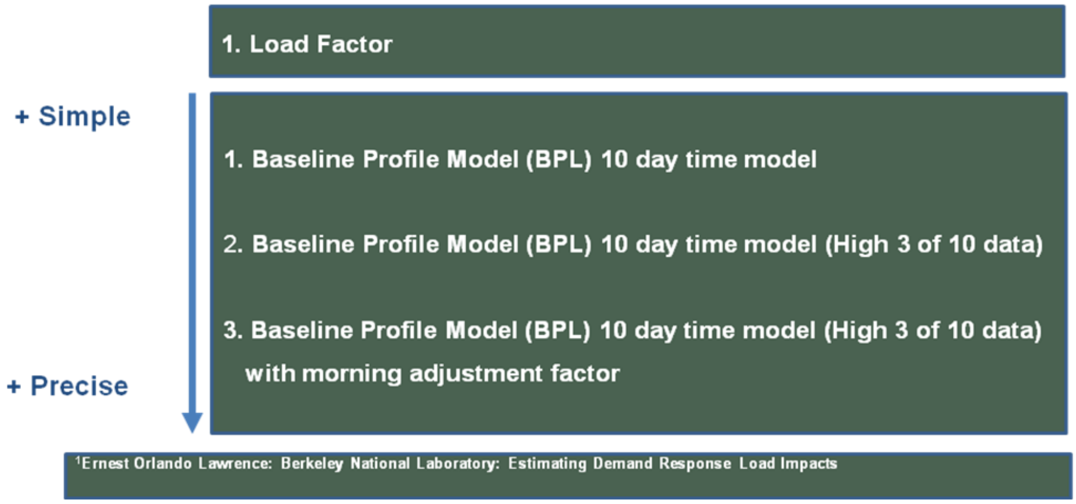

Figure 2-13 – Demand response baseline methodologies

2.4.2 Use of the load factor metric

The load factor (LF) is defined as the value obtained by dividing the minimum power demand by the maximum power demand of a building, i.e.:

LF = (min power demand)/(max power demand)

The closer the load factor is to the value 1, the less the demand curve peaks. If the building load curve peaks correspond to the electricity network peaks, movement towards 1 can represent useful peak shaving for the utility. The following example shows the case of a house, one day in august. The graph shows the normal power load of the client (blue line) as well as the corrected load obtained by applying a demand response program (displacement of normal consumption curve). Comparing both calculations of LF, it can be seen how LF raises from 0.38 to 0.44, **leveling the load curve.**

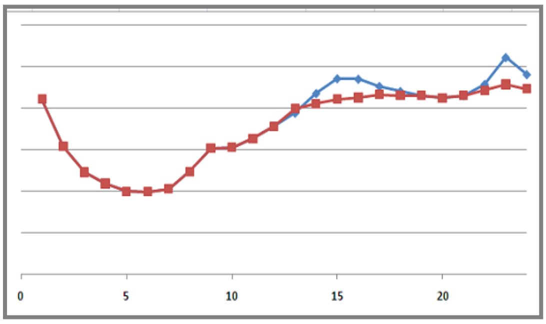

Figure 2-14 – Example of peak shaving

	Normal load (kW)	Corrected load (kW)
Max	10,45	9,15
Min	3,99	3,99
Load factor	0,38	0,44

Figure 2-15 – Table with peak shaving results

Use of load curve calculations limited to one building is not ideal. Building peaks may not correspond to network peaks, giving a false sense of improvement. Also, in residential settings defining an appropriate the minimum value may be difficult if a tenant presents demand = for example a light cut or cleaning a fridge in a low demand period, with no other energy consumption. Such a minimum would lead to false load factor values and an inappropriate demand response assessment.

2.4.3 Estimator as average over 10 day baseline

Baseline profile models (BPL) are used to estimate the shaving of peaks which occur unpredictably on particular days, the peak “event”. To estimate non-intervention consumption at the peak event, it is generally accepted that a baseline period of 10 business days directly prior to the event reasonably represents consumption for normal operations. The reporting period is typically the 24 hours of the event day. A 10-day baseline time frame is short enough to account for near-term trends and long enough to limit opportunities for manipulation. In this model the average represents the non-intervention reporting period (event day) estimate. Actual consumption on the event day is compared to this average to quantify the peak shaving. The consumption over the 10 days is averaged as follows:

b:(d1(t,h)+d2(t,h)+d3(t,h)+d4(t,h)+d5(t,h)+d6(t,h)+d7(t,h)+d8(t,h)+d9(t,h)+d10(t,h))/10 for the number of hours of the event

	Power Demand (kW)
day 1, hour 20:00	4,00
day 2, hour 20:00	4,15
day 3, hour 20:00	4,00
day 4, hour 20:00	3,90
day 5, hour 20:00	4,00
day 6, hour 20:00	4,30
day 7, hour 20:00	3,85
day 8, hour 20:00	4,05
day 9, hour 20:00	3,95
day 10, hour 20:00	4,10
Baseline	**4,03**

Demand Response consumption =
Demand event day (day 11) – Baseline (average)

Demand Response consumption = 3,70 kW – 4,03 kW = 0,33 kW

Figure 2-16 – Example of an average baseline[12]

2.4.4 Estimator as average of top 3 of 10 day baseline

Given some problems with simply averaging 10 previous days as baseline, other methods specify the averaging of the 3 highest consumption figures from the previous 10 days, which must exclude other event days, holidays etc. The estimator for the non-intervention event day consumption is:

b: max (1,3) (∑dn(t,h))/3

[12] Concerning figures 2-27 to 2-29 it has to be considered that the equation example bases on absolute values.

	Power Demand (kW)
day 1, hour 20:00	4,00
day 2, hour 20:00	4,15
day 3, hour 20:00	4,00
day 4, hour 20:00	3,90
day 5, hour 20:00	4,00
day 6, hour 20:00	4,30
day 7, hour 20:00	3,85
day 8, hour 20:00	4,05
day 9, hour 20:00	3,95
day 10, hour 20:00	4,10
Baseline	**4,18**

Demand Response consumption =

Demand event day (day 11) – Baseline (high 3 of 10)

Demand Response consumption = 3,70 kW – 4,18 kW = 0,48 kW

Figure 2-17 – Example of a demand response baseline

2.4.5 Estimator as average of top 3 of 10 day baseline with morning adjustment

Finally, to take account for the fact that customer demand is often heaviest on event days, capturing day-of realities in a customer load profile is essential to delivering accurate performance calculations. A simple way to address this need is through an adjustment based on day-of event conditions. Here the estimator for event day (reporting period) non-intervention consumption is:

b': max (1,3) (∑dn(t,h))/3

P: (d(t,h-1) – b(t,h-1) + d(t,h-2) – b(t,h-2))/2

e.g. P: (4,15-3,75) + (4,00-3,50)/2 = 0,45

	Power Demand (kW)
day 1, hour 20:00	4,00
day 2, hour 20:00	4,15
day 3, hour 20:00	4,00
day 4, hour 20:00	3,90
day 5, hour 20:00	4,00
day 6, hour 20:00	4,30
day 7, hour 20:00	3,85
day 8, hour 20:00	4,05
day 9, hour 20:00	3,95
day 10, hour 20:00	4,10
Baseline	**4,18**

	Power Demand (kW)	Baseline (kW)	
day 11, hour 18:00	4,00	3,50	0,50
day 11, hour 19:00	4,15	3,75	0,40
		Adjustment Factor	0,45

Demand Response Savings:

Demand event day – Baseline (high 3 of 10) + adjustment factor

Demand Response Savings = 3,70 – 4,18 + 0,45 = 0,93 kW

Figure 2-18 – Example of demand response savings

2.4.6 Estimating CO_2 emissions

If a peak shaving of the demand curve is achieved, emissions will be avoided because the electricity produced in off-peak hours has a fewer contribution of highly pollutant generation plants and the renewable sources, generally, have priority. Therefore the CO_2 emissions associated to this peak period of consumption are lower. On the contrary, the emission factor during the peak hours is generally higher, because of the fact that the contribution of fossil fuels to the generation mix is higher.

The CO_2 emissions avoided, related to demand response, are calculated as:

CO_2 avoided emissions (kgCO_2/a) = consumption energy displaced (kWh/a) *(emission factor peak hours (kgCO2/kWh) - emission factor off- peak hours (kgCO_2/kWh))

3 Example applications

3.1 Use of working tables in eSESH

The eSESH basic consumption measurement approach is transformed in two standardised measurement tables:

1. Detailed Consumption Measurement Table
2. Consumption Analysis Matrix

The Detailed Consumption Measurement Table serves as a data base which collects all basics and details regarding the consumption data gathering. The table was established with the idea that - when studying 10 different pilot sites which themselves are implementing various ICT solutions in different environments - the likelihood of facing different measurement conditions is very high. For that reason a detailed description of that "measurement environment" of each site is necessary. The aim is getting a comprehensive inventory of measurements, statements, data transmissions, etc. of each site. Furthermore this information allows the appraisal of observed differences between consumption savings assessed on different pilots.

The main themes in that table are:

- Definition of building, energy types, characteristics of the baseline:
  - For what building type/area (and which kind of area definition is used)?
  - For what application: heating/hot water/cooking…?
  - Used baseline: control group, historical data, estimates…
- Definition of measurement requirements related to fuels/energy types = unit used and frequency of meter reading (proposed minimum: monthly):
  - Heating (proposed unit: kWh resp. KWh/m^2)
  - Hot water (proposed unit: kWh)
  - Gas (proposed unit: kWh)
  - Electricity (proposed unit: kWh)
  - Cold water (proposed unit: m^3).
  - Indoor temperature: Is it known/measured or contractually defined by landlord?
- Measurement of outdoor conditions
  - Outdoor temperature
  - Methodology of adjustment for climatic conditions

Some ratios, given for example in the IPMVP methodology, require the knowledge and the understanding of calculation methods of data which seem at first view uniformly:

- The definition of a kWh, for example, in the case of gas: Gas consumption data can be established in kWh PCS or PCI (calorific value with or without humidity in gas). The difference between both depends on the standards used.
- The definition of kWh/m^2: The calculation of specific heat energy consumption figures kWh/m^2 may include common areas, balconies, etc. That depends on particular standards.

This information is essential to ensure consistency and justification in comparisons of consumption data made between different pilots. The expression of savings at each site as a percentage (relative difference) may solve this problem, but, nevertheless, differences in measurement methodologies used at each site necessarily imply differences in interpretation.

Based on the detailed description of measurement characteristics a working table was created, which serves as an analysis matrix. The analysis matrix includes all available consumption data on an at least monthly basis over several time periods (e.g. heating periods).

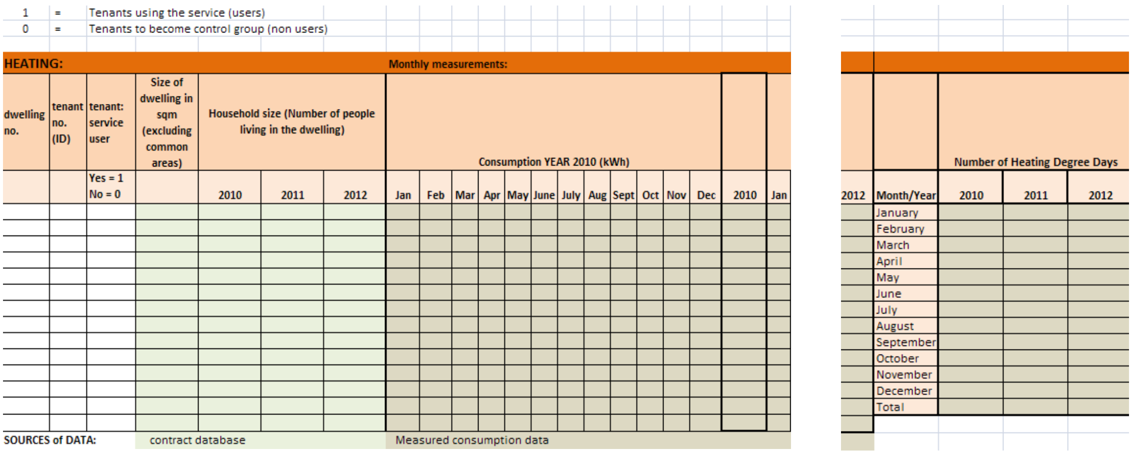

Figure 3-1 – Using the example of eSESH: Consumption Analysis Matrix (here: heating)

The MS Excel sheet contains dwelling or tenant ID numbers, which allow the assignment of consumption data and – in the case of eSESH – survey data; the user or non-user status; the dwelling size and household size as basis for specific calculations of kWh per m^2 resp. kWh per person, monthly consumption data and heating degree days for temperature adjustments. The heating degree days allow calculations of routine adjustments. The household size, which could vary when comparing several years, allows non-routine adjustments. In addition to that, a CO2-Calculator provides relevant information on avoided emissions. The emission factors are taken from various scientifically proven sources.

3.2 Applying IPMVP Option C in 3e-Houses

As a summary: Energy savings > 10% + no sub metering (utility meter).

The calculation of savings follows the formula:

Option C Savings = Baseline Energy – Reporting Period Energy ± Adjustments.

Therefore it is possible to explain the residential consumption with the next formulation:

- Electricity consumption = constant + X * number people + Y * HDD + Z * CDD
- Combustible consumption = constant + X * number people + Y * HDD + Z * CDD
- Water consumption = constant + X * number people

It is possible to reduce the previous formulation (full equation: constant + X *number people + Y * HDD + Z * CDD):

- No heating: constant + X * number people + Z * CDD
- No cooling: constant + X * number people + Y * HDD
- Occupancy constant: constant + Y * HDD + Z * CDD

Example – Baseline (Before EEM implementation)

Consumption (kWh): 11,037 * HDD + 362,56

	Baseline (kWh)	HDD
January	3.746,80	299
February	3.033,87	189
March	2.666,27	206
April	1.778,29	118
May	1.396,91	62
June	471,53	19
July	366,56	3
August	109,28	5
September	571,41	18
October	1.269,90	80
November	2.158,28	249
December	4.066,22	318
	21.635	1.566

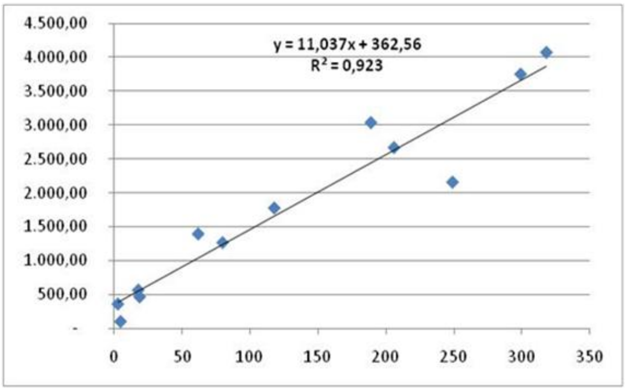

Figure 3-2 – Example table and graph of energy consumption related to HDD regarding to an individual dwelling

Example – Baseline (before EEM implementation)

It's necessary adapt the previous consumptions to the actual consumptions conditions

This year is coldest than the baseline year and will increase the reference consumption

Baseline year

	Baseline (kWh)	HDD
January	3.746,80	299
February	3.033,87	189
March	2.666,27	206
April	1.778,29	118
May	1.396,91	62
June	471,53	19
July	366,56	3
August	109,28	5
September	571,41	18
October	1.269,90	80
November	2.158,28	249
December	4.066,22	318
	21.635	1.566

Baseline year adjusted

	Baseline (kWh)	HDD
January	3.894,40	320
February	2.581,00	201
March	2.294,04	175
April	2.018,11	150
May	1.234,48	79
June	583,30	20
July	417,75	5
August	406,71	4
September	583,30	20
October	1.355,89	90
November	3.232,18	260
December	4.059,96	335
	22.661	1.659

Figure 3-3 – Example tables with baseline year and adjusted baseline year (before ESI) regarding to an individual dwelling

Example – After EEM implementation

Baseline year adjusted

	Baseline (kWh)	HDD
January	3.894,40	320
February	2.581,00	201
March	2.294,04	175
April	2.018,11	150
May	1.234,48	79
June	583,30	20
July	417,75	5
August	406,71	4
September	583,30	20
October	1.355,89	90
November	3.232,18	260
December	4.059,96	335
	22.661	1.659

–

Real consumption

	Real consumption (kWh)
January	3.055,50
February	2.003,00
March	1.895,00
April	1.609,00
May	934,00
June	550,00
July	400,00
August	395,00
September	450,00
October	1.100,00
November	2.978,00
December	3.345,00
	18.715

= Savings 17,4%

Figure 3-4 – Example tables with baseline year and adjusted baseline year (after ESI) regarding to an individual dwelling

The baseline energy consumption will be adjusted by inserting the number of degree days of the reporting period in the regression equation in figure 3-2. The adjusted baseline energy consumption is the energy consumption of the baseline period transferred to the temperature conditions of the reporting period.

3.3 Evaluation of user behaviour in eSESH - longitudinal three-stage-design[13]

In the given context an expedient longitudinal study design includes a three-stage data collection with control group[14] which could be realised, for example, as a quantitative tenant survey (see example in figure 3-5). In that case the first stage delivers baseline data prior to the introduction of the service, the second data collection takes place shortly after the introduction of the services and the final stage is reached after an adequate use period of the provided services. In order to get comparable responses each survey stage has to be addressed to the same pilot households (ideally to the same members of the households who are in charge of energy issues).

The advantage of a control group design is the ease of conclusion that actually the provided service and no other aspects effected changes in energy consumption behaviour of tenants. Energy awareness and energy consumption behaviour is – as described below in chapter 4.2 – influenced by a lot of different parameters, independently from the usage of the service. Changes can occur, for example, because of a new living situation (my new girl friend lives in a very energy conscious way and I want to do what people dear to me think I should do), because of attitudinal and behavioural changes as a result of man-made or natural disasters or because of the alarming power cost billing. That's why, it is important to ensure that observed differences in self-reported tenant behaviour and awareness of multiple measurement points are neither caused by such factors nor due to random effects.

[13] Please remark: Not all pilot sites in eSESH could realise that recommended basic approach.
[14] In eSESH a quasi-experimental design is carried out. In contrast to an experimental design ("real control group design") both groups will not be selected randomly. Instead of that, for example, the housing providers decide on the assignment of tenants to experimental or control group.

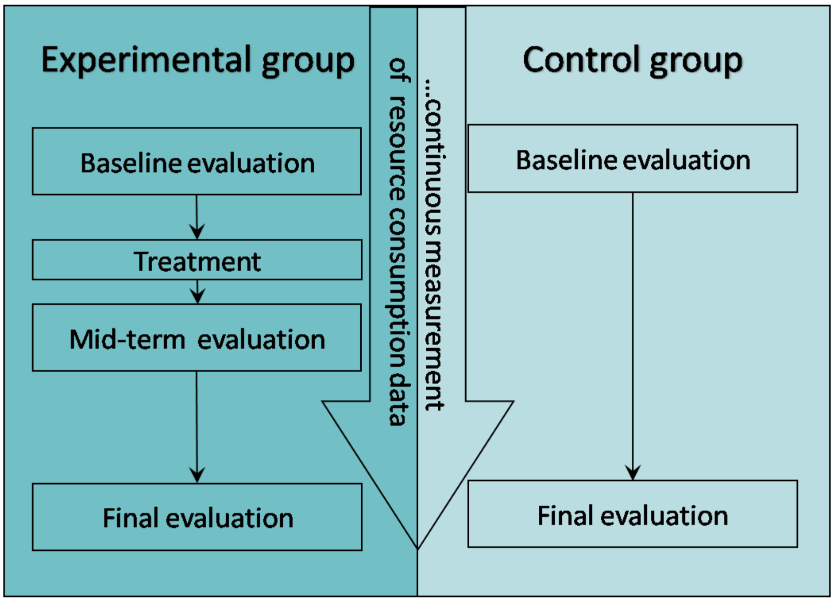

Figure 3-5 – Tenant-related evaluation approach carried out as longitudinal study

When carrying out above described longitudinal studies with three stages (survey waves) the key topics of baseline and final data collection could be questions dealing with tenant's attitudes and everyday energy consumption behaviour in order to identify changes caused by the treatment. The second data collection, which is only relevant for the experimental group, could be a beta test or the like which contains questions about the functionality, manageability, etc. of the services. The following table 3-1 contains a compilation of potential modules of questionnaires which was developed in the evaluation work package in the eSESH project and which can be used in several survey stages (e.g. baseline, mid-term and final survey) and for several groups. Where applicable, different pilots shall use standardised survey questions (about socio-demographic characteristics, energy consumption behaviour, attitudes and knowledge about energy saving issues, user acceptance, etc.), that allows cross-project comparisons. Five main issues are included:

1. Socio-demographic characteristics of tenants
2. Energy consumption behaviour
3. Attitudes and knowledge
4. User acceptance concerning consumption feedback services
5. Interest in the service and reasons for non-usage of passive users

In the following table the phasing "all groups" means the question is appropriate for all above described tenant groups: experimental group (active users and passive users) and control group. The same applies to "all stages" what means that the question is appropriate for all survey stages.

Table 3-1 – Compilation of potential items of evaluation surveys in eSESH

ASPECT	SUGGESTED WORDING OF QUESTIONS/OPTIONS	CHARACTERISTICS/VALUES
1 – SOCIO-DEMOGRAPHIC CHARACTERISTICS [all stages; all tenant groups]		
Gender[15]	Your gender?	☐male ☐ female
Age	Option A: When were you born?	_________ year [Please fill in.]
	Option B: To which age group[16] you belong? [Select one only.]	☐ aged 15 to 24 years ☐ aged 25 to 39 years ☐ aged 40 to 54 years ☐ aged 55 years or more
	Option C: To which age group you belong? [Select one only.]	age groups of the national statistics
Household size/ household structure	Option A: How many people live in your household, yourself included?	_____ people [Please fill in.]
	Option B: How many people live in your household, yourself included? Thereof, how many children (less than 15 years old) live in your household?	_____ people [Please fill in.] _____children [Please fill in.]
	Option C: How many people live in your household, yourself included?[17] [Please fill in.]	less than 15 years old ______ aged 15to 24 years ______ aged 25 to 39 years ______ aged 40 to 54 years ______ aged 55 years or more ______
	Option D: How many people live in your household, yourself included?	age groups of the national statistics
Duration of daily stay at home	Please think of a weekday of your normal course of life last month. Which of the following statement is corresponding best to your personal situation and the situation of the other members of your household? • I was… • Household member 2 was… • Household member 3 was… • … [number of persons has to correspond answer concerning household members]	☐ ...at home most of the day and only out of home awhile short-term errands ☐ ...at home longer than half a day and few hours out of home ☐ ...at home half a day and out of home half a day ☐ ...less than half a day at home and mostly out of home ☐ ... at home only for sleeping at night
Time of absence for holidays or the like	How many weeks during the last 12/6 months [depends on stage of survey] was no one of your household at home (because of holiday journeys or the like)?	_____ weeks [Please fill in.]
Migration background	Were you born in [country of the site]? If no: In which country were you born? When do you or does your family move into …?	☐ yes ☐ no _____ [Please fill in the country.] _____ [Please fill in the year.]

[15] in each case: gender and age of the respondent
[16] The age groups are taken from the EUROBAROMETER. They may differ from national statistics what may be a problem between the probable request for local comparability and a cross-project analysis.
[17] ditto

ASPECT	SUGGESTED WORDING OF QUESTIONS/OPTIONS	CHARACTERISTICS/VALUES
	Which language do you prefer getting the information of the tenant portal?	______ [Multiple answers shall be possible.]
Education level[18]	What is your highest level of education you have attained?	☐ no school-leaving qualification ☐ primary/secondary modern school leaving qualification ☐ secondary school leaving qualification ☐ university/university of applied sciences entrance qualification ☐ university/university of applied sciences degree ☐ doctorate
Predominant source of housing income	What is the predominant source of housing income?	☐ Income from employment/self employment ☐ Training/students' remuneration ☐ Unemployment benefits ☐ Social Aid[19] ☐ Support for elderly/for persons not able to work full time ☐ Pensions ☐ Maintenance paid by parents/marital partners ☐ Other ____ [Please fill in.]
Amount of the net household income per month[20]	Amount of the net household income per month/income classes: To which category does your household belong? Select one only. →compare to the national mean/median of household income in country; amount poverty level	☐ below 500 € ☐ 500 – below 900 € ☐ 900 – below 1,300 € ☐ 1,300 – below 1,500 € ☐ 1,500 – below 1,700 € ☐ 1,700 – below 2,000 € ☐ 2,000 – below 2,600 € ☐ 2,600 – below 3,200 € ☐ 3,200 – below 4,500 € ☐ 4,500 – below 5,500 € ☐ 5,500 € and above
in Germany:	Are your rent and running costs paid by the municipality?	☐ yes ☐ no
Internet access	Do you have a permanent access to internet? Multiple answers are possible.	☐ yes, at home ☐ yes, at the office ☐ yes, with a web-enabled device (e.g. mobile) ☐ no

[18] The education levels are taken from the German statistics. They probably will differ from other national statistics. That's why we suggest using the actual national typology. We assume that an allocation to the categories of the e.g. European Social Survey (ESS) shall be possible.

[19] Social aid and support for elderly. May be typical German transfer payments. The national equivalence at the other sites has to be considered.

[20] The income groups are taken from the German statistics (Statistisches Bundesamt, Mikrozensus). They probably will differ from other national statistics. A European-unique approach is not known. That's why we suggest using the actual national typology. Afterwards we shall be able to compare at least low income groups.

ASPECT	SUGGESTED WORDING OF QUESTIONS/OPTIONS	CHARACTERISTICS/VALUES
2 – ENERGY CONSUMPTION BEHAVIOUR		
Everyday behaviour pattern [all stages, all groups]	How do you act usually? For each select one only. a) Do you turn off the heating/the radiator when you open the windows? b) Do you turn the heating down when you leave a room unused? c) Do you turn the heating down when you leave your home for a longer time? d) Is your heating equipped with an automatic night setback? e) If you don't have a night setback: Is your temperature at night usually lower than by day? f) Do you switch off TV or other equipment when there is no one in the room for a longer time? g) Do you turn out the light when no one is in a room? h) In winter time: Do you mind to keep shut the windows and doors of the commonly used rooms of the tenement (in the basement, staircase, laundry, etc.)? i) Do you mind the energy consumption when you purchase new electric appliances? j) Do you separate your waste? k) Do you completely switch off an appliance with Stand by-function when you have finished using it? l) Do you rather take a shower instead of a bath? m) Do you use cold water to wash your hands? n) Do you wait until you have a full load before you use your washing machine or your dishwasher? o) …	☐ yes ☐ rather yes ☐ rather no ☐ no ☐ don't know
Changes in everyday behaviour pattern as a result of the use of the service [appropriate to the final survey of the exp. group]	<u>Option A (half-open question):</u> Did you change your everyday energy consumption behaviour as a result of the usage of the tenant portal? If yes, please give a short description. ______ <u>Option B (closed question):</u> Did you change any of these above mentioned behaviour patterns as a result of the usage of the provided tenant portal? If yes, which behaviour pattern did you change? Please use the alphabetic character from the question above.	☐ yes ☐ no ☐ don't know
Ventilation behaviour (winter) [all stages, all groups]	Does your home have a mechanical ventilation system (with heat recovery)?	☐ yes ☐ no ☐ don't know
	How do you usually ventilate your home in winter time or on colder days? For each select one only. a) living room b) bedroom c) kitchen d) bathroom e) other room (e.g. children's room)	☐ I open the windows widely at times. ☐ I leave the windows ajar at times. ☐ I leave the windows ajar often or all the times. ☐ I do not open the windows. ☐ don't know
Ventilation behaviour (summer)	Does your home have an air conditioning system?	☐ yes ☐ no ☐ don't know

ASPECT	SUGGESTED WORDING OF QUESTIONS/OPTIONS	CHARACTERISTICS/VALUES
[all stages, all groups]	If yes: How often do you use your air conditioning system in a hot summer?	☐ less than 1 hour a day ☐ 1-3 hours a day ☐ 4-8 hours a day ☐ more than 8 hours a day ☐ don't know
	How do you usually ventilate your home in summer time or on hot days? For each select one only. a) living room b) bedroom c) kitchen d) bathroom e) other room (e.g. children's room)	☐ less than 1 hour a day ☐ 1-3 hours a day ☐ 4-8 hours a day ☐ more than 8 hours a day ☐ don't know
Room temperature (winter) [all stages, all groups]	Option A: Which room temperature does your living room have in winter? Please fill in.	____ °C ☐ don't know
	Option B: Which room temperatures do you have in winter in much used rooms and in little used or unused rooms? Please fill in.	much used rooms: ____°C little used/unused rooms: ____°C ☐ don't know
Room temperature (summer) [all stages, all groups]	Option A: Which room temperature does your living room have in summer? Please fill in.	____ °C ☐ don't know
	Option B: Which room temperatures do you have in summer in much used rooms and in little used or unused rooms? Please fill in.	much used rooms: ____°C little used/unused rooms: ____°C ☐ don't know
3 – ATTITUDES AND KNOWLEDGE		
Norms (a-b), awareness (c-d), interests (e-f) attitudes (g-h) and perceived behavioural control (i-j) [all stages, all groups]	To what extent do you agree or disagree with the following statements? For each select one only. a) I think I should save more energy at home. b) My family or friends think that I should save more energy at home. c) In my opinion protecting the environment is a very important issue. d) To ensure the decrease of carbon dioxide emissions is important for the protection of the environment. e) I'm interested in my energy consumption at home. f) I'm interested in possibilities of saving energy at home. g) Energy conservation means I have to live less comfortably. h) Energy conservation will restrict my freedom. i) I can reduce my energy use quite easily. j) I know how I can save energy.	☐ I strongly agree. ☐ I rather agree. ☐ I neither agree nor disagree. ☐ I rather disagree. ☐ I strongly disagree. ☐ don't know
Motivation [all stages, all groups]	Which motivates you more to save energy – saving money or protecting the environment?	☐ solely to save money ☐ save money more than protect the environment ☐ both equally ☐ protect the environment more than save money ☐ solely to protect the environment

ASPECT	SUGGESTED WORDING OF QUESTIONS/OPTIONS	CHARACTERISTICS/VALUES
Information level about… [all stages, all groups]	How informed do you feel about… a) the possibilities to protect the environment b) the consumption of heat energy/water/power in your home? c) the possibilities of saving heat energy/water/power in your home?	☐ I feel very well informed. ☐ I feel fairly well informed. ☐ I feel neither well nor badly informed. ☐ I feel fairly badly informed. ☐ I feel very badly informed. ☐ don't know
Knowledge acquisition [all stages, all groups]	If you want to learn more about your energy consumption and the possibilities to save energy in your home, what kind of information would be useful for you in general? a) Your current energy consumption figures? b) Your energy consumption in comparison with the average consumption of the building/neighbourhood? c) The development of your energy consumption figures in comparison with previous years? d) Your energy costs? e) Energy saving tips? f) …	☐ yes ☐ rather yes ☐ rather no ☐ no ☐ don't know
4 – USER ACCEPTANCE CONCERNING THE PROVIDED ENERGY AWARENESS SERVICE (EAS)		
Interest in a tenant portal (prior to the implementation of a tenant portal) [appropriate to the baseline stage of the tenant survey; addressed all tenant groups	If your housing provider offers a tenant portal which gives you an exact overview of your home's current consumption of energy and hints about how to save energy would you be interested?	☐ yes ☐ rather yes ☐ rather no ☐ no ☐ don't know
	Do you think you would be likely or unlikely to regularly use such a tenant portal?	☐ likely ☐ fairly likely ☐ fairly unlikely ☐ unlikely ☐ don't know
Expectations concerning a tenant portal [appropriate to the baseline stage of the tenant survey; addressed all tenant groups	To what extent do you agree or disagree with the following statements? For each select one only. a) By using such a/the tenant portal I expect a significant reduction (at least 5 %) of my heat energy consumption. b) By using such a/the tenant portal I expect a significant reduction (at least 5 %) of my electricity consumption. c) By using such a/the tenant portal I expect a significant reduction (at least 5 %) of my water consumption. d) By using such a/the tenant portal I expect a significant reduction (at least 5 %) of my energy or water costs.	☐ I strongly agree. ☐ I rather agree. ☐ I neither agree nor disagree. ☐ I rather disagree. ☐ I strongly disagree. ☐ don't know
Frequency of usage [appropriate to mid-term and final stages of the tenant survey; addressed to tenants of the experimental group]	Portal users: How often do you log in this energy portal usually? Select one only.	☐ several times a day ☐ once a day ☐ several times a week ☐ once a week ☐ several times a month ☐ once a month ☐ at least quarter-annually ☐ at least semi-annually ☐ less frequently ☐ never ☐ don't know

ASPECT	SUGGESTED WORDING OF QUESTIONS/OPTIONS	CHARACTERISTICS/VALUES
Usefulness of various kinds of data and information of the EAS [appropriate to mid-term and final stages of the tenant survey; addressed to tenants of the experimental group]	To what extent you find the data and information presented in the tenant internet portal useful in your daily life? For each select one only. a) Current consumption figures, if applicable real-time consumption figures • heating • electricity • cold water • hot water • gas b) Current energy cost figures • heating • electricity • cold water • hot water • gas c) Average consumption of the settlement/building/neighbourhood d) Consumption history over several time periods, if applicable previous day, week, month, year e) Room temperature f) Tips for a heat energy saving behaviour g) Tips for a water saving behaviour h) Tips for a electricity saving behaviour i) Time-programming heating device j) Personal setting of benchmarks k) Personal setting of alerts l) Self-assessment-tool, energy quiz m) …	☐ Very useful. ☐ Rather useful. ☐ Neither useful nor useless ☐ Fairly useless ☐ Very useless ☐ don't know
Satisfaction with the EAS in general [appropriate to mid-term and final stages of the tenant survey; addressed to tenants of the experimental group]	Are you satisfied with the service in general? Select one only.	☐ I'm very satisfied. ☐ I'm fairly satisfied. ☐ I'm neither satisfied nor dissatisfied. ☐ I'm fairly dissatisfied. ☐ I'm very dissatisfied. ☐ don't know

ASPECT	SUGGESTED WORDING OF QUESTIONS/OPTIONS	CHARACTERISTICS/VALUES
Satisfaction with the EAS in detail [appropriate to mid-term and final stages of the tenant survey; addressed to tenants of the experimental group]	Are you satisfied with… a) the clarity of the provided information? b) the comprehensibility of the provided consumption data? c) the amount of information? d) the manageability/ease of use of the tenant portal? e) the confidentiality? f) …	☐ I'm very satisfied. ☐ I'm fairly satisfied. ☐ I'm neither satisfied nor dissatisfied. ☐ I'm fairly dissatisfied. ☐ I'm very dissatisfied. ☐ don't know
Intentions motivated by the usage of the portal [appropriate to mid-term and final stages of the tenant survey; addressed to tenants of the experimental group]	Thinking of the provided tenant portal… a) would you say, that you are now more interested in energy saving issues? b) would you say that you now know more about your energy consumption at home? c) did you keep an eye on your energy consumption? Do you intend to conserve heat energy next winter? Do you intend to conserve electricity/water… in the future?	☐ yes ☐ rather yes ☐ rather no ☐ no ☐ don't know
Reasons for using the EAS [appropriate to mid-term and final stages of the tenant survey; addressed to tenants of the experimental group]	Why you use the tenant portal? To what extent do you agree or disagree with the following statements? For each select one only. a) I would like to reduce my energy consumption permanently. b) I would like to know more about my energy consumption. c) I would like to keep an eye on my energy costs. d) I would like to reduce my energy costs. e) I would like to control my annual energy bill. f) I would like to receive advices in order to act in a more energy saving way. g) I would like to know more about how my energy consumption is changing in the course of time. h) I would like to know more about how my energy consumption is changing in comparison with other tenant households. i) … j) Other, namely ____________	☐ I strongly agree. ☐ I rather agree. ☐ I neither agree nor disagree. ☐ I rather disagree. ☐ I strongly disagree. ☐ don't know
5 – SPECIFIC QUESTIONS FOR PASSIVE USERS: INTEREST IN THE SERVICE AND REASONS FOR NON-USAGE		

ASPECT	SUGGESTED WORDING OF QUESTIONS/OPTIONS	CHARACTERISTICS/VALUES
Interest in energy saving issues in general [appropriate to mid-term and final stages of the tenant survey; addressed to the passive users]	Are you interested in information about energy consumption issues? Are you interested in information about the possibilities of saving energy in your home? [if above chapter 3. is not appropriate]	☐ I'm very interested. ☐ I'm fairly interested. ☐ I'm neither interested nor uninterested. ☐ I'm fairly uninterested. ☐ I'm very uninterested. ☐ don't know
	Where do you prefer getting the information from? Multiple answers are possible.	☐ Governmental organisation ☐ Other institutions (e.g. environmental organisations, research institutions) ☐ Landlords, housing provider ☐ Internet ☐ TV ☐ Newspapers, Magazines ☐ Information brochures ☐ other ☐ …
Interest in the offered EAS [appropriate to mid-term and final stages of the tenant survey; addressed to the passive users]	Your housing provider offers a tenant portal which gives you an overview of your home's current consumption of heating and energy and hints about how to save energy. Did you already hear about that?	☐ yes ☐ no ☐ don't know
	Are you interested in the usage of that tenant portal?	☐ yes ☐ no ☐ don't know

ASPECT	SUGGESTED WORDING OF QUESTIONS/OPTIONS	CHARACTERISTICS/VALUES
Reasons against the usage of the tenant portal [appropriate to mid-term and final stages of the tenant survey; addressed to the passive users]	If no: What is to be said against the usage of the tenant portal? To what extent do you agree or disagree with the following statements? For each select one only. a) I'm not interested in the issue of energy saving. b) I'm not interested in Internet. c) I prefer information concerning my energy consumption on paper. d) I know enough about my energy consumption and need no further information. e) I have no way of using the Internet. f) The annual energy bill is sufficient for me. g) I use alternative channels in order to learn more about energy saving issues. h) I don't know how the tenant portal works. i) The usage of the tenant portal is too time-consuming. j) The cost I have to pay for the service is too high. k) I have concerns about the confidentiality of my private data. l) … m) Other, namely ____________________	☐ I strongly agree. ☐ I rather agree. ☐ I neither agree nor disagree. ☐ I rather disagree. ☐ I strongly disagree. ☐ don't know

Concerning the equipment and usage of electrical appliances the suggested operationalisation of 3E-Houses (see following subchapter; impact questionnaire D) was recommended for using in eSESH.

Best analysis results could be reached:

- if attitudinal and behavioural characteristics of the involved pilot households as well as metered consumption data of both experimental and control group will be compared directly for baseline and reporting periods,
- if groups with different socio-demographic and user characteristics will be compared and
- if the frequency of tenant portal use will be metered on the basis of portal log-ins.

3.4 Evaluation of social and behavioural changes in 3e-Houses – a longitudinal two-stage design

The following methodology is designed to evaluate social and behavioural changes resulting directly from the implementation of energy monitoring and energy management through ICTs. The impact assessment covers four key topics:

1. *Socio-economic level* of the tenants will be an important variable in the analysis of the socio-economic impact of ICT. A questionnaire of socio-economic level will be handed out to tenants at the very beginning of the project[21]. Several analyses will be carried out:
    - Evaluation of indicators for energy savings versus socio-economic status (analysis of the social and/or economic variables which are most influential)
    - Evolution of indicators for energy savings versus nationality (analysis of different nationalities with similar socio-economic levels)
    - Evolution of indicators for energy savings versus cost of energy (tenant savings as a function of cost of energy and their link with rent level and the socio-economic level of the tenants)

2. In addition to that participants will be asked to complete a questionnaire to evaluate their physical and mental *perception of comfort*. This questionnaire will be circulated at the end of the pilots/replication to the tenants. The aims of the questionnaire are to create indicators to compare the comfort perception of the tenants about ICT solution and to know the features more appreciated within the ICT solution deployed. Physical comfort can be defined as a specific status of the human body related to overall positive perception of the closest surrounding material (physical) environment. Physical comfort is a compound result from two main aspects:

    - The health and physiological condition of the person under question
    - The closest physical environment of the person under question

    There is a need for a question to determine psychological comfort specifically with;

    - The automated actions of the system (i.e. lights turning off without intervention)
    - The level of monitoring, modelling and archiving of activity data of individuals/ households

    There might also be a more general question to determine whether the presence of the ICT at close quarters, in the domestic setting has had a broader impact on reducing levels of nervousness or discomfort (technophobe) around any ICT.

    The closest physical environment will be investigated because of the assumption that the general health of our participants is a variable outside of our consideration. It is defined by:

    - Temperature of the closest environment
    - Humidity of the closest environment

[21] Data from two partners were already available.

- Air flows within the closest environment
- The availability of light in the closest environment
- The space availability of the closest environment (space is a relevant variable as the ICT occupy part of peoples living area - i.e. display screens, sensors -or may inhibit access or movement in that area – i.e. trailing wires or cables)

3. The aim of a third questionnaire regarding *perceived usability/usefulness of ICT solution* is:
   - To know the most useful features of the ICT solution: electricity information, thermal energy information, automation…
   - To know the most useful user interface: display/web/sms
   - To know which user interface were most frequently used: display/web/sms
   - To know which user interface was the easiest to use: display/web/sms.

   This questionnaire will be defined and conducted at the end of the pilots/replication with the tenants.

   The usability of a system refers to the ease with which users can interact with, and understand a system, to efficiently achieve their desired goals and actions, so it is focussed on the user specific experiences of operation of the ICT solution rather than the general sense of benefit from adding ICT to their environment.

   Perceived usefulness of ICT solution is actually experienced advantage by use of various ICT devices compared to prior situation (before implementation of pilots).

4. In order to measure and evaluate *tenant behaviour* and their evolution during the project will be developed a questionnaire regarding behaviour changes in energy use and habits. The aim of the questionnaire is to evaluate the impact of the information provided via the system on energy behaviour: heating use and control, air conditioning use and control, DHW and Cold water use and control, appliances usage level/retrofitting. Tenants' behaviours will be evaluated with two questionnaires:

   1. The first questionnaire will be handed out to tenants during the engagement campaign. This will generate the Baseline assessment.
   2. At the end of the project a final questionnaire will be circulated to tenants to determine their progress.

The evaluation of social impact will be measured quantitatively as well as qualitatively. The variables with measurable impact in quantities are all analyses described in first key topic (socio-economic level). All three further key topics are variables with qualitative impact.

The following table 3-2 contains all four impact questionnaires.

Table 3-2 – Overview of four impact questionnaires in 3e-Houses

Operationalisation of tenant survey

Impact questionnaire A: Socio-economic level

A1.- Sex of the Interviewee

- Man
- Woman

A2.- Are you the main income contributor of your family?

- Another person is the main income contributor
- Interviewee is the main income contributor

A3.- What is the main supporter's age?

(TO BE ASKED ONLY IF INTERVIEWEE IS NOT the main supporter of the family)

A4 How many children under eighteen live in your home?

- None (Go to C6)
- One
- More than one

(To be asked to all interviewees)

A5.- If one: Specifically, how old is this child? If more than one, how old is the youngest child living in your home?

(If there are children in your home)

A6.-.-Level of education of interviewee and of the person providing more income.

- Below elementary education
- Elementary education completed
- Compulsory Secondary education
- GCSE (High School certificate)
- Associate degree or Senior degree Technician
- Bachelor of Science
- Master of Science
- Doctorate

(TO BE ASKED TO ALL INTERVEWEES)

A7.- Work of the interviewee and of the main income provider of the family

- . Employed
- . Unemployed who has worked before
- . Unemployed First employment seeker
- . Jubilee/Retired
- . Student
- . Housewife/husband

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A8.- Activity of the interviewee and of the main income provider of the family (*)

- Self-employed / freelance
  - Member of an Agricultural /non Agricultural cooperative/society
  - Agricultural businessman/woman without employees
  - Agricultural businessman/woman (1 to 5 employees)
  - Agricultural businessman/woman (6 or more employees)
  - Businessman/woman / shopkeeper without employees
  - Businessman/woman / shopkeeper without employees (1 to 5 employees)
  - Businessman/woman / shopkeeper without employees (6 or more employees)
  - Liberal Professional (physician, lawyer…)
  - Manual labourer (builder, plumber…)
- Employed by third-party
  - Director / Member of Board (25 employees or more)
  - General Manager (companies below 25 employees)
  - High level post (private enterprise)/ (HHRR Manager …)
  - Intermediate post (private enterprise) / (Chief, Skilled worker ...)
  - Foreman-woman/ Person in charge / Army Non-commissioned officer
  - Agents: trade, sales, artists …
  - Administrative assistant, clerk
  - Specialized worker / Policeman-woman
  - Shop assistant
  - Unskilled labourer / Housework services
  - Subordinate employee (Caretaker, receptionist ...)
  - Other unskilled professional
  - Agrarian day labourer

(If they are employed or have been employed before)

A9. - Do you have a second dwelling to spend your vacation or to go over the weekend?

- Yes
- No

A10. - Proportion of their total monthly income they spend on energy? __________

Impact questionnaire B: Comfort perceived

B.1. How comfortable where you with the automatic actions the system enacted?

Scale: 1 2 3 4 5 *(Where 1 is more uncomfortable, 3 is the same and 5 more comfortable)*

- B.1.1. Home temperature control (in pilots with temperature control)
- B.1.2. Home humidity control (in pilots with humidity control)
- B.1.3. Hot water control (in pilots with hot water control)
- B.1.4. Air flow control (in pilots with air flow control)
- B.1.5. Lighting control (in pilots with lighting control)
- B.1.6. Appliances control *(in pilots with appliance control)*
- B.1.7. Actuators (others) *(if applicable)*

B.2. To what extent did the location of these ICT devices affects your immediate environment?

Scale: 1 2 3 4 5 *(Where 1 is affect a lot and 5 not affect)*

Operationalisation of tenant survey

B.3. What features of the system did you most?

Scale: 1 2 3 4 5 *(Where 1 is not appreciated and 5 very appreciated)*

- B.3.1. Temperature control *(in pilots with temperature control)*
- B.3.2. Humidity control *(in pilots with humidity control)*
- B.3.3. Hot water control *(in pilots with hot water control)*
- B.3.4. Air flow control *(in pilots with air flow control)*
- B.3.5. Lighting control *(in pilots with lighting control)*
- B.3.6. Appliances control *(in pilots with appliance control)*
- B.3.7. Actuators (others) *(if applicable)*
- B.3.7. Ecopoints
- B.3.8. Energy information (consumption)
- B.3.9. Energy comparatives (with your neighbours, country …)
- B.3.9. Energy advice (about how to save energy)

B.4. How comfortable where you with the technology deployed?

Scale: 1 2 3 4 5 (Where 1 is less comfortable, 3 same comfortable and 5 more comfortable)

- B.4.1. At your home
- B.4.1. With your heating system
- B.4.1. With your air conditioning system
- B.4.1. With your hot water system
- B.4.2. In communal areas (*if applicable*)

B.5. Did you attempt to over-ride any of the automated actions?

- ☐ Yes
- ☐ No

If so please explain how?____________________

Impact questionnaire C: Usability/usefulness of ICT solution

C.1 How important was the information presented to you in order to help you to understand your energy consumption?

Scale: 1 2 3 4 5 *(Where 1 is unimportant and 5 is very important)*

- C.1.1. Consumption of electricity
- C.1.2. Consumption of gas
- C.1.3. Consumption of heating energy (in pilots with thermal energy sales: for example in case of district heating system or community boiler)
- C.1.4. Consumption of hot water (in pilots with thermal energy sales: for example in case of district heating system or community boiler)
- C.1.5. Produced hot water with renewable energy (in pilots with solar collectors installed)
- C.1.6. Produced electricity with renewable energy (in pilots with photovoltaic installed)
- C.1.7. humidity status (in pilots with humidity status information)
- C.1.8. Temperature status (in pilots with temperature status information)

C.2. Usability of interfaces (user friendly rate):

Scale: 1 2 3 4 5 *(Where 1 is unfriendly and 5 very friendly)*

- C.2.1 User display
- C.2.2 User web
- C.2.3. User sms messaging

Operationalisation of tenant survey

C.3. Frequency of use of interfaces

- C.3.1 User display
  - ☐ Several times a day
  - ☐ 1 time per day
  - ☐ Several times a week
  - ☐ 1 time a week
  - ☐ Several times a month
  - ☐ 1 per month
  - ☐ Less than 1 time per month
- C.3.2 User web
  - ☐ Several times a day
  - ☐ 1 time per day
  - ☐ Several times a week
  - ☐ 1 time a week
  - ☐ Several times a month
  - ☐ 1 per month
  - ☐ Less than 1 time per month
- C.3.3. User sms messaging
  - ☐ Several times a day
  - ☐ 1 time per day
  - ☐ Several times a week
  - ☐ 1 time a week
  - ☐ Several times a month
  - ☐ 1 per month
  - ☐ Less than 1 time per month

C.4. What interface is easier to use?

scale: 1 2 3 4 5 *(Where 1 is difficult and 5 very easy)*

- C.4.1 display
- C.4.2 web
- C.4.3. sms messaging

C.5. How clear was the information presented to you about your energy consumption?

Scale: 1 2 3 4 5 *(Where 1 is unclear and 5 very clear)*

C.6. How obvious were the actions you could take to reduce your energy consumption?

Scale: 1 2 3 4 5 *(Where 1 is unclear and 5 very clear)*

C.7. How straightforward was it to understand how to operate the system?

Scale: 1 2 3 4 5 *(Where 1 is complicated and 5 very straightforward)*

C.8.How far do you feel the system has helped you to be aware of and reduce your [energy] consumption?

Scale: 1 2 3 4 5 *(Where 1 is not useful and 5 very useful)*

C.9. How much of effort was required to operate the system satisfactorily?

Scale: 1 2 3 4 5 *(Where 1 is considerable effort and 5 minimal efforts)*

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C.10. How accurate do you feel the information presented by system was?

Scale: 1 2 3 4 5 *(Where 1 is highly inaccurate and 5 highly accurate)*

C.11. How often did you experience technical problems with the system?

Scale: 1 2 3 4 5 *(Where 1 is frequently and 5 never)*

C.12. How much control of your environment and energy use did you feel the system gave you?

Scale: 1 2 3 4 5 *(Where 1 is minimal control and 5 considerable controls)*

Impact questionnaire D: Energy Behaviour

D.1. Heating system central distribution.

- Do you close the valves on the radiators in those rooms that you do not use?
  - YES NO
- Standard Temperature setting in winter (ºC):
  - <20ºC 20-24ºC >24ºC
- Do you switch off/turn down the thermostat at night?
  - YES NO
- Temperature the thermostat lowered to (ºC):
- Timetable: the system is running with different temperatures:
  - < 20ºC 20-24ºC >24ºC
  - Number of Hours__________

D.2. Air conditioning (cool) system

- Standard Temperature setting in summer (ºC):
- Timetable the system is running with different temperatures:
  - < 22ºC 22-25ºC >25ºC
  - Number of Hours__________

D.3. DHW production

- Standard Temperature setting DHW (ºC):

D.4. Lighting

- Cleaning of bulbs: YES NO

Operationalisation of tenant survey

D.5. Appliances

Freezer

- Times per day that opens the Fridge:

Washing machine

- Washing use: Standard program short medium large
- Duration washing program (minutes):
- Washing Program Temperature (ºC):
- Scheduling full load or half load: Full Half It depends

Dryer use

- Duration drying time (minutes):

Dishwasher

- Temperature program (ºC):
- Usual program Short medium large
- Duration washing program (minutes):
- Full or partial load to wash: Full Partial

Microwave

- Micro Wave is used for: Cook Thaw

Oven

- Oven is used for: Cook Thaw

TV

- Use the Standby YES Switch off during the night NO

DVD

- Use the Standby YES Switch off during the night NO

HOME CINEMA

- Use the Standby YES Switch off during the night NO

APPLIANCE CONSOLE (WII, PLAY STATION)

- Use the Standby YES Switch off during the night NO

PC

- Use the Standby: YES Switch off during the night NO

HIFI equipment

- Use the Standby: YES Switch off during the night NO

Have you changed any of the appliances for more efficient ones during the timeframe of this pilot?

- YES Which ones?
- No

D.6. Water

- Double flushing device toilet cisterns YES NO
- Low-flow showerhead: YES NO

*(*)**Note**:* For British replication the clearest and most intuitive employment definitions for UK participants are those from the NS-SEC. In order to obtain usable data for the UK, this replication will use these definitions. The employment categories for UK participants are:

- Modern professional occupations [such as: teacher - nurse - physiotherapist - social worker - welfare officer - artist - musician - police officer (sergeant or above) - software designer]
- Clerical and intermediate occupations [such as: secretary - personal assistant - clerical worker - office clerk - call centre agent - nursing auxiliary - nursery nurse]
- Senior managers or administrators [(usually responsible for planning, organising and co-ordinating work and for finance) such as: finance manager - chief executive]
- Technical and craft occupations [such as: motor mechanic - fitter - inspector - plumber - printer - tool maker - electrician - gardener - train driver]
- Semi-routine manual and service occupations [such as: postal worker - machine operative - security guard - caretaker - farm worker - catering assistant - receptionist - sales assistant]
- Routine manual and service occupations [such as: HGV driver - van driver - cleaner - porter - packer - sewing machinist - messenger - labourer - waiter / waitress - bar staff]
- Middle or junior managers [such as: office manager - retail manager - bank manager - restaurant manager - warehouse manager - publican]
- Traditional professional occupations [such as: accountant – solicitor medical practitioner - scientist - civil / mechanical engineer]
- The equivalent job roles between those used in the UK replication and other European partners are:

European Role Description	UK Equivalent
Self-employed / freelance	
Member of an Agricultural /non Agricultural cooperative/society	Semi-routine manual and service occupations
Agricultural businessman/woman without employees	Semi-routine manual and service occupations
Agricultural businessman/woman (1 to 5 employees)	Middle or junior managers
Agricultural businessman/woman (6 or more employees)	Middle or junior managers
Businessman/woman / shopkeeper without employees	Middle or junior managers
Businessman/woman / shopkeeper without employees (1 to 5 employees)	Middle or junior managers
Businessman/woman / shopkeeper without employees (6 or more employees)	Middle or junior managers
Liberal Professional (physician, lawyer, ...)	Traditional professional occupations
Manual labourer (builder, plumber, ...)	Technical and craft occupations
Employed by third-party	
Director / Member of Board (25 employees or more)	Senior managers or administrators
General Manager (companies below 25 employees)	Senior managers or administrators
High level post (private enterprise)/ (HHRR Manager, …)	Senior managers or administrators
Intermediate post (private enterprise) / (Chief, Skilled worker, ...)	Middle or junior managers
Foreman-woman/ Person in charge / Army Non-commissioned officer	Middle or junior managers
Agents: trade, sales, artists …	Modern professional occupations
Administrative assistant, clerk	Clerical and intermediate occupations
Specialized worker / Policeman-woman	Modern professional occupations
Shop assistant	Routine manual and service occupations
Unskilled labourer / Housework services	Routine manual and service occupations
Subordinate employee (Caretaker, receptionist, ...)	Clerical and intermediate occupations
Other unskilled professional	Routine manual and service occupations

4 Further information

4.1 Comparison between pilot results in different EU member states

Quantified comparisons between pan-European projects implicitly have to take into account that divergences in regulations of the participant member states or differences in the characteristics of the service provided by landlords to their tenants itself may exist. For example:

- In France, the comfort inside temperature is statutorily set at 19 °C, but landlords could increase the inside temperature to more than 19 °C (20 °C, 21 °C).
- In Germany, predominantly each radiator is equipped with thermostatic valves, so that tenants can adjust their room temperatures individually. Accordingly, one dwelling may differ from another and broad ranges of indoor temperatures people feel comfortable with are identifiable.

At first view on a building scale, outdoor temperature and consumption figures may appear uniformly, but they can imply differences in inside temperatures as a consequence of differences in the energy performance of the building. That becomes important when quantifying (behaviour-related) energy saving capabilities.

4.2 Understanding user behaviour

When carrying out interventions which aim at significant reductions of energy consumption and CO_2-emissions in the residential sector the inclusion of the resident's resp. – in the present case – tenant's perspective shall be mandatory. On the one hand tenants play an important role in the achievement of energy saving targets by accepting retrofitting measures, by using awareness services, by renting energy efficient flats, etc. On the other hand the consideration of user requirements and user demands in an impact analysis of instruments or measures delivers important information for optimisation. A profound knowledge of the target group makes the exploration of that topic easier. That's why the following chapter tries to sketch a general background of which has to be considered when planning a tenant evaluation approach.

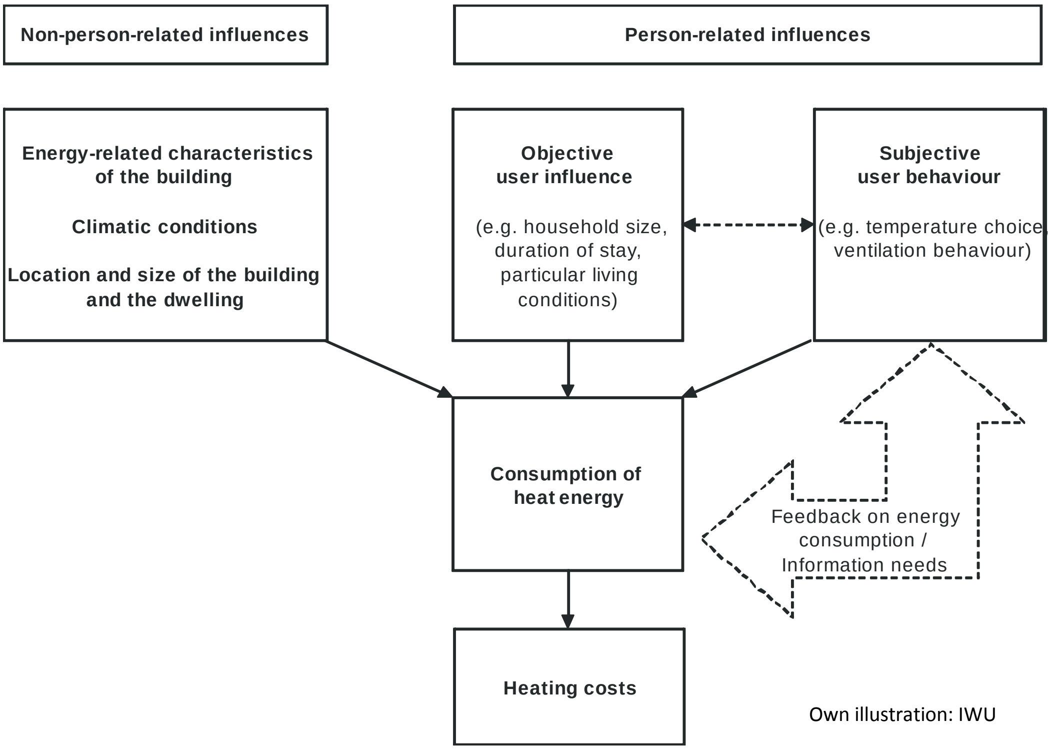

Figure 4-1 – Non-person-related and person-related influences using the example of heat energy consumption

The energy consumption of private households depends on two drivers – non-person-related and person-related influences. Using the example of heat energy, the non-person-related factors are the energetic characteristics of the building (type of heating, insulation, glazing, etc.), the climatic conditions and the orientation and the size of the building and the particular dwelling in it. Person-related factors are the user influence such as household size (Lives there a one-person household or an extended family?), the duration of stay/occupancy (Lives there a full-time employed person or a pensioner?) or the individual living situation (Live there people with special heat demand like babies or elderly persons?). The second important person-related influence is the user behaviour such as temperature choice or ventilation behaviour.

From a psychological point of view the behaviour-related energy use is shortly categorised as a triangle between economic considerations on the one hand, values, attitudes and norms on the other hand and practical daily life as a third aspect. All three factors are closely connected and overlap one another.[22]

[22] cf. Berker (2008). Energienutzung im Heim als soziotechnische Praxis – Energy use at home as socio-technical practice. In: Fischer (ed.). Strom sparen im Haushalt – Electricity saving at home. München. 175-192, p. 179.

Figure 4-2 – Triangle of psychological influences on behaviour-related energy use

Cost-benefit-reflections include not only monetary considerations, but imply further aspects like economy of time, ease of everyday routine or standard of living.

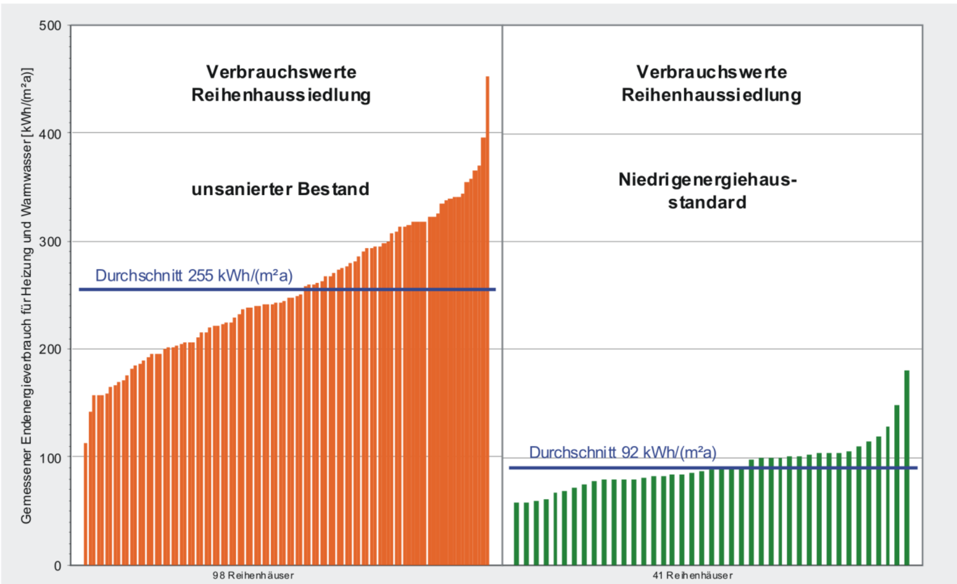

Figure 4-3 – Person-related variances in heat consumption figures of not renovated and low energy terraced houses[23]

Both facets – user influence and user behaviour – can lead to big differences in energy consumption figures metered in identically constructed houses. A number of empirical studies demonstrated such results. For example, figure 4-3 compares the heat energy consumption in 98 not renovated terraced houses (left hand side) and 41 low-energy-houses (right hand side). The big impact of the thermo-technical quality of a building is to be seen as expected. However, there also can be identified broad variances in consumption figures of different households in mostly identical buildings which are – independently from energetic building standards – based on user influences and user behaviour. Another example in figure 4-4 shows variations in heat energy (blue marked) and hot water

[23] Source: Loga et al. (2007).). Querschnittsbericht: Energieeffizienz im Wohngebäudebestand – Cross section report: Energy efficiency in the residential building stock. Studie im Auftrag des VdW südwest e.V. Darmstadt: IWU.

consumption (red marked) of 28 households referred to the average consumption based on a one-year measurement. It shows that high heat energy consumption is not necessarily attended by high hot water consumption and vice versa. Therefore, the energy saving potential of different households is related to different energy types and can additionally differ within the family. Different people prefer different room temperatures, which often depend on the room use too. The same applies to ventilation behaviour or (hot) water consumption.

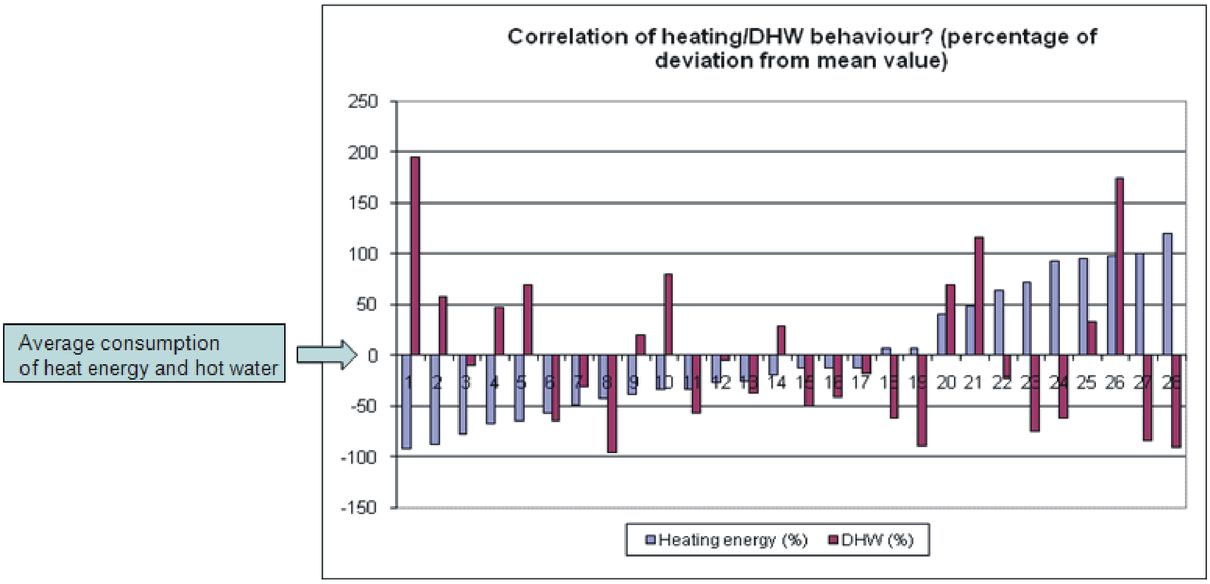

Figure 4-4 – Deviation from the average consumption of heat energy and hot water of 28 households in %[24]

Concerning electricity can be observed that especially the degree of equipment with entertainment electronics, information and communication technologies increased permanently (see a German example in figure 4-5). The constant rising tendency describes an international trend as figure 4-6 shows. The level of power consumption depends on user influences (e.g. equipment characteristics and operations of electrical appliances, purchase behaviour concerning new acquisitions) again and varies when comparing similarly sized households.

[24] Source: SAVE@Work4Homes, Deliverable 6.3, 2009, p17

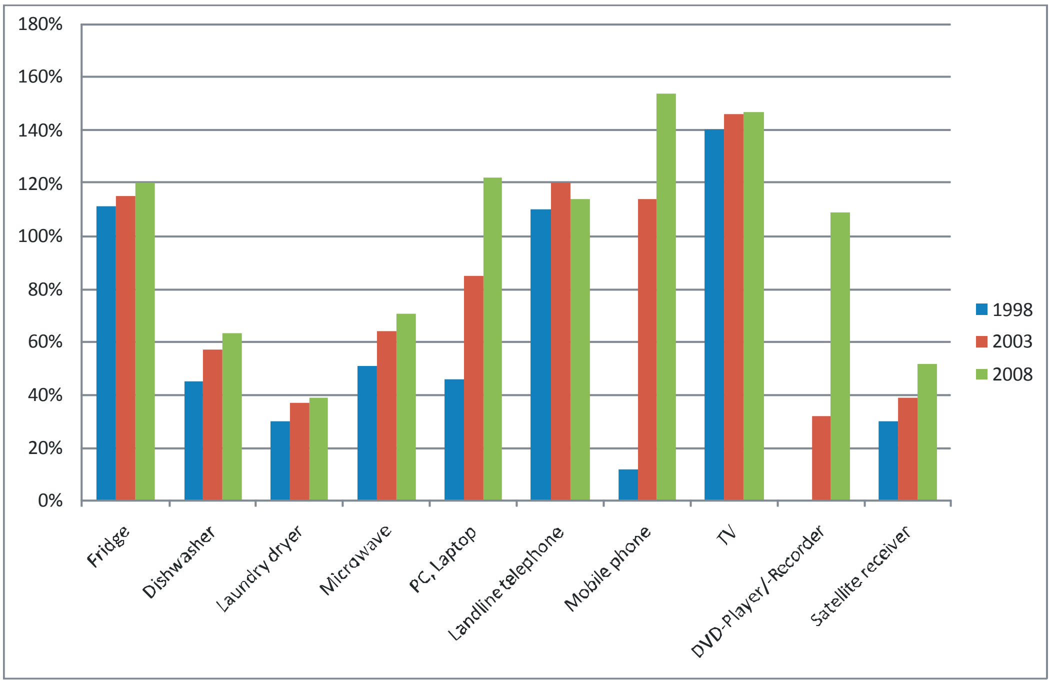

Figure 4-5 – Changes in equipment stock of selected electrical appliances of German households from 1998 to 2008[25]

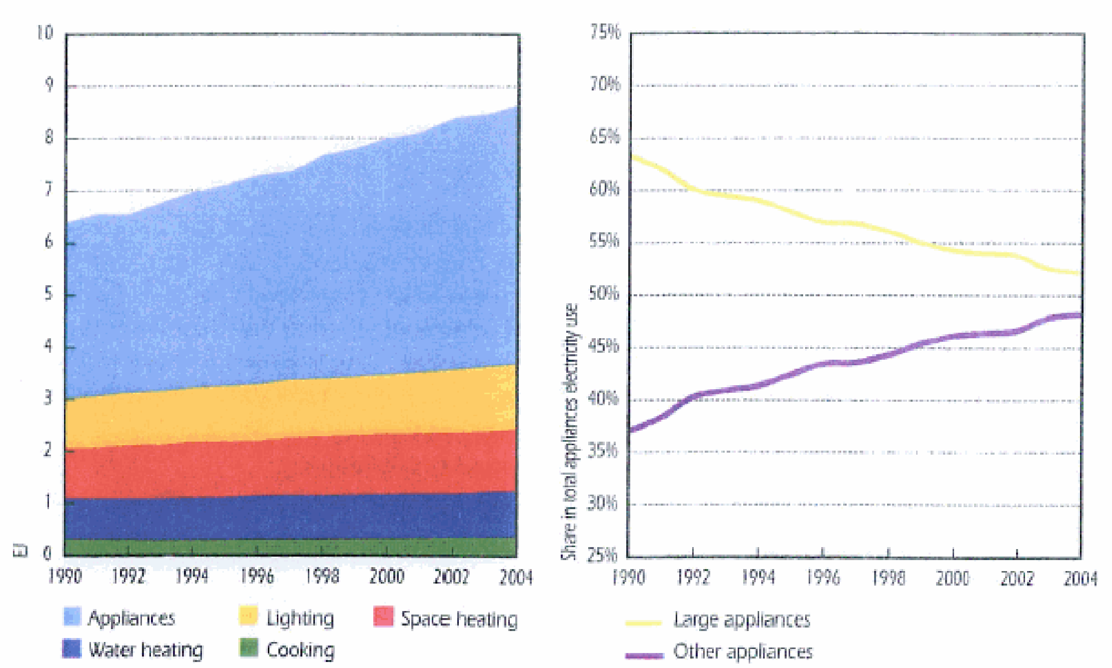

Figure 4-6 – Household electricity demand by end-use and the role of appliances[26]

[25] Statistisches Bundesamt – Federal Statistical Office (2008). Fachserie 15 Heft 1. Einkommens- und Verbraucherstichprobe. Ausstattung privater Haushalte mit ausgewählten Gebrauchsgütern – Sample survey of income and expenditure. Equipment of private households with selected consumer goods. Wiesbaden.

[26] Source: OECD, IEA (2007). Energy Use in the New Millenium. Paris: International Energy Agency, p70. (in relation to IEA15: Austria, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, UK, USA)

In order to answer the question, when such variances describe a waste of energy (which implies high energy saving potential) and when it is a justified increased consumption because of special energy needs of the household (which implies a low energy saving potential), an in-depth investigation of target groups (e.g. tenant groups with different socio-demographic characteristics) is necessary.

Aimed at energy saving in the residential sector another problem seems to be that most people have only an inexact idea of how much energy they are using for different purposes and what sort of difference they could make by changing day-to-day behaviour.[27] In addition to that, most people are not self-motivated for dealing with energy saving issues. To encourage them is a difficult task by above described reason of individual attitudes and comfort levels. Furthermore it has to be taken into account that energy consumption behaviour is an automatic behaviour. Once learnt, people do not pay much or special attention on it. Energy use takes place more or less habitually.[28] To change energy consumption behaviour implies that first of all behavioural routines have to be cracked in order to make them aware. Behaviour influencing factors can be one of three types of factors:

1. Motivating factors are individual, internal drivers of behaviour. These factors are awareness, knowledge, social influence, attitude, perceived capabilities and intention. For people to intentionally change their energy behaviour, they must become aware of their energy use, pay notice to it, and be informed about the consequences. They must then be motivated to use the available information and instruments to control their energy use. Approaches in order to achieve higher motivation are to get in touch with the target groups at an early stage of the project – for example in the form of information events, workshops or trainings.
2. Reinforcing factors are those consequences of actions that give individuals positive or negative feedback for continuing their behaviour. These include information about the impacts of past behaviour (e.g., lower energy bill), feedback of peers, advice, and feedback by powerful actors.
3. Enabling factors are the external constraints on behaviour. These factors allow new behaviour to be realised.

From a psychological point of view there are four aspects relevant in order to raise the motivation to save energy:[29]

1. Strengthening of awareness and attention regarding the possibilities of saving energy
2. Accentuation of possibilities of saving energy without comfort losses
3. Improvement of knowledge concerning complex consumption-related interrelations at home
4. Consideration of social comparison, for example in neighbourhoods

Consumption feedback strategies (e.g. tenant portals) enable users to get a better knowledge about their energy consumption at home. Smart metering technologies allow well-illustrated feedback of

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[27] e.g. Darby (2006). The effectiveness of feedback on energy consumption. University of Oxford: Environmental Change Institute.

[28] e.g. Bargh (1996). Automaticity in social psychology. In: Higgens & Kruglanski (ed.) Social psychology: Handbook of basic principles. New York, 169-183, p172.

[29] Wortmann (1994). Psychologische Determinanten des Energiesparens – Psychological determinants of saving energy. Weinheim: Psychologie Verlags Union.

consumption-periods of less than a year with historical (previous periods), comparative and normative comparisons (average consumption of the building, the neighbourhood, similar households, etc.). In addition to that most of the tenant portals provide further information on energy consumption issues, energy saving tips and tools which allow a self-assessment of someone's current energy consumption behaviour or a personal benchmarking and alert system. Based on that tenants can learn to act in a more energy conscious way.

An expensive, but in parallel very successful strategy in combination with consumption feedback approaches are on-site advisory services provided by an energy consultant or the like. That means, an energy consultant calls on a tenant in the tenant's home, analyses the energy consumption of the tenant's specific living situation and equipment and gives hints of how to save energy in that special case. Results of the evaluation of the German CARITEAM project showed that on an annual average savings of 16 % electricity, 22 % water and 4 % heat energy could be achieved. Participants of that project were permanently unemployed persons and welfare recipients.[30]

Of interest in that context are two main questions: Are consumption feedback services an appropriate instrument in order to influence the user behaviour to the point of acting in a more energy conscious way? And - if applicable because of the need of sufficient long observation periods – are potential behavioural changes stable over longer time-periods? The appropriate method to analyse both questions could be a multi-stage survey with control group design. The purpose of investigation in tenant's behaviour and attitudes is to increase the knowledge about the tenant population as the most important basis for target-group-specific strategies. Feedback approaches are more effective when combining continuous frequent consumption feedback with additional energy-related information and when fitting exactly the needs of target groups.[31]

4.3 Other information sources

- Methodology for Energy Efficiency Measurement
    - International Performance Measurement and Verification Protocol. Concepts and Options for Determining Energy and Water Savings Volume I (2009). Efficiency Valuation Organization www.evo-world.org
    - Model Energy Efficiency Program Impact Evaluation Guide. Consortium for Energy Efficiency http://www.cee1.org/eval/evaluation_guide.pdf
    - Residential Demand Response Evaluation: A Scoping Study. Ernest Orlando Lawrence Berkeley National Laboratory. http://drrc.lbl.gov/pubs/61090.pdf
- Changing Energy behaviour http://www.energy-behave.net/pdf/Guidelines_Changing_Energy_Behaviour.pdf
- A summary of the evaluation report into the impact of the energy matters programme http://www.cse.org.uk/downloads/file/pub1025.pdf
- Context sensitive behaviour change http://www.energychange.info

[30] Dünnhoff et al. (2009). Evaluation des Cariteam-Energiesparservice in Frankfurt am Main – Evaluation of the Cariteam-Energy saving service in Frankfurt am Main. ISOE + ifeu.

[31] Abrahamse (2007). Energy conservation through behavioural change: Examining the effectiveness of a tailor-made approach. University of Groningen.

5 List of figures and tables

FIGURES

TABLES