Supported by Intelligent Energy Europe	Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe REMODECE EIE/05/124/SI2.419657

REMODECE WP3 -Sub task 3.1

D4: Harmonised Monitoring Surveying Methodology

Authors: Robert ANGIOLETTI, Pascal LARSONNEUR
ADEME
24.07.2006

Table of content

Harmonised monitoring and survey methodology

Introduction

The purpose of this document is to establish a harmonised monitoring and survey methodology to be used for the REMODECE project.

REMOCEDE aims to improve understanding of the energy consumption of various types of equipment in households in the EU-25+2, in parallel with the consumer behaviour and level of comfort.

More particularly, an expected outcome of the project will be an innovative methodology to combine the use of selective monitoring with a wider scale questionnaire based survey. This methodology will be harmonised to enable cross comparison of the energy efficiency and performance of similar equipment and households in the different countries involved.

A prerequisite is the definition of the types of data that have to be measured, e.g. electricity consumption and loads, and what other parameters must be known in order to analyse results and allow cross comparison of the measurement campaigns.

The consistency of a common methodology also implies agreeing on what the main targets and measurement stakes are in each country and what end-uses or appliances will be monitored.

1. Key issues

Four questions have to be clearly addressed in order to define the harmonised methodology:

- What appliances and end-uses energy consumption knowledge do we want to improve? These should be chosen within the list already drawn up in the project contract (Table 1), and what main results and indicators do we expect from the monitoring campaigns?

- How shall we combine or/and sort monitoring results per equipment, per end use, per household and per country using different filters depending on the main determinants of consumptions? What are the main determinants that can enable realistic interpretation and analysis of results?

- How to establish a statistical sample for the common monitoring campaign? What are the main criteria to be used to define the sample as, for cost reasons, the number of households to be monitored is limited? Is it possible to find a rule for correcting the campaign results to reduce the bias between the measured sample and the whole population?

- How will the result of cross country comparison be presented, depending on the data base structure defined in WP2?

2. Appliances to be monitored

2.1 Target by group of countries

The countries participating to the REMODECE campaign focus on different applications according to their past experience and expectations. Two main groups have been defined, which should try and have a common approach to the monitoring campaign in order to produce comparable results.

Central and Eastern European (CEE) countries have little or no data available from previous monitoring campaigns about domestic appliances in general. Therefore they should focus on end-uses causing the biggest electricity consumption in the households.
Older EU member states and Norway, who already have carried out monitoring campaigns about domestic appliances, are interested in evaluating the raise of new loads, such as electronics with special attention towards their standby consumption.

2.2 Definition of end-uses to be monitored

Due to the wide variety of equipment rate that can be encountered and the limited number of households willing to be monitored, we cannot expect to find households with exactly the same profiles for comparison. A certain degree of consistency must still be respected. The list of end-uses defined in the contract must be used as a guideline to follow as closely as possible. In all cases the mains must be monitored in order to record the household global consumption profile. Lighting will also be a common target, with 10 main light sources monitored per household.

Tables 1 and 2 list the appliances or en-uses to be monitored:

Countries	As agreed in the contract	If possible
Bulgaria Czech Republic Hungary Romania	- Total consumption (mains) - Washing machine - Tumble dryer - Entertainment as a group of appliances in living room: TV, DVD, CD - Computer and peripherals as a group for home office - Refrigerator - Freezer - 10 most used lamps individually or the sum of lighting by groups - All kinds of standby consumptions recorded at the time of installation	Sum of computer and TV set per teenager room Cooker including oven Dishwasher Oil or gas burner including circulation pump

Table 1 List of appliances to be monitored in CEE countries

Countries	As agreed in the contract	If possible
Belgium Denmark France Germany Greece Italy Portugal Norway	- Total consumption - TV + VHS + DVD - Large TV screen or other unusual appliance might be monitored separately - CD + stereo - Computer and peripherals as a group in office room - Sum of computer and TV set for every teenager room - All kinds of standby consumptions recorded at the time of installation - 10 most used lamps individually or the sum of lighting by groups - Air condition (Southern countries)	Washing machine Tumble dryer Cooker including oven Dishwasher Refrigerator Freezer

Table 2 List of appliances to be monitored in older member states

2.3 Electric thermal end uses

According to previous monitoring campaigns it is clear that thermal electricity appliances (heaters, air conditioners, DHW, cookers…) and end-uses are of a great influence on the total energy consumption in a dwelling when they are in use.

However the monitoring of heating and domestic hot water heating requires a specific complex methodology and various measurements, whose cost would undermine the efforts made on monitoring of other end uses. These applications should be the focus of a dedicated campaign and are left out of the REMODECE campaign.

It will nonetheless be recorded when electric heating appliances play a significant role in the household electricity consumption.

For Southern countries air conditioning is one of the focuses of the REMODECE monitoring campaign.

In all countries a questionnaire based survey will also be conducted in order to complete the monitoring campaign with a behavioural study.

2.4 Shared definition

To avoid risks of misunderstanding in the cross country comparisons, it seems useful to clearly share some common definitions on items or devices which are the main targets of the monitoring and survey campaigns.

2.4.1 Household

The term household refers to a housing unit or all the persons occupying a housing unit.

2.4.2 End-uses

The monitoring campaign should produce measurement data which can be compared by end-uses. It is however important to know what the end-uses are composed of, in terms of number and types of appliances. A common denomination must be used for both end-uses and types of appliances in all countries.
Therefore, for each monitored household, information about each metered appliance should be carefully collected.

End-uses are defined by the appliances targeted by the REMODECE campaign. The exact denomination of each type of appliance is specified in WP2. Each end-use and each type of appliance are given an identification code in WP2.
End-uses include, as follow:

- **Cold:** refrigerator, freezer, fridge-freezer combination
- **Washing:** washing machine, dishwasher
- **Drying:** tumble dryer
- **Lighting:** light bulbs including fixed ceiling or wall bulbs and movable plugged lamps
- **Entertainment electronics:** TV set, DVD and VHS players, home cinema sets, amplifier, stereo (CD player and similar, radio), play stations, satellite set top box
- **Office electronics:** computer and peripherals (incl. scanner, printer, fax, modem, etc.)
- **Cooking:** electric cooker, microwave oven, fan, food processors, etc.
- **Air conditioning:** mono/multisplit systems, mobile air conditioners, fan, humidifier, circulation pumps, heat pump
- **Other:** aquarium, automatic door, gardening utensils, etc.

(Note: the content of end-uses is still subject to changes due to harmonisation with WP2)

2.4.3 Standby power and consumptions

Estimating the total unnecessary consumption is a goal of the REMODECE project.
Standby power and consumption definition have already been discussed. According to international standardisation (IEC 62301 “House electrical appliances – Measurement of standby power” - June 2005 – and European transcription EN 62301), the definitions are:

- Standby mode: lowest power consumption mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when an

appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions.
- Standby power: average power in standby mode.

In this definition are included all situations where the appliance does not fulfil its primary technical function but still drains electricity from the mains. However, in order to assess standby consumption one must distinguish several cases. The following terms are used in the methodology:

§ **Off mode:** the appliance is turned off but a residual consumption still takes place.

§ **Standby mode:** the appliance is put in standby mode, does not fulfil its primary function but is ready to do so.

§ **Active standby mode:** the appliance is put in on mode but is not actually used, for example a computer left on but no action is performed.

3. Expected results of the monitoring campaign

3.1 Goal of the monitoring and survey campaigns

The main goal of the REMODECE project is to provide the policy makers and market stakeholders with a set of policy recommendations for promoting energy efficient equipment in the residential sector in order to induce successfully market changes.

The study aims at improving knowledge of the following points:
- Appliance energy efficiency,
- Electricity consumption by end-use, which requires grouping appliances by category (e.g. washing machine and dish-washers, sum of different light bulbs, etc.)
- Household global electricity consumption, which should show trends about behaviours towards electricity consumption, equipment uses and general comfort needs in each country

A first set of indicators, related to appliances, will provide stakeholders in one particular appliance market with the most significant figures pointing at needs for improvement of the efficiency, which requires investing in research and development, and for market transformations driven by standardisation, energy labelling or minimum efficiency requirements

The second set, which is related to household behaviour in terms of electricity consumption, will provide policy makers, electricity utilities and market stakeholders with interesting figures that should help to identify the main energy saving potentials and to define energy efficiency policies.

Applications will be more particularly in the field of information and communication campaigns targeting consumers and households in order to help with selection of energy efficient appliances and to encourage energy saving behaviours for each end use. The indicators should also be useful to utilities and ESCOs for developing and proposing to households new energy efficiency services in the liberalised energy market.

3.2 Indicators for appliances

Four main indicators should be defined for assessing the energy efficiency of the selected appliances:
- Appliance energy consumption (kWh/year)
- Appliance peak load and average load profile (W)
- Appliance standby power (W)
- Appliance standby consumption (kWh/year)
- Appliance standby rate (% of yearly consumption)

3.3 Indicators for end-uses

The same indicators should be defined for a global picture of electricity end-uses and in the household:

- Household total energy consumption in each end-use (kWh/year)
- End-use share of total consumption (%)
- Global peak load and average load curve (W)
- Accumulated appliance standby power (W)
- Accumulated appliance standby consumption (kWh/year)
- Accumulated appliance standby rate (% of yearly consumption)

3.4 Indicators for households

For a global picture of energy consumption in the household, the indicators are:

- Household total energy consumption (kWh/year)
- Global peak load and average load curve (W)
- Accumulated standby power (W)
- Accumulated standby consumption (kWh/year)
- Accumulated standby rate (% of yearly consumption)

4. Relevant determinants to achieve cross comparison

Cross comparison should be carried out within 3 kinds of analysis:
- Appliance energy efficiency and annual consumption, at European level
- Household annual consumption, at European level
- Cross comparison among countries in Europe of both these indicators

A number of determinants need to be known for analysis and cross comparison of energy efficiency and level of comfort to be relevant.

Relevant determinants are:
- Yearly electricity consumption invoiced by the utility
- Size and structure of the household in terms of number of people by age category
- Highest education level in the household (no degree or certificate, secondary high school, vocational or trade certificate, university degree)
- Type of dwelling: apartment or house
- Location: rural vs. urban

Other specific data will be needed for consumption analysis and cross comparisons of air conditioning, such as the outdoor temperature during the monitoring, the indoor temperatures of the conditioned room and of non-conditioned rooms.

These specific household and dwelling data and characteristics must be recorded in a questionnaire in order to achieve a better representativeness of the sample and/or to correct for the bias between the sample population and the national population, so that cross comparison is feasible.

5. Harmonised methodology

5.1 General level of the shared harmonised methodology

Discussions have been going on among partners about how the monitoring campaign is to be carried out in each country. Unfortunately due to budget limitation and the potentially high cost of the monitoring campaign the conditions in which the campaign takes place, the timing, the measurement method, the sampling method and sample representativeness will be different for each country. This has obviously consequences on how the data can be used and trusted for analysis. Therefore a common ground must be established to ensure a minimum of consistency among partners.

Different uses of data are foreseen, both in the data collection process and in the data processing and analysis, which implies it is necessary to define a multilevel structure for the database itself:

- Researchers often need and use very disaggregate raw data and information, even though the time step is 10 minutes
- Other potential users of the database, such as policy makers, utilities or appliances manufacturers or distributors, etc. , are usually more interested in aggregate and general results such as annual energy consumptions, peak loads and load profiles on daily, weekly or monthly periods.

The shared harmonised methodology will mainly apply to studies and analysis of general results for main stakeholders.

Researchers will have to define their own in-depth methodology to use unprocessed measurement data on a case by case basis. The future database design has been defined within WP2, which gathers existing and future data to be shared within the project, defines their characteristics, the database structure and use.

5.2 Measurements to be carried out

5.2.1 Number of households to be monitored

In order to keep the cost of the monitoring campaign within the allocated budget, it has been agreed to carry out measurements on 100 households per country, the measurement campaign being completed by a questionnaire based survey, which should target a minimum of 500 households per country. This figure is discussed in the survey sampling methodology.

Reduction of the number of meters is achieved by monitoring only 10 households at a time, the meters being used successively in several rounds of monitoring. It implies that monitoring cannot last for a whole year in the same household. Instead monitoring period is reduced to a whole month, which will be extrapolated to determine the yearly consumption.
The duration of 1 month is a target. Some partners have specified they would make ½ month monitoring.

5.2.2 Number of end-uses to be monitored

It is planned to dedicate on average 10 meters to major appliances or end-uses per household (cold, washing, consumer electronics…). In the case of lighting, at least the 10 main light sources should be monitored per household. The end-uses and appliances to be monitored are detailed in table 1 and table 2.

5.2.3 Measurement time step

The measurement time step will depend on the equipment used, but should be of the same order of magnitude for all partners. A time step of 10 seconds is commonly used for this type of monitoring and should be used if possible. All measurements within a country should be done with the same time step to facilitate analysis.

5.2.4 Electric heating

Monitoring of electric heating and water heating is out of the scope of the project and should not be monitored but it must be mentioned when they are used in the household.

5.2.5 Standby consumption

The total standby consumption cannot be directly measured, since even at night some appliances are necessarily on while fulfilling their primary function, such as cold appliances. In households where heating is not electric, the average total standby load may be estimated by subtracting the average consumption of cold appliances, the lighting consumption and if relevant that of monitored loads likely to run at night (e.g. washing appliances when night fare is used) at the same period of night. The resulting value may be regarded as "active" standby consumption, which also takes into account all appliances left on at night but not actually used.

The average standby consumption for a particular end use can be estimated in the same manner, that is, by taking the lowest consumption at night. The night period should be taken, by default, as 3 am to 4am, which could be adjusted when experience is gained.

When meters are being installed, spot measurements should be made on appliances, for off mode, standby and active standby mode.

5.2.6 Air conditioning

Air conditioning represents a special type of emerging end-uses and must be dealt with in a different manner: it is present in a limited number of households and yet should be monitored over a longer period (summer period: 4 months). In this way no extrapolation is needed and the exact conditions of use will be known.
In countries where this end use is to be investigated, it should be monitored in 20 households.
In these households the temperature must be monitored simultaneously with the electricity consumption in the conditioned room, outdoors and if possible in non conditioned rooms. The surface of the conditioned area must be recorded.

5.3 Consistency and robustness of measurement data

5.3.1 Robustness of measurement data

Given the huge amount of data to be collected (for one particular appliance in one household a month of data collection with a 10 minute time step represents 4320 values, or 52 560 values for a yearly extrapolation), it is important to collect robust and consistent data and check consistency when collecting the data.

At the stage of monitoring data collection, non physical values (i.e. negative values, etc.) should be discarded, while outstanding but still physical values should be kept. These may however be discarded at a later stage of analysis for a particular purpose, for instance to calculate average energy consumption, a method to limit the risk of calculation strongly influenced by some outstanding measurement data consists in discarding the first and last deciles (i.e. the 10% lowest values and 10% highest values).

5.3.2 Representative recovery and correction of sample measurement results

The issue of sample representativeness is critical to determine how the data can be used. However the number of households and the range of types of appliances measured during monitoring campaign are limited due to the budget available in each country for this task. Limitations arising in terms of representativeness of the sample are discussed in D6. The sample selection is of high importance in the methodology.

The aim of the campaign is to build up knowledge of household electricity consumption at national levels, which implies deducing trends from a limited number of monitored households per country. The monitoring campaign is thus completed by a questionnaire based survey, which targets a broader and more representative sample of at least 500 households per country. The monitored households will also be included among respondents to the survey. Hence comparing answers from monitored households and their actual consumption should provide complementary information about electricity end-uses in surveyed households.

On the other hand the bias in representativeness observed between the monitored sample and the actual population in each country may be corrected for based on several criteria: household structure, equipment rate, etc. When a criterion is not defined at national level, the correction could be based on the results from the questionnaire based survey.

5.3.3 Extrapolation of time series measurement data

In the REMODECE monitoring campaign, the duration of monitoring is relatively short compared to the reference period (1 year): 1 month for specific end-uses, 4 months for air conditioning). Measurement results must therefore be extrapolated and the period when monitoring is carried out must be clearly identified.

The energy consumption and load profile of all kinds of appliances are influenced by seasonality, at varying degrees according to the geographical location. The influence is direct because of climate conditions in the case of cold equipments (however depending on the location of the appliance, but the question is complex and not all cases can be considered), lighting, space heating and air conditioning, or may be indirect for others as household way of life may vary a lot according to the season, and in a greater extent in countries with contrasted seasons. People tend to stay at home for longer periods and make a more extensive use of domestic appliances during rainy, cold or short daylight seasons. An accurate method is unlikely to apply to all countries equally, but a common method must be defined to produce seasonal extrapolations.

For each type of end-use to be corrected for seasonality, a seasonal determinant must be defined (e.g. daylight duration for lighting) that will be used for extrapolation.
The extrapolation methods are yet to be tested and this point is kept open at the moment since they will be refined or redefined after testing it on an existing yearly sample provided by Enertech.

For appliances for which no methodology can be validated, monthly measurements should be extended equally to the whole year.

5.4 Identification of the household

The information for identification of the household is detailed in the first section of the monitoring questionnaire, which must be duly filled out.
In case of the survey questionnaire, anonymity should be guaranteed to the respondent. This is both for practical and legal reasons: some respondents might be deterred from answering the whole questionnaire if they judge questions are too personal, and gathering this information without anonymity might not be legal in some countries.

5.5 Presentation of results for each different type of appliance

The indicators to be retrieved from the monitoring data, when relevant and possible, are listed in the following tables. For each single appliance, measurement results and analysis outcome must be arranged so as to be compatible with the database defined in WP2.

5.5.1 Energy consumptions and load per appliance

Appliance	Unit	Appliance_ID n°1	Appliance_ID n°2	…	…	Appliance_ID n
Total annual energy consumption	kWh/year					
Monthly consumption	kWh					
Daily average load curve (24 values)	W					
Standby power	W					
Standby rate in % over the year	%					
Standby yearly consumption	kWh					
Off mode consumption	W					

Table 3: Average energy consumptions and load per appliance - [appliance name, as defined in WP2]

5.5.2 For each kind of end-use, in average by household

For each end-use of the list:

- Cold
- Washing
- Drying
- Lighting
- Entertainment electronics
- Office electronics
- Cooking
- Air conditioning
- Other specific end-uses

End-use	Unit	End-use name
Total annual energy consumption	kWh/year kWh/capita	

Table 4: Average energy consumption per end-use - [end-use name, as defined in WP2]

5.5.3 For each "representative" household category

Categories of household will be defined when all monitoring campaigns are over.

End-use	Unit	Category N°1	Category N°2	Category N°3	Category N°4	Category N°5	Category N°6
Total annual energy consumption	kWh/year kWh/capita						
Maximal peak load	W W/capita						
Standby power	W W/capita						
Standby annual energy consumption	kWh/year kWh/capita						

Table 5: Average energy consumptions and load for each household category

5.5.4 For all different kind of end-uses and each category of households

Country	Unit	Country N°1	Country N°2	…	…	…	Country N°n
Total annual energy consumption	W W/capita						
Maximal peak load	W W/capita						
Standby power	W W/capita						
Standby annual energy consumption	kWh kWh/capita						

Table 6: Average energy consumptions and load of EU - [appliance or/and end use or/and household category name]

ANNEX 1 SURVEY QUESTIONNAIRE

ANNEX 2 MONITORING QUESTIONNAIRE