AIM

Deliverable 2.3

Appliances profile specification

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Abstract

In this deliverable, power modes of various appliance types, particularly white goods, audiovisual and communications equipment which are particularly considered in AIM project, were analysed, in order to define their power consumption profiles. Thus, power consumption data for the appliances in different power modes, e.g. standby and active, considering also particular appliances' internal functions, were collected and will be used for specification of energy profiles. Since energy consumption is not constant for all appliance types but varies as a function of various external factors, the deliverable commences with a categorisation of appliances in three groups, for each one a different profiling model is developed.

Disclaimer

Impressum

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Executive summary

The main purpose of this deliverable is to define the energy profiles of three appliance types; white goods, audiovisual and communications equipment. Although profiling can be conceived in many different ways, it must always take into consideration usability factors, such as:

- profiles management by the end-users,
- profiles scalability and future-proof concept,
- integration issues with peripheral architectural components, when realising energy saving applications.

After analysing in detail these usability factors, expressed by corresponding requirements set out in D2.1, the AIM project has decided to implement appliances energy profiling taking into account the following aspects:

- The diversity of appliances concerning the way they consume energy: specifying accurate energy profiling methodologies greatly helps development of granular energy models that are able to represent even the energy consumed by internal appliance functions. To emphasise on this concept, the document distinguishes appliances into three categories, which are profiled using different energy measurement methodologies.
- Normalisation of profiles among some appliance manufacturers: the energy profiles must be generic so as to be applicable for all appliances of the same category. Otherwise dependencies with particular manufacturer models will be created and the whole profile management solution will loose its significance. To deal with the problem the energy figures measured in the scope of the project have been given upper and lower margins so as to fit to the energy figures given by same appliance manufacturers outside the AIM consortium.
- Profiles compatibility with ongoing energy standardisation initiatives: for solution viability reasons, the energy figures measured should be compatible with those set by the European and worldwide initiatives on energy profiling. This means that the energy figures defined in this document should be identical with those defined by the CoC for active and standby modes, while for appliances not undergone classification, new energy figures should be defined. To address the latter issue AIM accounts energy consumption for particular appliance programmes that are generic to all appliances of the same category, such as cooking programmes, washing programmes, etc.
- Ease of profiles integration within the overall network architecture of the AIM project: ideally energy profiles should consist of information elements able to fit to any implementation. In AIM this issue is solved simply by specifying energy consumption figures as sole metrics, leaving implementation of information elements up to architecture specification. As we claim in D2.2 (Architecture specification), doing so allows application developers to engineer and adopt the information elements that mostly suit their own architectures, without minimising generality of solution.

In the reminder of the document, description of the AIM energy profiling concept commences with appliances categorisation in three groups depending on the way they consume energy. Following this categorisation a profiling methodology is drawn up for each appliance separately, followed by a number of appliance types chosen for profiling. Finally, based on the measured energy consumption figures, particular energy profiles are defined per addressed appliance type. The collected terms for power consumption in active and standby modes are presented and compared, including a consideration of internal functions (e.g. concrete device programmes) for the three appliance types. The achieved profiling results will be useful for final definition of the AIM architecture in Task 2.2 and the specification of the EMD operations.

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Abbreviations

ACPI	Advanced Configuration and Power Management Interface
ADSL	Asymmetric Digital Subscriber Line
AIM	FP7 Project number ICT- 224621 acronym
API	Application Programming Interface
A/V	Audio / Video
CPU	Central Processing Unit
DECT	Digital Enhanced Cordless Telecommunications
DSL	Digital Subscriber Line
DSL Forum TR 69	Broadband Forum Technical Report 069, a remote management protocol
DVD	Digital Versatile Disc
EMD	Energy Management Device
Hi-Fi	High Fidelity
IAD	Integrated Access Device
ICT	Information and Communication Technologies
IEC	International Electrotechnical Commission
IP	Internet Protocol
LAN	Local Area Network
PC	Personal Computer
PoE	Power over Ethernet
UPnP	Universal Plug and Play
WiFi	Wireless Fidelity (wireless networking)
WLAN	Wireless Local Area Network
XML	Extensive Mark-Up Language

1 Introduction

In our world we surrounded ourselves with technology. We became so dependant that without it our society would break apart. In a short period of our history our scientific knowledge has expanded tremendously during technological revolutions. This trend is slowing while we take comfort in the various appliances being within arm's reach.

Following the concept of Sustainable Development we are responsible for the environment to remain as much as suitable to future generations as it was for us. According to measurements ICT industry was responsible for about 2% of the global CO_2 emission in 2007. This value is projected to be multiplied in the next decades [1]. We are in a position to stop this increase.

In the area of information technology there is an ongoing trend toward centralism. This trend was introduced with the spread of Internet and become legitimate by mobile phones. Now we are at the cutting edge to bring this centralism into our household appliances. Doing so will not only make power usage more manageable, but will turn people to be more conscious about the effects of their decisions.

The trend towards fully networked devices could be observed since many years. A microwave oven with integrated web browser has been put on the market already ten years ago[1]. For about the same time the vision of the networked refrigerator has been presented which automatically re-orders used or perished goods. Several pilot households have been built, which are completely networked. Examples are the private house of Bill Gates, the Philips HomeLab [2], France Telecom show room near Paris and others.

The marketing argument for all cited examples is comfort, but this was obviously was not working. Probably people fear the complex configuration – as most of them are already overburdened by the task of programming their video recorder. Engineers have tried to cope with this problem with adaptive concepts. The house control starts with a default operation and the user does corrections. The automatic house would remember that the light was switched on at 17:00 and do the same 24 hours later automatically.

The probably strongest selling argument for automatic household was security. People fear burglars while they are abroad and therefore need presence simulation by automatic light, shutters etc. as well as remote control with alarm sensors, cameras etc. Although involving a number of appliances the security requirement did not lead to completely networked households. A partially networked house is sufficient for this application.

With energy saving another strong marketing argument comes into play. To assess and control the energy consumption of a house all its electrical appliances must be networked. Some simple devices such as water heater, iron, lamps, etc. are especially power hungry and must be included in the energy consideration.

Another, technical driver for networking devices is the possibility to download SW updates. Especially for consumer electronics this – partially – bi-directional procedure is more and more used.

Hence it can be summarized that networked electrical devices are coming – but slowly. Even if every new sold electrical appliance would be networked and manageable it would need many years until all devices in the households would be replaced. Hence to speed up the process some intermediate solution must be provided. It is called Energy Monitoring Device (EMD). In the scope of the project the EMD will be introduced to provide interface to the household appliances. The purpose of EMD which will be connected to the network is to manage a group of appliances. At the beginning a simple networked power outlet can fulfil the role of the EMD.

Features of the networked power outlet are:

- ground loop detection,
- electronic fuse (programmable),
- re-switch on protection – short circuit detection,

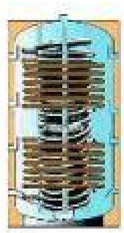
[1] http://www.cnn.com/TECH/computing/9809/14/microwave.idg/index.html

- ground current (delta current) detection in off-state
- measurements implementation.

Categorization of Appliances

The goal of the AIM project is to reduce the energy consumption of different appliances. Therefore, inline with this energy-centric objective, we identified a different type for categorizing appliances. More specifically, we categorize devices depending on their ability to manage with flexibility the required electricity consumption. In the paragraphs below, we provide representative examples that motivate this decision made by the AIM consortium.

A representative example is the electric water heater (boiler). Its energy consumption is high and also flexible. A boiler can be considered as large energy storage with long integration time. Boilers optimised for solar energy have especially high insulation and layered water temperature, so that hot water is available for typically three days. Only under very special conditions the heating up of the water is of primary importance. For example the family comes home from a week long trip and everybody wants to take a shower. The boiler has been switched off and water is cold. In such condition the heating of water should not be interrupted. Some boilers have an “instant heat-up” button for this special case. However, an intelligent house control could heat up the water in advance – provided the user has programmed the return time. In normal operation an intelligent boiler control could monitor its daily energy need and schedule the heating times. As the boiler is also easy to control (it has only on and off state) and it’s “fill” state can be measured easily it is recommended to integrate it into the controlled household appliances first. Some examples for boilers are shown here from large (left) to small (right):

A similar example is the floor heating system. The large mass and a latency time of 6 to 12 hours make it an ideal energy storage system. Both boiler and floor heating can be disconnected from power for periods of up to one hour without any deterioration of comfort.

A totally different example – although with similar function – is the electric water kettle in the kitchen. It has a high load (wattage), its use is unpredictable and the heating should not be interrupted, as users want hot water as fast as possible. In a similar category falls the vacuum cleaner.

Refrigerators and freezers can be disconnected for some time, as usually they are well isolated and therefore maintain the temperature in a given range. Especially freezers are categorized into 24 hour and 48 hour autonomy types. In addition, both appliances could predict their energy need for the next time by observing the parameters temperature and door-open time.

Washing machines and dishwashers are devices which once started could not be paused, while the user may choose to start them later.

Next category can be called “nice to have”. Example is the ambient light for television with makes watching nicer, but might be less important than the news content. In another situation the ambient light might be essential, for example to make movie watching more relaxing. Hence another measure could be “must have”, such as Philips’ online Streamium Radio or Digital Photoframes. They used to be "not there" and changed from "feature" to "must have" in this decade.

An interesting example is the oil burner of the oil heating (picture to the right). It consumes little electrical energy (<100W), but is essential. If the oil burner fails on a cold winter day in-house temperature drops within a few hours to very uncomfortable values. With 2-3 days temperature can drop below zero and then water tubes of service water and heating circuit can burst causing big damage.

Hence a scale for the importance of energy need could be defined as shown in Table 1.

Importance	**Examples**
Essential for life	Medical equipment, emergency phone, emergency light
Very important	Heating, refrigerator, TV (standard resolution), radio (information), Internet access, hot water
Must have	Cooking, light,
Nice to have	Music, photo frames, HDTV
Real luxury	Ambient light of TV set

Table 1: Importance of Appliance Services

However, these priorities must be individually adjustable. And some of them could take place depending on the situation, for example when the user is hungry he might give higher importance to cooking than to the heating of water for a shower.

Also, these importance values can be assigned to functions only, not to the equipment. For example the TV set has three functions with different levels, standard resolution, HDTV and ambient light.

To better understand importance of appliance functions we define an additional classification criterion based on energy consumption, as shown in the following table for indicative appliances:

Appliance	Amount of power manageable	Moment of consumption manageable	Consumption predictable
Washing machine, dishwasher	No	If user enabled within a few hours	Yes
Tea water heater, Coffee machine	No	No	Yes
Vacuum cleaner	No	No	No
Refrigerator, freezer	No	Yes	Yes
TV set	Yes	No	No
Clock radio	No	No	Yes
PC	No, driven by application	No	No
Laptop	No	Yes (charging time)	No
DSL modem	No, driven by user need	No	Yes

Table 2: Appliance categorization

2 Appliance types addressed by the AIM profiling methodology

This section summarises the appliances and their internal functions that will be profiled in terms of energy consumption. Profiling is necessary as it allows establishment of a relationship between the programme at which an appliance is in and the energy it consumes at real time.

Having that relationship documented, the network will be able to measure the energy that a household consumes by monitoring the current programmes that the appliances are in. In addition, the network may control the overall energy consumed within a household by changing the programmes of the connected appliances. This can be done by submitting appropriate control primitives over appropriate network interfaces. Building upon that principle the system may become even more 'intelligent' by being able of maintaining maximum energy consumption levels, collectively for all appliances, which can be further specialized per daytime, season, etc.

2.1 Categorisation of appliances by manageability of consumed energy

Profiling the energy that household appliances consume is a complex issue for a number of reasons.

Many appliances, such as TVs and PCs, implement several operation modes, in which energy consumption is quite different, while for many others energy consumption is not steady but fluctuates as a function of time and the program performed.

To maintain overview of the difficulties each household appliance emerges in terms of energy manageability we distinguish them in three categories:

- Appliances of which instantaneous power consumption is manageable: In this category fall household appliances of which only the <u>instantaneous</u> energy consumption can be managed. Indicative appliances of this category are:
  - washing machine
  - dishwasher
  - refrigerator
  - freezer
- Appliances of which total amount of energy consumption is manageable: In this category fall appliances, which when operating in a certain mode (e.g. a washing programme) consume a fixed amount of energy, which is also measurable and manageable. Indicative appliances of this category are:
  - Television set.
  - Lighting (dimming).
  - Vacuum cleaner.
- Appliances of which instantaneous and total amount of energy consumption is hardly manageable: In this category fall appliances of which consumed energy is not steady and therefore cannot be easily managed. Such appliances cannot have predictable energy consumption because the energy they consume is influenced by external factors such as the water temperature for water heaters, program interruptions for coffee machines, the amount of traffic being handled for modems, etc. Indicative appliances of this category are:
  - water heater
  - Coffee machine
  - Radio
  - PC
  - ADSL modem

Moreover, energy profiles must be normalised so as to be applicable to all appliance models of the same appliance category, e.g. all washing machines should consume same amount of energy in the eco-program.

At international level normalisation of energy consumption levels is hosted in the context of the Code of Conduct activity administered by the European Commission. The CoC activity has the objective of building up concession between appliance manufacturers so that they conclude to commitments concerning the energy consumption of the appliances they manufacture.

An issue not covered by the CoC activity is the specification of associations between the energy consumption levels of the appliance and its internal operation modes.

In an attempt to fill in that gap, in the following section we explain the rationale that the project has adopted for the specification of operation modes and their associations with the energy consumption levels of the selected appliances. Based on that ground, in the reminder sections of chapter 2, we give an analysis of the operation modes, which the project has identified for profiling for each of the addressed appliances.

Because household appliances are made up of electronic components, the energy they consume can be estimated in simple terms as the sum of the energy that the individual electronic components consume. Thus, energy profiles can be drawn up by estimating the amount of energy appliances consume while being in a particular operation mode.

On the other hand, specification of operation modes can be defined in two ways. One way is to follow the modes set for the internal electronics of the appliance, as set by the manufacturer, (e.g. hot plates function for cooktops) or to follow the modes defined by appliance manufacturer as user programme, e.g. the eco-washing programme of washing machines. The former operation mode type is applicable on manufacture level, while the latter is applicable on user level.

To select the operation mode that best fits to the project it must be taken into consideration that by definition all components of the AIM architecture can only function on the basis of user-oriented operations and therefore have no knowledge of any operation mode that may relate to internal appliance operations. Moreover, the semantics of the virtualisation environment should only represent user-level operation modes in order to be understood by the residential user during definition of energy saving services.

Furthermore, from the point of view of the AIM architecture, utilisation of user level operation modes makes easier normalisation of energy profiles among all appliances of same type as it eliminates dependency from complex manufacturing data (e.g. manufacturing technology) that change from model to model and manufacturing technology.

Thus, selecting to use user level operation modes reinforces viability of the AIM architecture. Scalability is also strengthened as new operation modes may be profiled independently of the existing ones.

Following the user level operation mode concept, we may estimate the total energy amount that an appliance consumes with the following formula:

$$E(p) = \sum_{i=n} E(p,i),$$

where:

p: is the user level operation mode (programme type),

E(p)= is the sum of energy consumed by the appliance, while it functions in programme p,

E(p,i)= is a two-dimensional array with i columns corresponding to the energy consumed by the i internal component that participates in the implementation of programme p.

The formula expressed above is directly applicable on the second appliance category (appliances of which total amount of energy consumption is manageable), but it may also be used for the first appliance category (appliances of which instantaneous power consumption is manageable) if peak consumption values are to be profiled.

In the following sections we document the appliances the project has selected for profiling along with a number of the user level operation modes and the conditions under which energy measurements have been taken.

2.2 White goods

White goods selected for the project capable to be interconnected with the AIM system are the following three:

- *Refrigerator*
    - Model: Indesit BAN 33 NFP
    - Electronic Full No Frost Fridge-Freezer
    - Efficiency class: A
    - Net volume of fridge compartment: 202 l
    - Net volume of freezer compartment: 65l
    - Climate class: SN-N-ST
- *Washing machine*
    - Model: Ariston Aqualtis AQXXD 169
    - Electronic 7 kg load washing machine
    - Energy efficiency class: A+
- *Oven*
    - Model: Hotpoint/Ariston Open Space
    - Electronic no Pyrolitic Oven with Divider (being able to have three compartments in one single muffle: the main big one (XL) has 70 litre volume, the medium (M) has 47 liter, the small 20 liter)

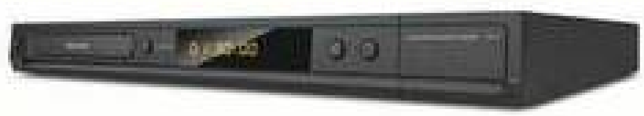
The appliance models selected are to be intended as indicative. However, main functionalities and settings will be chosen having in mind that they must be generally present in all appliances of the same type, so as to guarantee generality of solution.

2.3 A/V

The A/V appliances that were used for measuring purposes are the following:

DVDR 3600 - DVD Recorder Player

HDR3600 - Hard Disk/DVD Recorder



HTS6100 - Home Cinema System

MCM393 - Micro HiFi system

DVDR5500 - DVD Recorder Player (with Freeview tuner)

HTS6600 - DVD Home cinema System

HTS8100 - DVD Home cinema System

TV Sets

Type	40PFL9704H/12	46PFL9704H/12	52FPL9704H/12
Size	40” Full HD 1080p Digital TV	46” Full HD 1080p Digital TV	52” Full HD 1080p Digital TV
Resolution	1920 x 1080p	1920 x 1080p	1920 x 1080p

2.4 Communication equipment

Most devices in today’s household appliances are phones, PC with peripherals, modem/router and sometimes switches and fax machines. Some typical examples were investigated in 5.3 and 6.3. To gather data about the equipments, their technical specifications were examined. These specifications contain power levels, and power consumption figures for each power level. This section summarises which communication appliances are mostly used in today’s households and selects some of them to be measured and profiled against energy consumption.

Market figures concerning user demand for home communication appliances show that residential users are mainly interested in two product categories; broadband communication equipment and wireless access points.

These two product categories can be further split up in equipment for data communication and equipment used for telecommunication purposes. This product distinction is today true but in the future it will disappear as penetration of the NGN technology will be become apparent.

For the time being we choose to follow the later product categorisation as it helps to identify communication equipment taking from the user perspective.

Taking this categorisation into account we may indicatively identify a number of popular appliances from both categories:

Telecom equipments:

- Telephone (powered by main cord, external supply should not be required)
- Cordless phone with base station
- IP phone with PoE
- Facsimiles

Datacom equipments:

- Wired network devices, such as routers, switches, residential gateways, xDSL modes, ISDN modems, PLC modems.
- Wireless communication equipment, e.g. WiFi hot spots
- Notebooks
- Standard tower PCs

Figure 1: End user equipment

To address consistently usability aspects we choose to examine appliances from both user categories:

Telecom equipment:

- DECT phone.
- Wired IP phone with PoE.

Datacom equipment:

- Home gateway prototype with ADSL, DECT and IEEE 801.11 physical interfaces.
- Ethernet switch with PoE.

3 Methodology for appliance profiling

This section summarizes the methods that have been followed in order to profile the appliances in terms of energy consumption.

These methods consist of ways of measuring the energy consumption of the appliance, when the appliance is in operation at any particular programme.

Devices are more or less difficult to profile. For example an electric kettle is very simple to describe. It has only two states, one with maximum power and one with zero power.

Much more difficult to profile is a PC. Already the processor has various power-performance levels, can power down periphery, display etc.

Important for profiling is a clear view of the various states an appliance can have. In the following an indicative collection of power mode states is given.

Mode	Application	Description
Active	All devices	The maximum power consumption for all devices
Standby (Turned off)	All devices	Only basic functions are available (e.g. clock)
Standby	Phones	Ready for call reception
Ready	Fax machine	Ready for fax reception
Off mode (Energy Star) S5 state (ACPI)	PC	The power consumption level in the lowest power mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when the appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions.
Sleep mode (Energy Star) S3 state (ACPI)	PC	A low power state that the computer is capable of entering automatically after a period of inactivity or by manual selection. A computer with sleep capability can quickly "wake" in response to network connections or user interface devices with a latency of $\leq$ 5 seconds from initiation of wake event to system becoming fully usable including rendering of display. Sleep mode most commonly correlates to suspend to RAM state.
Idle state (Energy Star)	PC	The state in which the operating system and other software have completed loading, a user profile has been created, the machine is not asleep, and activity is limited to those basic applications that the system starts by default.
Active state (Energy Star)	PC	The state in which the computer is carrying out useful work in response to a) prior or concurrent user input or b) prior or concurrent instruction over the network. This state includes active processing, seeking data from storage, memory, or cache, including idle state time while awaiting further user input and before entering low power modes.

Hibernation S4 state (ACPI)	PC	Suspend to disk state. In this state, all content of main memory is saved to non-volatile memory such as a hard drive, preserving the state of the operating system, all applications, open documents etc. That means that after coming back from S4, the user can resume work where it was left off in much the same way as with S3. Computer can be brought to G2 state (soft off) or G3 state (mechanical off) and back to S4 without loss of data.
Soft off G2 state (ACPI)	PC	Computer can "wake" from input from the keyboard, clock, modem, LAN, or USB device
Mechanical off G3 state (ACPI)	PC	Power cord can be removed and power consumption is zero. Typically, only the real-time clock is running off its own small battery.
Charging offline	Mobile devices	Battery connected and the device is turned off
Charging online	Mobile devices	Battery connected and the device is turned on
CD Play	A/V devices	The audio processing chipset is in active mode
DVD Play	A/V devices	The video decoder chipset is in active mode
RF	A/V devices	The RF DVD tuner is in active mode
Standby eco mode	A/V devices	This mode is device dependent
Record	A/V devices	The video encoding SW task is also active
FM Radio	A/V devices	The FM radio tuner is on
Tuner	A/V devices	The analog TV tuner is on
Disconnect	All devices	No electricity, zero power consumption

Table 3: Collection of power level denominations

In addition to assessing the various activity levels of an appliance also the time is important a device is in a certain state. For simple devices such as the water boiler the on-time can be measured to obtain the energy consumption.

3.1 White goods

Beside the three white goods appliances (refrigerator, washing machine, dishwasher, oven) Indesit may furnish a Power Metering Adapter, able to output relative consumption of the relative provided appliance. The device can be connected via RS232 with external communication nodes interfaces. With information regarding instantaneous power & energy consumption appliances could set white goods loads management (power levelling management) by means of information about maximum admissible power peak, given by the utility in the home environment and supplied by Gateway. Using priority algorithms it could be able to modulate “switch on” and “switch off” of all white goods present; e.g. ovens will have higher priority than washing machine in the “switch on” phase; at the contrary ovens will have lower priority in the “switch off” phase. These algorithms could be present within Indesit appliances.

The methodology for profiling energy consumptions varies among the selected appliances:

- *Refrigerator:*

  The standard which is used for the profiles of energy consumptions is the CEN EN 153: 2006 **[5]** (Methods of measuring the energy consumption of electric mains operated household refrigerators, frozen food storage cabinets, food freezers and their combinations, together with associated characteristics). The energy consumption is measured with appliance closed doors in climatic standard chamber:

- Constant room temperature of 25 ±0.5°C, air velocity ≤ 0.25 m/sec;
- Appliances must be placed over a wood base with lateral screens, having layout and dimensions as defined in EN153.
- Refrigerating appliances intended only for building-in or for placing under a counter or under a worktop, or between cabinets (under-counter types), shall be built-in or placed in a test enclosure of dull black painted, with door(s) dimensions in accordance to manufacturer's specifications.
- Product stabilized by at least 24 hours from the last thermostat setting;
- Freezer loaded with standard sized packets having thermo-physical characteristics of beef; some of those (called "M" packets) are provided of probes for t°C measurement. Packets layout is defined by manufacturer, according to EN153.
- In case of full no-frost appliances the fridge is also loaded with three standard M sized packets at three different compartment heights.
- Target temperatures for energy consumption:
  - fridge compartment: (arithmetic) average temperature ≤ 5°C measured by three thermocouples (TC) at different heights, single temperature during each cycle must be not greater than 10°C;
  - freezer compartment = temperature of M standard sized packet: non greater than -18°C for 3 star compartment or -12°C for 4 star compartment. Different compartment types (e.g. 3 star and 2 star) in the same appliance could be possible.
- The power absorption is measured for (at least) 24h in steady state (after stabilisation) at 230V and 50Hz. The energy consumption in energy label is expressed as kWh/year (kWh/day x 365).

Take into account that in case of full (or partial) no-frost appliances:

- In the test period a defrosting cycle must be included. If no defrosting cycle is observed during the first 24h of test, the test itself must continue until the first defrost phase. The test cannot run longer than 48h: it means a defrost cycle must occur within 48h. In case of partial no-frost appliance the above mentioned limit is moved up to 72h.
- The max temperatures after the defrosting cycle cannot be higher than 10°C for fresh food compartments and -15°C for frozen food compartments and -12°C for 2 star compartments. After defrosting phase the target temperatures must be restored within max 4h.

If during the energy consumption test the required compartment temperatures (e.g. +5°C/-18°C) are not reached, a second test must be done varying the thermostat setting in order to reach colder (or warmer) temperatures respect to the first one. The energy consumption is then calculated by linear regression of temperature compartments, as defined by EN153.

- *Washing machine:*

  The energy consumption tests were performed on washing machine Aqualtis AQXXD 169 with 7kg (or respective) standard load according to European Standard IEC60456 5th Edition **[6]**. This International Standard specifies methods for measuring the performance of clothes washing machines for household use, with or without heating devices utilising cold and/or hot water supply. It also deals with appliances for water extraction by centrifugal force (spin extractors) and is applicable to appliances for both washing and drying textiles (washerdryers) with respect to their washing related functions. This international standard also covers washing machines which specify the use of no detergent for normal use. The object is to state and define the principal performance characteristics of electric household washing machines and spin extractors and to describe the test methods for measuring these characteristics. Within this standard there are all the environmental conditions, which must be respected during the test:

- The supply voltage to each test washing machine shall be maintained at the rated voltage ±2 % throughout the test. If a voltage range is indicated, then the supply voltage shall be the nominal voltage of the country in which the appliance is intended to be used. Power supply voltage in Italy = 230±1 [V]
- The supply frequency to each test washing machine shall be maintained at the rated frequency ±1 % throughout the test. If a frequency range is indicated, the test frequency shall be the nominal frequency of the country in which the machine is intended to be used. Frequency in Italy = 50±1 [Hz]
- The temperature of the laboratory supply water to each test washing machine shall be:
  - for cold water (15 ± 2)°C for all reference programmes except Cotton 20°C,
  - for cold water (20 ± 2)°C is the recommended option when using the Cotton 20ºCreference programme. This is recommended for test washing machine programmes with no internal heating and cold fill only (cold water wash).The cold water supply temperature to the reference machine in this case may be the same as the test washing machine or it may be 15 ºC as specified above,
  - for hot water the temperature indicated by the manufacturer ±2 K, or (60 ± 2)°C, if no value is given.
- The ambient temperature of the test room shall be maintained at (23 ± 2)°C throughout the washing machine test. The measured ambient temperature for washing machine testing shall be reported.
- Where an ambient controlled room or chamber is used for conditioning the base load, the following conditions shall be maintained:
  - ambient temperature: (20 ± 2)°C
  - ambient humidity: (65 ± 5)%

  The measured ambient temperature and humidity for conditioning base load items shall be reported.

- *Oven*

  The standard which is used for energy consumption profiles is the CEI EN 50304:2002- 00 **[8].** The standard applies to electric ovens for household use. The object of this standard is to specify in accordance with the Council Directive on energy labeling and standard product information:
  - Energy consumption using a standardized load during a standardized test procedure;
  - Some performance characteristics (like volume, time for heating a load and baking trays area);
  - Permitted tolerances to values declared by the manufacturer and control procedures for checking these delayed values.

  As this particular oven has three compartments (XL, M, S) the measurements have been performed following:
  1) Big Compartment (XL): GRATIN function is used for valuing energy class
  2) Mid Compartment (M): VENTED function is used for valuing energy class
  3) Small Compartment (S): STATIC vault function is used for valuing energy class

  The energy consumption test is carried out in a draught free room in which the ambient temperature is maintained at (23±2) °C during the complete test. The supply voltage shall be maintained at 230V±1%. The load for test shall be a brick with two holes for temperature measurement sensors (as to CEI EN 50304 [8]). The brick must be weighted in dry conditions, as to standard. The weight measurement will then be repeated after the brick has been immersed in water, for at least 8 hours, at a temperature about 5±2 °C (humid condition). The value difference between dry and humid conditions must be 1050 ±50 g. The test starts by positioning the humid brick in the centre of the oven, using K type thermocouples for temperature measurements. Oven, timer and power meter devices are simultaneously switched on. When thermocouples register a Δ of 55°C the test is completed. After the test the brick is removed from the oven and weighted again; this determine the quantity of evaporated water.

3.2 A/V

This process was carried out according to the draft of IEC 62087 Ed. 2.0 [9].

The IEC 62087 draft that defines standardized ways for power measurements in A/V devices. The procedures explained below are precisely what the standard specifies.

Power Supply: Measurements were carried out at the rated voltage and the rated frequency of the power supply. The fluctuation of the power supply voltage during the tests did not exceed ± 2%. The frequency fluctuation and the harmonic components of the power supply did not exceed ± 2% and 5% respectively.

Environmental conditions: Ambient temperature should be between 15 Celsius and 35 Celsius. During our measurements the average was 20 Celsius.

Input signals: The input A/V signals are not explicitly described in the standard. The nominal signals as specified by each A/V device were applied during the test.

Measurement procedure: The device was switched off for at least 1 hour. 30 min for warming up before any measurement was taken. In active mode, the average power was measured for 10 min. Static power measurement was taken for 1 min. Standby power measurement was taken for 10 minutes. When an operational mode switch took place, the power consumption of each appliance was also measured 15 min after it has been switched into the relevant operating mode. Some appliances switch after a time delay from a mode to another which is characterized by different power consumption. The power consumption before and after the switching was also measured and considered as part of the energy of the newly transitioned mode. Finally, when the power consumption in a certain operating mode had more than one stable level, the measuring time was at least 1 hour so as to measure the correct average value. All these measurements were carried out directly by means of a wattmeter.

3.3 Communication equipment

Profiling communication equipments equals to QoS support. The availability of these devices is required around the clock. A VoIP phone is to have the highest priority thus the required bandwidth always has to be provided. The operation of a fax machine should also be QoS supported, but it is not as critical as the phone meaning that delays are allowed. Current network devices satisfy the requirements of power consumption because of their continuous operation no "standby mode" needed. Nevertheless there are state of the art energy efficient equipments in existence even such comprising the networking element, the phone and the fax machine in a single device. This level of integration is to be achieved wherever is possible before dealing with the power consumption of the individual devices.

As of today most communication equipments have extensive power saving modes implemented. For example DECT base stations switch off the transceiver when the phone is plugged in. The only means to improve energy savings via control from outside is by adding the **overall view**, which is not available locally in the device. For example if all phone calls are re-routed to an operator mailbox the phones in a house could be completely switched off.

The Broadband Equipment Code of Conduct - version 2 from 17 July 2007 (CoC) covers the following end-use equipment:

- DSL modem
- Cable modem
- PLC modem
- (DSL) router with/without WLAN up to 5 ports (1WAN port and 4LAN ports) up to 1000 Mbits/s

- Small hubs and switches up to 8 ports (10/100/1000 Mbits/s)
- WLAN access points
- WiMAX*
- Small printer server (connected to broadband)
- Home gateway*
- Telephone devices for VoIP (ATA or VoIP-Handset)
- Optical network termination (ONT)
- Equipment that is a combination of one or more of the equipment above

The power requirements for computers are covered by the Energy Star programme. The specification [11] for computers is permanently updated to follow the rapidly moving market. For each type of computer, desktop, laptop, server etc. the power states (see Table 3) and the typical use cases are defined, such as:

For notebooks two use cases are defined, conventional and proxing, the latter referring to a fully networked computer. A conventional notebook is typically for private use, the fully networked for work use.

Notebook use time	Conventional	Proxying
Off time	60 %	45 %
Sleeping time	10 %	35 %
Idle time	30 %	25 %

Table 4: Use time example from Energy Star specification for computers

Using these use times for the respective power levels the total energy consumption (TEC) over the year is calculated using this formula:

$E_{annual} = (8760/1000) * (P_{off} * T_{off} + P_{sleep} * T_{sleep} + P_{idle} * T_{idle})$

Then the classification according to Energy Star for the notebook example is:

Category A: less than 36.5 kWh per year
Category B: less than 50.7 kWh per year.

To calculate the energy consumed by the telecom and datacom equipment selected in section 2.4, we need to take into account the mode in which the appliance operates and the time interval for which this operation mode is active:

$$Etotal = \sum_{i=n} Em(i)$$

E_{total}: Total energy consumption
$E_m(i)$: energy consumed in operation mode i

Since $E_m(i)$ is a function of time it can be calculate with the following formula:

* Power values will be included in the next revisions of the CoC for broadband equipment only when reference definitions, standards and/or data are available

- Appliances of which instantaneous power consumption is manageable: $Em(i) = \int_{t=0}^{t=n} Em(t)$, where $E_m(t)$ is the energy consumed at time t, and n is the total time the appliance is in the operation mode m.

- Appliances of which total power consumption is manageable: The energy consumed in mode m, E_m is steady.

- Appliances of which energy consumption of hardly manageable: E_m may be only experimentally measured.

The preconditions for measuring E_m, such as environmental temperature, port settings, etc, are not the same for each communication device. For example, for broadband equipment, energy consumption measurement requires appliance set up according to the ETSI ETS 300 132-2 standard [7].

3.4 Profiling Methodology

In this section we discuss a methodology for the development of a generalised, single profiling methodology and data layout.

The basis for this work is offered by the general observation that such methodology should be generic enough so as to describe the “energy profile” of any appliance type currently used but also those that will appear in the future.

Following this point of view, we propose adoption of the following general parameters, for the high-level definition of the energy profile structure:

- Appliance type
- Appliance model
- Power states

This high-level part of the energy profile structure is enough to establish an one-way relation between the profiled appliance with its energy consumption figures.

The next step in our profiling methodology is the establishment of a means for representing the real energy consumption figures of the profiled appliance within the high-level profile structure.

The best way is to link this information to the “Supported user programmes” field of the high-level profile in a structured way using the interrelation shown in Figure 2.

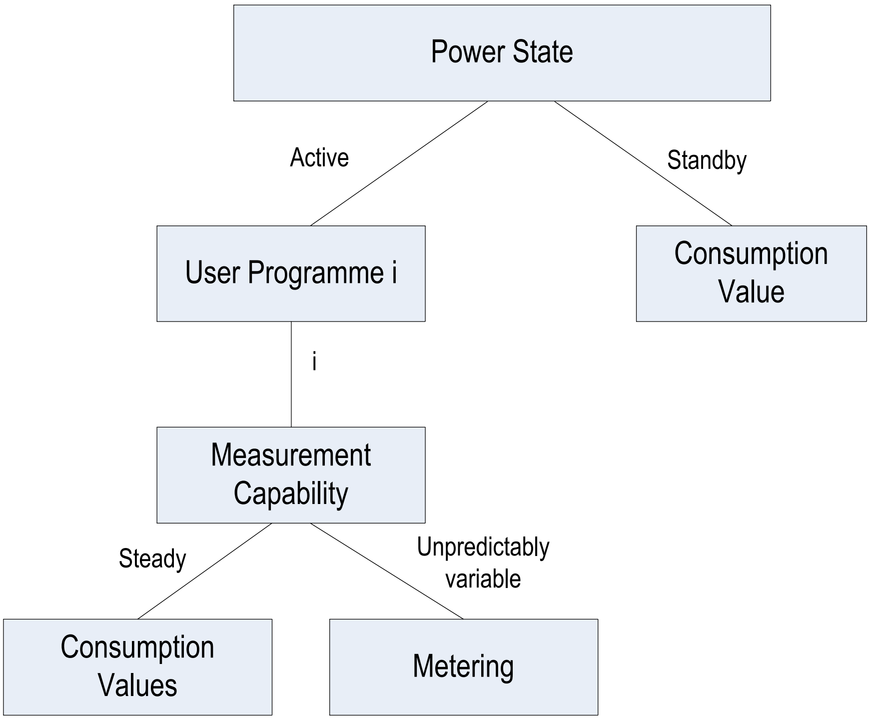


Figure 2: Relational tree between the appliance type and energy consumption values

In the relational tree shown above for each appliance type and model there is a power state linked that encodes the basic power states supported by the appliance that is active and standby. For the "active" power state the relational tree is further expanded with the involvement of an array containing the supported user programmes. Then, for each supported user programme i, there is a Boolean type variable used to encode whether consumed energy in the given programme cycle is steady or fluctuates unpredictably. In the first case, the data structure points to the energy consumption figures, while in the second case the system is instructed to resort to a short of metering technique for obtaining the instantaneous energy consumption figure experimentally.

3.4.1 Data structure layout

The next step following the definition of our profiling methodology is the establishment of a data structure that helps linking the profiling information described previously to the energy saving logic.

The layout of such data structure is defined as shown in Figure 3.

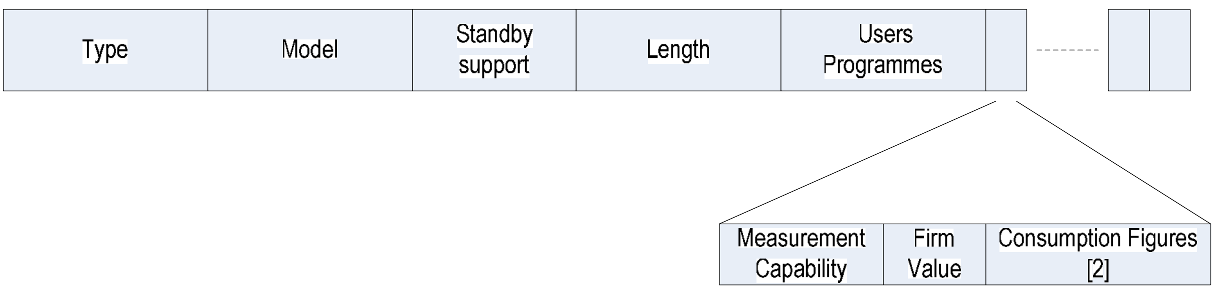


Figure 3: Data structure layout for the representation of energy profiles

Name	Type	Size in bytes (octets)	Description
Appliance type	Unsigned integer	4	The appliance type (e.g. fridge, oven, etc)
Appliance model	Unsigned short integer	2	The appliance model (e.g. DVDR5500)
Standby support	Boolean type	1	Indicates whether the appliance has standby mode
Length	Unsigned long integer	8	Gives the length in bytes of the user programmes field (the length field itself is not included)
User Programmes	Array of N elements, where N the number of supported programmes	18 (per element)	Each element corresponds to one supported programme
Measurements Capability	Boolean type	1	Indicates whether in this user programmes energy consumption can be measured or not (TRUE means yes)
Firm value	Boolean type	1	In case of measureable energy consumption the firm value defines whether the appliances consumption is steady or fluctuates within upper and lower limits (TRUE means it is steady)
Consumption figure	Two-element array of long unsigned integer type	8 (per element)	If Firm value field is FALSE the consumption figure gives the limits (first element low limit, second element upper limit)

Table 5: Data structure fields' description and type definition

The data structure depicted in Figure 3 should be exploited for the establishment of a data base to maintain all appliance profiles. This data base should relay at the residential gateway and will be linked to the energy saving applications through the energy saving service logic of the Device Virtualisation Environment.

4 Internal functions

This section summarises the functions of the appliances that may be identified as concrete programmes and therefore are subject to profiling.

Such functions may be either a single programme at which an appliance is in, e.g. a washing machine programme, or may be the sum of several functions, e.g. TV mode with backlight or TV mode without backlight.

It must be noted that in order for the network to be able to control energy consumption, all internal functions that are subject to profiling is possible to be controlled over the network via a particular or generic communication interface that will be identified and included in the specification of the overall system architecture, in deliverable 2.2.

Each internal function can be identified either proactively by the network, by means of measuring in real time the energy that each individual appliance consumes, using appropriate metering devices or can be made known to the network by the appliance itself, by means of exchanging particular status primitives over the connected network interface.

Which of the two methods is to be adopted is up to the provider of the appliances. In any case, the network architecture should support both methods.

4.1 Relation of the AIM profiles to the CoC initiative of the EC

In their effort to enforce certain levels on the consumer market, regulatory bodies and governmental institutions have set several Code of Conducts initiatives, with each one addressing a vast diversity of consumer products.

Concerning the energy consumption of household appliances the EU, in cooperation with related regulatory bodies (e.g. CENELEC) have set up CoCs prescribing certain levels of energy consumption for appliances operating in active and standby modes.

What the AIM profiling technology can offer to the CoC initiative addressing household appliances is a higher level of granularity that will enable more manufacturers to be committed to certain energy consumption levels for individual appliance programmes.

Being normalised per user programme, the AIM profiles are easier understood by residential users than the CoCs themselves and therefore can be wider diffused in the market area of household appliances, helping in the creation of user awareness about energy-hungry and environment-friendly appliance programmes.

In addition to their benefits for building up users' consensus on environmental policies, the AIM profiles may be seen as a future-proof way of implementing current and emerging CoCs through a specific data model structure that allows integration of energy consumption values into energy saving applications for residential users and governmental organisations.

4.2 White goods

Internal functions of white goods selected are specific type:

- *Refrigerator:*

  This selected fridge-freezer appliance has various functionalities that could be set by the user:

  - Holiday: triggers fridge compartment temperature at 12°C when user sets to holiday function. This prevents mould inside the compartment.
  - Eco: setting that allows good food storage capabilities by minimum energy consumption (great efficiency).
  - Super Cool: to quickly cool down the temperature within the fridge after rising of temperature caused by new warm items introduced.
  - Super Freeze: to quickly freeze fresh food in freezer compartment.

- *Washing machine:*
  The selected washing machine has different functions/cycles specialized for respective user needs:
    - Whites Cotton
    - Colorfast Cotton
    - Cotton with prewash
    - Synthetics delicate
    - Synthetics not delicate
    - Silk
    - Wool

- *Oven*
  Besides including the possibility to have more than one compartment in a single muffle, the oven has additional functions for cooking different kind of foods. These functions are special cooking programmes modes:
    - Pizza
    - Bread
    - Cake
    - Grill

4.3 A/V

A/V appliances are usually characterized by considerably different functionalities depending on the application type. Furthermore, depending on the evolution of the model, newer devices adopt more advanced internal functions/programs.

One common feature is that the standby function is common among to all appliances. In Hi-Fi/DVDR systems like the MCM393/HDR3600, the eco-friendly standby mode is also possible to be enabled. This mode basically shuts down all the internal functions/chipsets besides the remote control receiver functional block. This differentiation is important since it might affect significantly the QoS (latency in particular) that is perceived by the user. Therefore, this differentiation should be maintained and possibly exported in an AIM-enabled EM system.

In the active mode the possible tradeoffs between QoS and power consumption are even more. However, they depend directly on the appliance. For example, in active mode DVD recorders/players have two basic active modes namely "CD Play"/"DVD Play" respectively, and "Record". "FM Radio" mode is also available in certain models. Newer models include additional internal blocks, like the RF DVB tuner in HDR3600. Regarding the modern television sets, they have two basic modes that of normal TV viewing and the eco-friendly mode where the intensity of the backlight is dimmed according to the displayed video content. Note that audio power consumption is TV sets is minimal and it is usually ignored.

Below we provide some representative operation modes that can be addressed by AIM system, while a subset of them can be found in the devices that were tested:

- CD Play: The audio processing chipset is in active mode.
- DVD Play: The video decoder chipset is in active mode while decoding at full (HD) resolution.
- DVD Record: The video encoding task is also active at the digital signal processing hardware.
- FM Radio: The FM radio tuner is on while the remaining hardware is not active.
- Tuner: The analog TV tuner is on and the TV signal is also rendered in the screen.
- RF: The RF DVB tuner is in active mode and the extracted MPEG-2 bit-stream is also decoded and rendered.
- Eco mode: This mode is device dependent as we explained above.

- Standby: The device can be immediately transit into active mode while all the processors are inactive.
- Disconnect: This mode should be applicable to all devices. No electricity and zero power consumption. There is a need for a mechanical switch.

All the above are existing programs/functions that could be handled by a system like AIM. As we specified in D2.1, AIM should be able to accommodate further states/functions besides the ones mentioned above in order to be future proof.

4.4 Communication equipment

Communication equipments in households are turned on most of the time. As network devices are mostly stateless, power monitoring logic is required to allow automated mode switch over. For example, normal cord-phones usually cannot be turned off and besides the main cord, they don't usually have other power supply to support more sophisticated modes such as hibernate. On the other hand, an ISDN/ADSL modem may need to monitor phone usage in order to make statistics of called numbers/duration or even contact the line provider for momentary information about the call's cost. In that case a router should be able to monitor the traffic of the network, hence being able to operate proactively, outside the context of users' request.

Such usability requirements prompted communication equipment manufacturers to come up with device models able to function in more sophisticated ways, offering, alongside the possibility of functioning autonomously, new operation modes, e.g. long distance, energy saving modes, etc.

Recalling the two device categories introduced in section 3.3, following we identify in general the operation modes, these two categories generally support.

Telecom equipments usually have two states of power consumption, the **ready** or **standby** mode with lower consumption, and the **active state**, when the equipment is used with higher power consumption.

Datacom equipments are different in functionality. Network devices are usually turned on, but usually have higher power consumption when data is forwarded. Therefore we can define two **power level** states, the **idle state** and the **dataflow state**. Concerning utilisation of broadband equipment, such as xDSL, the Code of Conduct of the European commission specifies three power levels, thus operation modes: Off, Low power and On.

In **off mode** the equipment is connected to the power source and is switched off, i.e. does not fulfil any function. This mode coincides with the standby mode.

The **low-power mode** is identical to the idle mode defined above, whereby the equipment is powered on but with no load.

The **on mode** is the mode where the equipment is connected to the power source and the network is in normal operation regarding the input and/or output of data on the network.

In next chapter the above mentioned operation modes are summarized in tables showing the energy consumed in each mode by each one of the selected communication appliances.

4.4.1 The Danube, Infineon's Home Gateway solution

This new generation SoC for network applications includes a Power Management Unit (PMU). The features of the PMU are:

- Various power management modes
- Clock gating
- Individual module power on/off

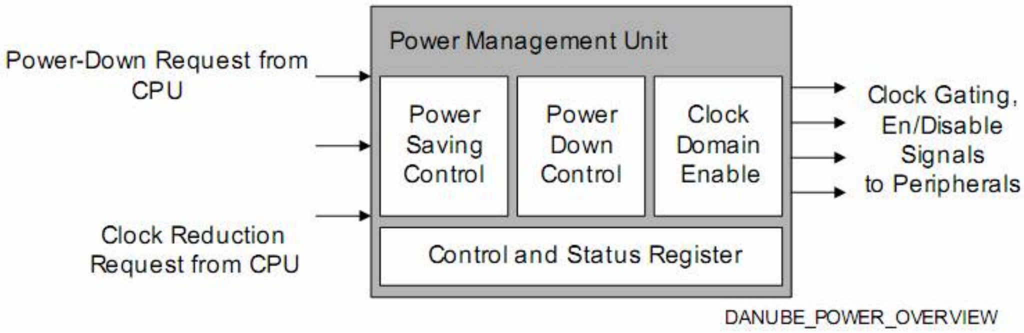


Figure 4 Power Management Unit

The Power Management Unit controls the overall power consumption. The PMU generates clock en/disable signals and comprises the power down control, clock domain enables and the power management registers, power saving is through clock gating, as shown in Figure 4.

In Power Down Mode, power consumption can be adopted to the requirements of the application due to enabling/disabling individual modules. Power Management affects only the CPU and reduces the power consumption of the CPU including caches. All peripherals continue to operate before the CPU enters Sleep Mode. Power Saving Mode is a software controlled power management mode offering a flexible way to control the power consumption. While requesting this power management mode, dedicated peripherals can be selected to be driven into reduced clock mode and thus save operation power.

Power saving mode of Danube is achieved mainly by clock reduction. MIPs subsystem and its associated clock domains can be fed at reduced frequency at lower as 84 MHz only of norminal clock (333MHz). FPI bus and its connected peripherals can be programmed to work at 1/2 of SDRAM clock. All the possible running clock frequency of various modules are listed in the following table.

Table 6 Operating Frequency List

Modules	**Possible Frequency**
MIPS subsystem	333, 111
FPI/AHB bus	84, 56
DDR-SDRAM Controller	167, 111
SDR-SDRAM Controller	111
DMA	Frequency of FPI or its fraction
PPE, ARC	Different clock domain
Other internal peripherals	f_{bus} or fraction of f_{bus}

The next table describes the behaviour of various modules during these power saving modes:

Table 7 Modules states In Power Saving Modes

<table>
<tr><th>Modules</th><th>Power Down Mode</th><th>Sleep Mode</th><th>Power Saving Mode</th></tr>
<tr><td>MIPS</td><td colspan="2">Pipeline frozen; internal clocks suspend</td><td>Running at reduced clock</td></tr>
<tr><td>OSC</td><td>Always on</td><td colspan="2">Always on</td></tr>
<tr><td>PLL</td><td colspan="3">Always running as normal</td></tr>
<tr><td>ICU of CPU0</td><td colspan="3">Always clocked</td></tr>
</table>

BIU of CPU0	Not allowed	Clocked	Running at reduced clock
FPI0/FPI1/AHB	Clock gated	Clocked	Running at reduced clock
SDRAM controller and S-Bus	Clock gated	Clocked	Running at reduced clock
DEU	Clock gated	Clocked	Running at reduced clock
PPE	Clock gated	Clocked	Running at reduced clock
DMA	Clock gated	Clocked	Running at reduced clock
ALM	Clock gated	Clocked	Running at reduced clock
USB	Clock gated	Clocked	Running at reduced clock
DFE	Clock gated	Clocked	Running at reduced clock
SDIO	Clock gated	Clocked	Running at reduced clock
UARTs	Clock gated	Clocked	Running at reduced clock
SPI	Clock gated	Clocked	Running at reduced clock
LEDC	Clock gated	Clocked	Running at reduced clock
EBU	Clock gated	Clocked	Running at reduced clock
PCI	Clock gated	Clocked	Running at reduced clock
USB_PHY	Clock gated	Clocked	Running at reduced clock
GPTC	Clock gated	Clocked	Running at reduced clock
AHB	Clock gated	Clocked	Running at reduced clock
TDM	Clock gated	Clocked	Running at reduced clock
PPE_UTP	Clock gated	Clocked	Running at reduced clock
PPE_ENET0	Clock gated	Clocked	Running at reduced clock
PPE_ENET1	Clock gated	Clocked	Running at reduced clock
PPE_TC	Clock gated	Clocked	Running at reduced clock

Each peripheral is driven into power saving mode if CPU programs the module clock into a reduced frequency. Power saving is performed individually per peripheral (all those peripherals connect to the FPI bus through BPI interface) using the clock gating and power-down functionality. This power saving mode is useful, if the maximum amount power should be saved.

4.4.2 Infineon's COSIC Single Chip Solution for DECT applications

COSIC (Cordless Single Chip) provides a number of features that can be used to reduce overall system power consumption in order to achieve long standby and talk times as well as allow the usage of cheaper batteries. For all the functional blocks there are power measures for example to enable/disable or scale the operation activity according to the workload demand. The functions can be grouped into the following subsystems:

System: Measures that have influence on the total system operation (e.g. system clock)

Processor Cores: Measures that have influence on the operation of the CPU, ADSP and DDSP.

DECT: Measures that have influence on the system operation of the DECT part (BMC, BB, RF, PA).

AFE: Measures that have influence on the operation of the codec and analog front end for audio and line interface.

Peripherals: Measures that have influence on the operation of other functional modules and interfaces such like SSC/SPI, I²C, PWM, LCD, Measurement interface, PCM, and GPIOs.

Power Supply: Measures that control voltage regulators in order to disable the power supply for entire subsystems. In addition to disabling certain modules they are also cut off from their power supply which allows reducing power consumption in idle mode to the lowest possible minimum.

List of Power Management HW Features:

1. System Power Management

   PLL Off: If the PLL is turned off it is switched to bypass mode, so the CPU is supplied with a low frequency clock of only 2.5MHz instead of 31 or 62MHz. This could be used for idle or power down modes, but special care should be taken if this is used by the user SW to avoid any problems for the BMC FW running in parallel.

2. Processor Cores Power Management

   CPU Clock Select: The CPU clock frequency can be selected to 31 or 62MHz.

   CPU Idle: The clock to the CPU core can be switched off. Any enabled interrupt will wake up the system again.

   CPU Power Down: The clock to the CPU core and its peripherals can be switched off. Only a reset will wake up the system again.

   CPU Standby: The complete CPU clock tree can be switched off thereby setting it into a standby mode. Any enabled interrupt will wake up the system again.

   CPU Microsleep: The firmware can write a value to the MICROSLP register and the CPU will be held in sleep mode for the number of clock cycles configured in MICROSLP. The CPU is waked up after this number of clock cycles or earlier because of a watchdog reset or normal reset. This function must not be used by user software but only by BMC firmware.

   ADSP Clock Select: The ADSP clock frequency can be scaled down by a factor of 2, 4, 32 or 128, so the following clock frequencies can be realized at the ADSP: 124MHz, 62MHz, 31MHz, 4MHz and 1MHz. When TSC_CLC.DVE is set to 0 the clock division is disabled and the output clock is 124MHz (=12*10.368MHz). This is the default setting and is the normal operation mode. When TSC_CLC.DVE is set to 1 the clock division is enabled and the clock is divided based on the contents of the register TSC_DIV and therefore the ADSP runs with reduced clock frequency

   ADSP Stop Mode: When TSC_CLC.STP is set to 1 the clock is stopped which puts the ADSP into stop mode. In this mode the clock of the ADSP is stopped by keeping the clock constantly low. The next interrupt reactivates the clock and clears the bit TSC_CLC.STP. When returning from stop mode the contents of the RAM and the registers of the ADSP are unaffected. In this mode the ADSP will only consume low leakage current.

   ADSP Subsystem Power Down: The complete ADSP subsystem is powered down by setting MSM_CTRH.PD which can be used for example in idle mode when no call is active.

   DDSP Power Up/Down, DDSP Clock Disable: The DECT DSP subsystem can be disabled if not used, e.g. if there is no active call. This is done by programming the PU and DISCLK bits in the DECT DSP Command Register (DCMD), however, the user SW must not access this register directly. Since programming has to be done in a specifc way, this is performed by the DDSP Firmware delivered by Infineon, and the User SW can just initiate to enable/disable the DDSP via the Firmware.

3. DECT

Fixed RF Transmit Power Control: A major part of the system power consumption is determined by the RF transmit power that is controlled by the BMC Firmware. The PA output levels can be programmed to stepless variable values between -38.0dBm and 26.5dBm (for DECT6.0: -38.0...23.0dBm). This can be used to implement "DECT ECO Modes" or "Green Modes" reducing radiation and power consumption.

Adaptive RF Transmit Power Control: In addition to the fixed RF transmit power control the Infineon specific implementation for adaptive RF transmit power control allows to further reduce RF power consumption down to the minimum while maintaining a perfect cordless link. The BMC firmware continuously monitors the RSSI values and communicates that information to the remote link partner which in turn adapts its PA output power dynamically according to the remote receive signal quality.

4. AFE (Analog Front End)

Audio/Line Codec On/Off: The system clock for the audio/line codec channels 1 and 2 including their hardware filters can individually be enabled/disabled.

Audio Path 1/2 Power Up/Down: The audio path of channels 1 and 2 can individually be enabled/disabled.

DAC On/Off: The Digital to Analog Converters (DACs) of channels 1 and 2 can individually be enabled/disabled.

HO1P, HO1N On/Off: The analog output buffers HO1P/AOP and HO1N used for headset/earpiece or line interface can individually be enabled/disabled. For the line interface only HO1P/AON is used, so the HO1N output buffer can be disabled separately.

HO2 On/Off: The analog high power output buffer (HO2P and HO2N) for the loudspeaker can be enabled/disabled.

MIC Supply On/Off: The power supply for the microphone can be enabled/disabled.

Central Biasing On/Off: The central biasing circuit for the entire AFE can be enabled/disabled.

5. Peripherals

Measurement Interface On/Off: The measurement interface module can be enabled/disabled.

SSC On/Off: The SSC module can be enabled/disabled.

I²C On/Off: The I²C module can be enabled/disabled.

PCM On/Off: The PCM module can be enabled/disabled.

PWM On/Off: The PWM module can be enabled/disabled.

LCD On/Off: The LCD module can be enabled/disabled.

Interfaces On/Off: Unused interfaces can be switched off via the SIGMUX settings. It must be noted that only the I/O pads are switched of, the corresponding interface module must be switched off separately.

6. Power Supply

VIOREG On/Off: The power supply for the I/O interfaces can be enabled/disabled.

VANAREG On/Off: The central power supply for the entire AFE can be enabled/disabled.

VDDDCDCREG On/Off: The DC/DC converter can be enabled/disabled. In normal mode it supplies the AFE (VANAREG), the white LED driver (VDDWLREG) and the I/O supply regulator (VIOREG). If those are not needed in power saving mode the DC/DC converter can be switched off

5 Profiling results in active mode

This section consists of tables summarising the energy consumed by the appliances when they operate in any of the internal functions that have been identified in section 4.

The methods used for measuring energy consumption are documented in section 3, while the internal appliance functions that are going to be supported are documented in section 4.

Particularly for A/V and communication equipment the power down modes are included in this chapter, as active and inactive modes cannot sometimes be clearly separated. For example a TV Set or a set-top-box have a multitude of power states, with lower clocked CPU, disk on/off, monitor on/off etc.

5.1 White goods

In this section there have been summarised all profiling results concerning the selected three household appliances:

- *Refrigerator:*

  The refrigerator is the only white goods appliance, which is always switched-on. In this case it is not appropriate to differentiate between profiling energy consumption in active mode and standby mode. By means of measurements standards described in section 3.1, following energy consumption have been measured:

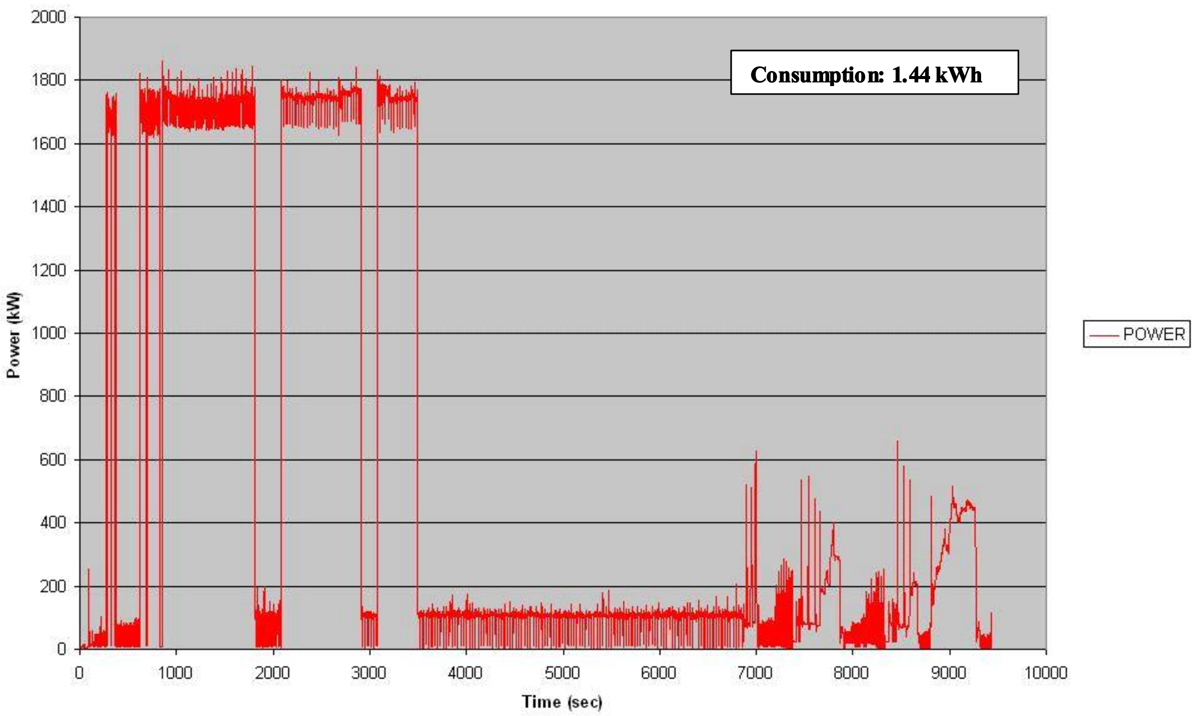
  - 339 kWh/year
  - 0,93 kWh/day

  The power consumption during the defrosting cycle is 150 W for about 30 min, resulting in about to 0,075 kWh/day. Values have been obtained with **one** defrost cycle per day. The frequency of the defrost cycles depends on various factors like door opening external temperature, consumer habits etc.

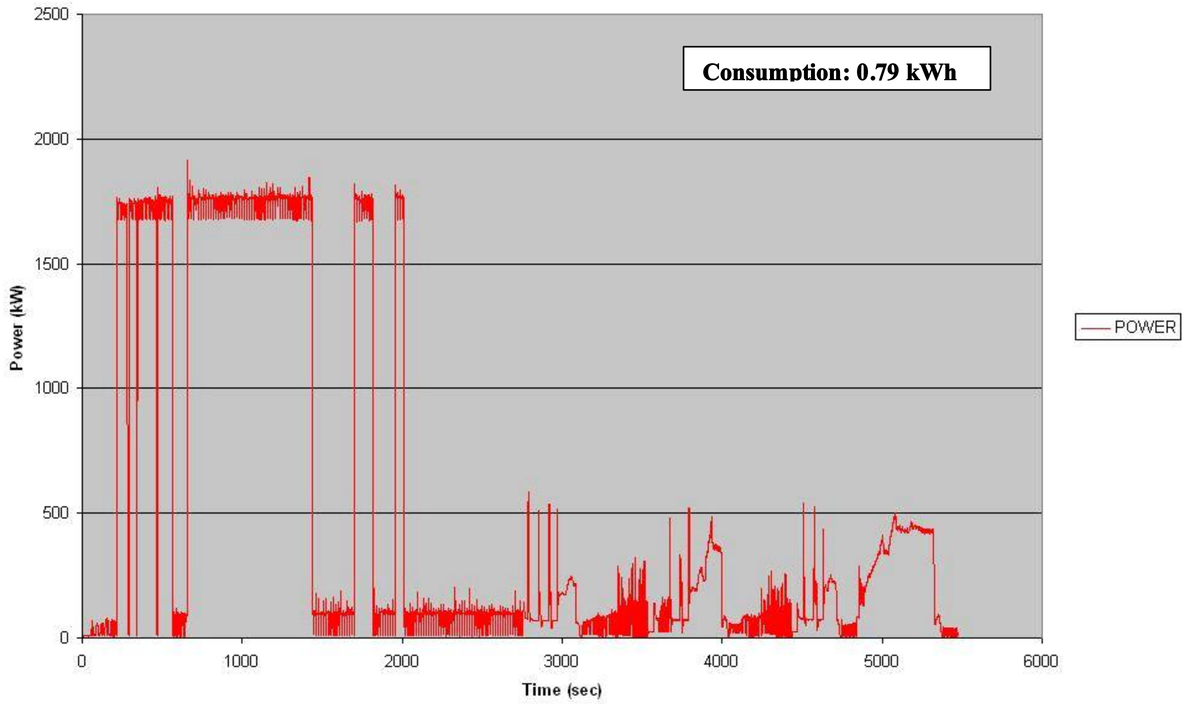
- *Washing machine:*

  Energy consumption tests have been made according to the aforesaid standard procedure and results are showed following:

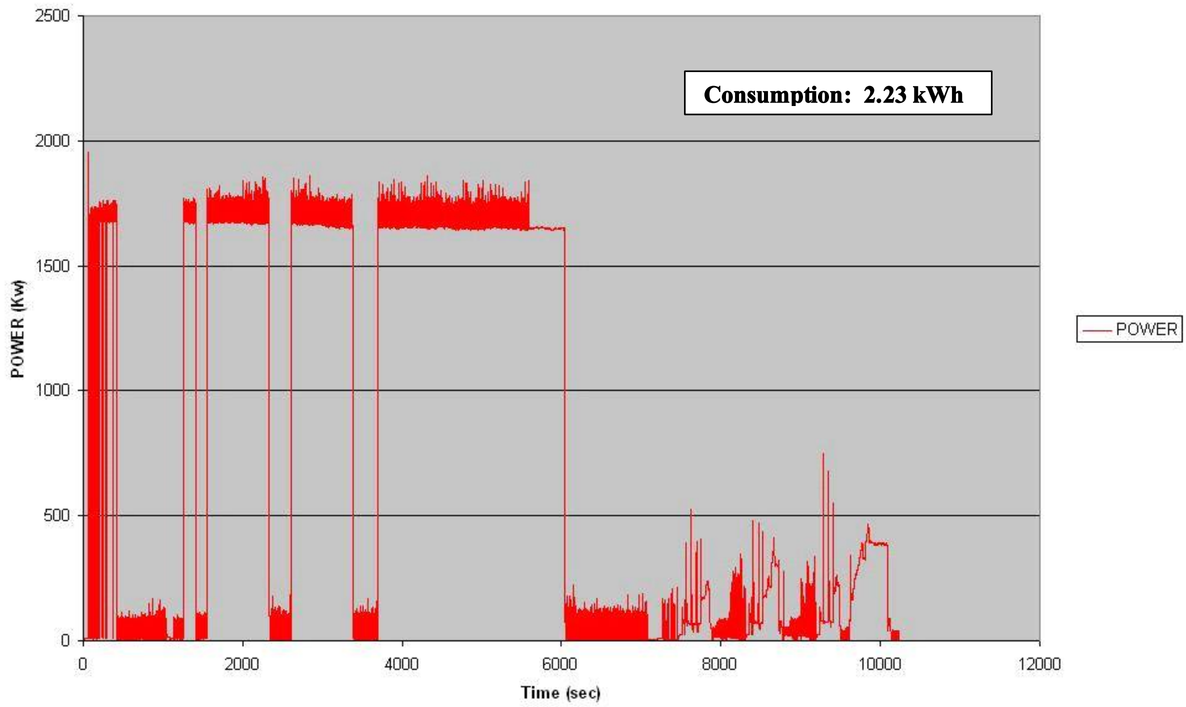
  - White cotton cycle
    - Load = 7 kg
    - Energy consumption = 1,44 kWh
    - Max Peak Power = 1,85 kW



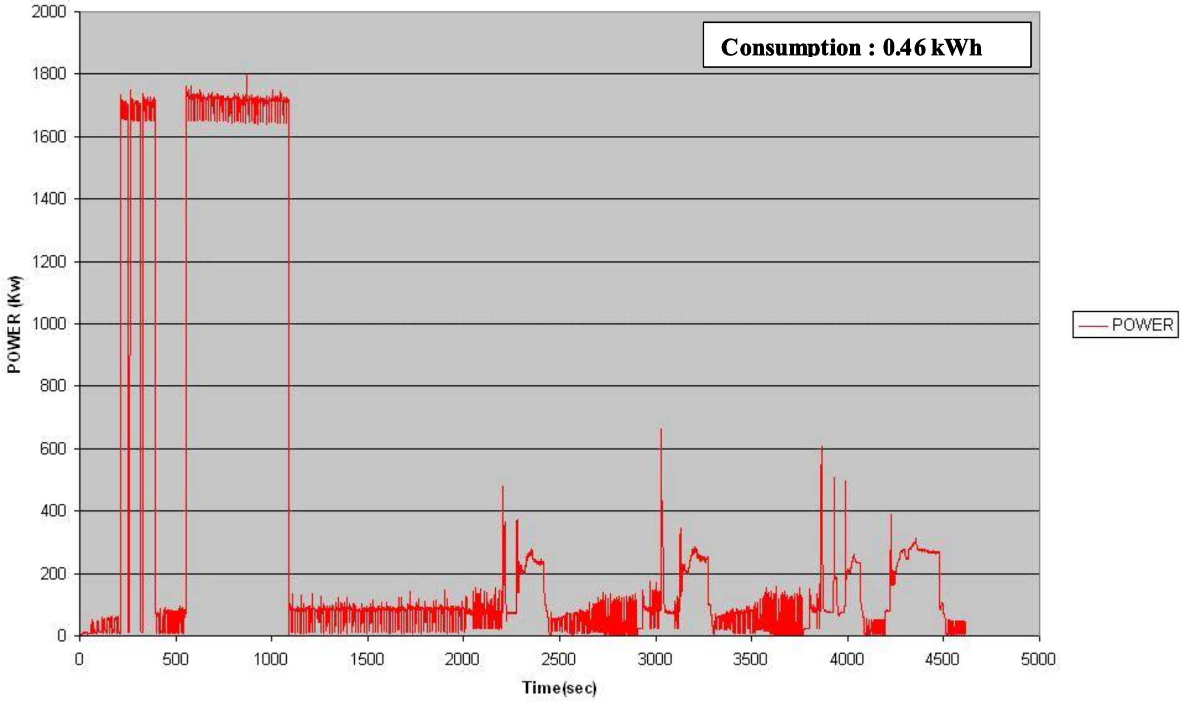
- Colorfast Cotton
  - Load = 7 kg
  - Energy consumption = 0,79 kWh
  - Max Peak Power = 1,9 kW



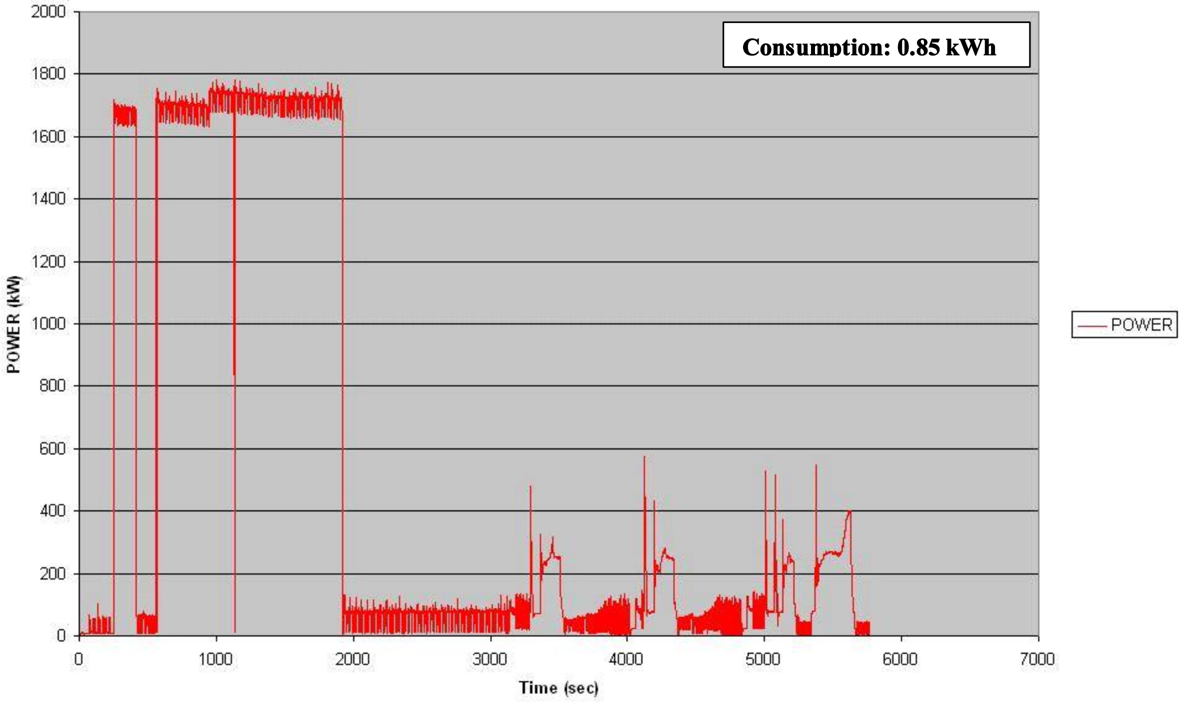
- Cotton with prewash
  - Load = 7 kg
  - Energy consumption = 2,23 kWh
  - Max Peak Power = 1,86 kW

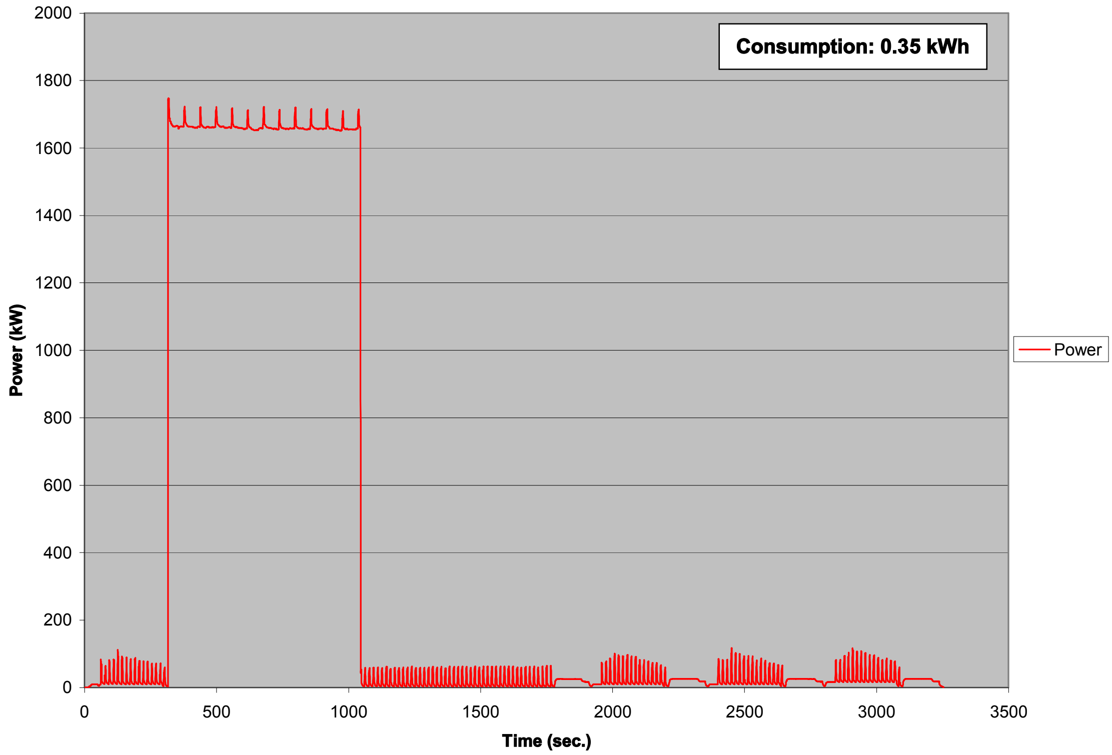


- Synthetics delicate
  - Load = 7 kg
  - Energy consumption = 0.46 kWh
  - Max Peak Power = 1,75 kW

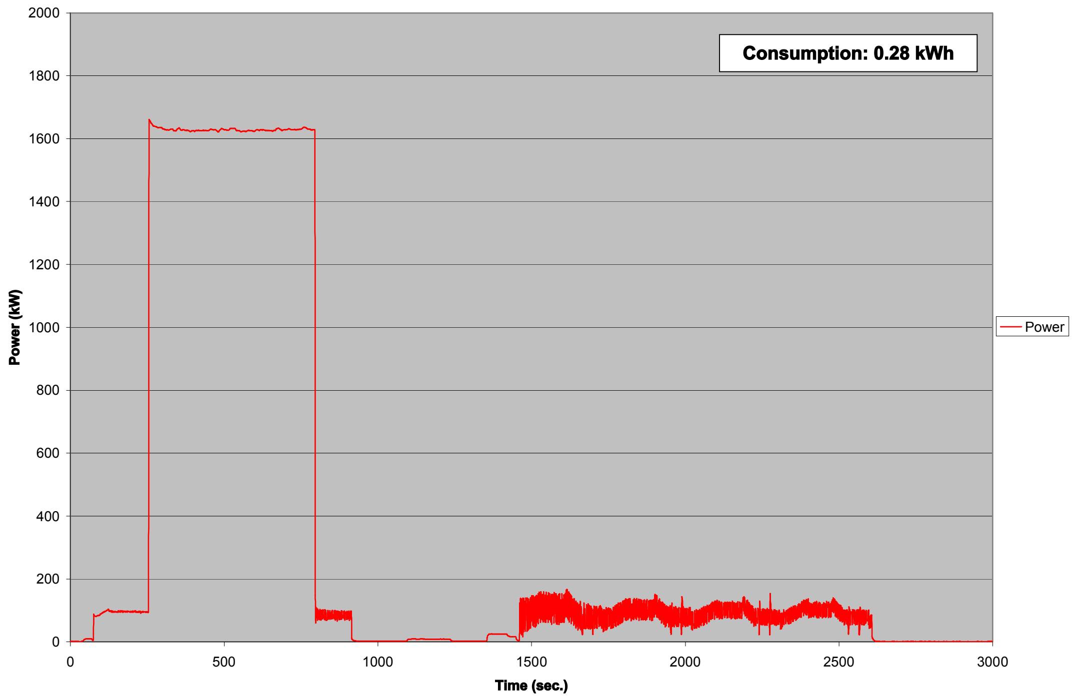


- Synthetics not delicate
  - Load = 7 kg
  - Energy consumption = 0.85 kWh
  - Max Peak Power = 1,77 kW





- Wool
  - Load = 5 kg
  - Energy consumption = 0.28 kWh
  - Max Peak Power = 1,66 kW



- *Oven*

  Standard energy consumption measurements as to CEI EN 50304 [8] have been performed in all three compartments (XL, M, S) with following results:
  - The total energy consumption measured in the big compartment (XL) is:921 Wh

- o The total energy consumption measured in the medium compartment (M) is: 827 Wh
- o The total energy consumption measured in the small compartment (S) is: 759 Wh

5.2 A/V

The profiling setup was explained in Section 4. In this section we provide actual results (given in Watts) for the different appliances we considered and the different operation modes that they support. In this paragraph we try to deduce some useful conclusions from these results. One observation we can make about these results is that the standby operation consumes little power in nearly all of the devices regardless of their functionality. The reason is that all the A/V devices are fairly optimized internally since they are able to shut down particular components at their discretion. This is an ongoing trend that we expect to continue in the future, i.e. highly optimized devices. Therefore, we expect that for an energy management (EM) system like AIM, it is enough to export and notify the system that the appliance is in standby mode without specific information about the energy consumption in that state. On the other hand, we also observed that the power consumption of different appliances varies significantly in active mode which is a result we anticipated, given the diversity of the used appliances. What this also means is that there is little or no value in defining and embedding generalized application states into an EM system. For example a state "DVD Play", will vary considerably in terms of functionality power consumption across different versions of the product and different manufacturers. This means for example that devices should export to an EM system appliance-specific states that are identified and selected locally by each device. Furthermore, each device should also be able to provide to the system the specific energy consumption of each supported/defined active mode.

CD Play	DVD Play	RF	Record	FM Radio	Tuner	Standby	Standby eco mode	Total
DVDR 3600								
15 W	15 W	-	-	-	-	2,5 W	-	33 W
HDR3600								
-	27 W	26 W	26 W	-	-	4,0 W	1,9 W	57 W
HTS6100								
31 W	31 W	-	-	29 W	-	0,27 W	-	91 W
MCM393								
10,43 W	-	-	-	-	8,65 W	0,96 W	0,96 W	21 W
DVDR5500								
-	20 W	20 W	-	-	-	4,2 W	-	44 W
HTS6600								

18 W	19 W	-	-	16 W	-	0,3 W	-	53 W
HTS8100								
22 W	22 W	-	-	20 W	-	0,3 W	-	64 W
TV - 40PFL9704H/12 - 1920 x 1080p								
92W						0,15W		-
TV - 46PFL9704H/12 - 1920 x 1080p								
104W						0,15W		-
TV - 52PFL9704H/12 - 1920 x 1080p								
116W						0,15W		-

5.3 Communication equipment

Infineon as a microchip manufacturer has no appliance products. Although in some cases the microchips are the key element of an appliance it is not possible to derive the energy consumption of the appliance. As a main cause the mains adapter efficiency significantly influences the energy consumption. Especially home consumer devices are under a strong cost pressure. A cheap adapter has about 50% efficiency, while a high quality switched mode mains adapter can have up to 90% efficiency. In addition there might be more circuitry in a device around the main chips.

As all semiconductor manufacturers Infineon provides evaluation boards and demonstration systems with their devices. Nevetheless, Infineon is involved in production of commercial products through associate manufacturers, form who the following energy consumption figures stem.

Telecom device	Manufacturer/ Device name	During charge	Standby	During Call (On mode)
IP phone	Siemens/Gigaset C470 IP	n.a.	0.5 W	1.3 W
Cordless phone	Siemens Gigaset S450	n.a.	2 W	3 W

Datacom device	Manufacturer/ Device name	Idle (Low-power)	On
DSL Modem	Radicom SlimModem3	0.1 W	0.268 W
Ethernet Router	O2Link router	2.4 W	3.4 W
Ethernet Switch w. PoE	D-Link DWL-2230AP	n.a.[2]	6 W without PoE 8 W with PoE
Ethernet Switch	D-Link DGS-2208	2 W	5 W
WiFi hot spot	D-Link DWL-G700	2 W	6 W

Infineon's DECT single chip solution COSIC (Cordless Single Chip) is part of many DECT equipment. Here is the consumption of this module in different modes (the supply voltage is 3.3 V):

power supply current, operational mode, full output power	40 mA
power supply current, operational mode, reduced output power (-10dB)	25 mA
Power supply current, idle–locked mode	2 mA

[2] Switch with PoE can not be in idle mode, because PoE must supply power to the client devices.

Concerning home gateways datacom equipment (or otherwise called IAD-Integrated Access Device, synonym for Home Gateway), four different models were measured in the two active mode operating cases, that is, the low power state and on state. The conditions under which power measurements were taken are summarised in Table 4.

State	ADSL2+	Ethernet LAN connected	Ethernet link 10/100 mbps	Ethernet payload (yes/no) (Mbps)	WLAN	WLAN 11b/g/n	WLAN payload (Mbps)	DECT	DECT call	FXO / POTS	FXS -Phone Number connected/open /state	telephony SW enabled	USB
LowPower	trained	1x	100Mbit	no payload	on	11g 100%	no payload	disabled	no call	not_connected, no call	1 on hook, 1 open	yes	not_connected
ON	trained	2x	100Mbit	yes	on	11g	20	disabled	no call	not_connected, no call	1 active call VOIP G711, 1 open	yes	not_connected

Table 8: Measurement conditions

Measurement results for the four different commercial products are summarized in Table 9[3].

System	State	Power at CPE input	quality power supply efficiency	Power at 230V quality ext supply
		(W)		(W)
IAD System 1	On	**8,13**	82%	**9,94**
IAD System 1	Low Power	**5,86**	79%	**7,43**
IAD System 2	On	**10,26**	84%	**12,22**
IAD System 2	Low Power	**9,14**	83%	**11,03**
IAD System 3	On	**11,28**	85%	**13,31**
IAD System 3	Low Power	**10,21**	84%	**12,17**
IAD System 4	On	**9,88**	84%	**11,82**
IAD System 4	Low Power	**8,70**	82%	**10,55**

Table 9: Measurements of four home gateways (IAD)

From Table 9 average values for residential gateways are calculated as following:

- Average power consumption in on state: 11.8W
- Average power consumption in low power state: 10.3W.

As is denoted in the tables above, not all communication equipments have standby modes. Instead, for those appliances not supporting that function, low power consumption is achieved in the idle state. Furthermore, some appliances don't support lower energy consuming functions in form of discrete operation mode. For such appliances lower energy consumption can be achieved indirectly, for example through lower communication rates.

[3] For confidentiality reasons the names of the vendors of the products are not disclosed.

6 Profiling results in standby mode

As household appliances' technology evolve new functions are made available as new operation modes promising to the user a more comfortable and ubiquitous use of the appliance. Among these new modes the standby mode has appeared on the market over the last decades with the objective of making appliance's services available with a press of a button.

Standby, also known as phantom power loads, are responsible for an incredible amount of electricity consumption. Practically every electronic device that is plugged into a socket continues to consume electricity after it is switched off. Examples include phone charges, notebook power adaptors, microwave ovens, game consoles, CD, video and DVD players.

Worldwide surveys have shown that the energy consumed by appliances in standby mode accounts for the 10% of the total energy consumed in households.

To help reduction of standby energy consumption, many manufacturers have chosen to motivate the users to unplug appliances when they are not used.

People might wonder why chargers don't have an off switch. Turning a charger off completely – so that is uses zero watts - can be only done using a hard switch. For safety reasons, this switch had to be placed on the charger block itself (the bit that plugs into the wall) not on the cable. It would be just as easy to unplug the charger as it would be to use this switch.

If, instead of a hard switch, there was an electrical switch it would be always a component connected to mains. So, although people might think the charger is switched off, it's really on a kind of standby and could still be using around 20mW.

So that's why manufacturers don't put an on/off switch on chargers at the moment. Instead, they encourage people to pledge to unplug their chargers, and incorporate reminders in all devices.

A charger that cuts out when the phone is full could be made, but doing so would need adding a lot of components to the charger to make it work. The environmental impact of doing this - in terms of the materials used and the energy it would take to produce them - would cancel out the benefits.

Also, as in the case of the on/off switch, it could mean the charger was still consuming energy when you thought it was off.

The industry is working on finding a long term, sustainable solution and in that context there new technologies under development and testing. Working in the same are AIM is trying to solve the problem with the design of a 'clever' outlet, the EMD, which will monitor appliance mode and perform switch off automatically following a number of rules presented in D2.2.

In order for the EMD to understand whether an appliance is in standby mode it needs to know either the amount of energy it consumes when in standby mode or be informed on by the appliance with appropriate command.

In addition, energy consumption in standby mode is needed in order to allow us measure the efficiency of the AIM system concerning its ability to save energy through standby devices management.

Therefore, the reason for needing the energy consumed in standby mode profiled is twofold. Firstly to be able to trace down appliances that are in standby mode when there is no mechanism for making known to the network the state of the appliance and secondly to be able to calculate in real time the energy that households consume.

This chapter consists of tables summarising the energy consumed by appliances when they are in standby mode.

6.1 White goods

The white goods belong to the category of easily manageable appliances concerning instantaneous energy consumption.

Taking into account the type of functions they provide we can easily deduce that from the three appliances types addressed in the project, only the washing machine can be highly benefited from standby management.

The standby management will be implemented by the EMD, in cooperation with the service logic of the residential gateway, as automated switching over between standby and OFF states on certain occasions, such as:

- The washing machine program is finished,
- during the night (cut-off time can be user programmable),
- permanent/long term leave,

Following, we summarise all profiling results obtained in standby mode for the three addressed appliance types:

- *Refrigerator:*

  As said for the active mode, the refrigerator is the only white good appliance that is always switched-on. Therefore there is no standby mode.

- *Washing machine:*

  This type of washing machine appliance has a logical switch on/off button. Therefore, when the device is switched off, there's still a minimum of power needed for the energy supply of the electronic mainboard. Energy consumption in standby mode and in off mode has been measured and results are following:

  - "Standby" state = 1,7 [W]
  - "Off" state = 1,0 [W]

- *Oven*

  Indesit electronic ovens, when connected to the mains, could have either two functioning states ("standby" and "run" mode) or three states ("standby", "on" and "run" mode):

  - "Standby" mode: user Interface visualizes always time;
  - "On" mode: after logical switch on the user interfaces shows all possible programs;
  - "Run" mode: when cooking cycle is running, user interface shows progressive cooking status;

  The selected oven has only 2 states ("standby" and "run" mode) and the energy consumption in standby mode is 3W.

6.2 A/V

All A/V appliances have standby modes so that they can be switched on and off using remote control. Considering the functions each of the supported A/V equipment maintains in standby mode, these can be found in the respective tables of chapter 5. For a detailed overview of all A/V equipment consumption figures in standby mode refer to section 5.2.

As is going to be specified in D2.2, switching between the standby and OFF sates will be performed by the EMD, taking into account usability factors, with some of them being:

- Presence of users at home,
- time zone & movement of users between rooms,
- on permanent/long term leave

More details on mode switching decision making of the EMD may be found in D2.2 and D3.1.

6.3 Communication equipment

Communication equipments usually do not have standby modes. Instead, manufacturers encourage their users to unplug them each time they do not use them.

Therefore the AIM work on implementation of OFF modes for communication equipments is expected to have great impact on saving energy consumed by such devices, because it will help sparing energy for several appliances under several occasions. For example, for xDSL modems left open during the night or wireless hot spots not serving anyone.

As in the case of the previous two appliance categories, implementation of switching between ON and OFF states will be also implemented by the EMD, automatically, under a number of usability factors, e.g.:

- Hot spot switching: when no user is in the coverage area,
- all communication equipment: during the night (cut-off time can be user programmable),
- on permanent/long term leave.

For a detailed overview of communication equipment consumption figures in standby mode refer to section 5.3.

A summary of energy profiles for appliances and devices used in the project can be found in Annex A.1. A summary of energy profiles for appliance and devices manufactures outside the project can be found in Annex A.2.

Details on mode switching decision making of the EMD may be found in D2.2 and D3.1.

7 Conclusions

The results obtained in this document were twofold. On one hand, intensive discussion about appliance profiling methodologies provided new aspects of energy consumption of household appliances, in general, and in particular new methods for appliance profiles normalisation, taking into account proceedings of standardisation bodies, future-proof concept of solution and integration aspects in energy saving applications. On the other hand it has been obviated that although appliances categorisation did not lead to a single profiling methodology, it helped to identify appliance specificities to be addressed by the AIM architecture in its specification phase.

Yet, an important issue throughout analysis of appliance power modes, was the systematic work in collecting energy consumption values and operation modes for appliances of manufacturers outside the AIM consortium. Thanks to this work the energy consumption figures included in this deliverable are so generic as to represent a wide part of manufacturers in the area. The obtained profiling results will be useful for final definition of the AIM architecture [10].

Annex A: Summary of Appliance Profiles

Annex A.1: Profiles from appliances used in the project

The energy profiles of the appliances addressed in the project are summarized in the table below:

Appliance type	Model	Standby consumption	Active mode consumption
White goods			
Refrigerator	All	-	Normal operation: 0,93 kWh/day Defrost cycle: 0,075 kWh/day
Wash machine	All	1,7 W	White cotton cycle: min 1,44 kWh, max 1,85 kW Colorfast Cotton: min 0,79 kWh, max 1,9 kW Cotton with prewash: min 2,23 kWh, max: 1,86 kW Synthetics delicate: min 0.46 kWh, max 1,75 kW Synthetics not delicate: min 0.85 kWh, max 1,77 kW Wool: min 0.28 kWh, max: 1,66 kW
Oven	All	3 W	Big compartment: 921 Wh Medium compartment: 827 Wh Small compartment: 759 Wh
Audiovisual equipment			
DVD player	DVDR 3600	2,5 W	CD Play: 15W DVD Play: 15W
Home Theatre system	HDR3600	4,0 W	DVD Play: 27 W RF : 26 W Record: 26 W
Home Theatre system	HTS6100	0,27 W	CD Play: 31W DVD Play: 31W
Micro Hi-Fi System	MCM393	0,96 W	DVD Play: 10,43W

			Tuner: 8,65W
DVD player	DVDR5500	4,2 W	DVD Play: 20 W RF : 20 W
Home Theatre system	HTS6600	0,3 W	CD Play: 18W DVD Play: 19W FM Radio:16 W
Home Theatre system	HTS8100	0,3 W	CD Play: 22W DVD Play: 22W FM Radio:20W
TV	TV - 40PFL9704H/12 - 1920 x 1080p	0,15W	92W
TV	TV - 46PFL9704H/12 - 1920 x 1080p	0,15W	104W
TV	TV - 52PFL9704H/12 - 1920 x 1080p	0,15W	116W
Communication equipment			
IP phone	Siemens/Gigaset C470 IP	0,5 W	During Call: 1,3 W
Cordless	Siemens Gigaset S450	2 W	During Call: 3 W
DSL Modem	Radicom SlimModem3	0.1 W	0.268 W
Ethernet Router	O2Link router	2.4 W	3.4 W
Ethernet Switch w. PoE	D-Link DWL-2230AP	-	6 W without PoE 8 W with PoE
Ethernet Switch	D-Link DGS-2208	2 W	5 W
WiFi hot spot	D-Link DWL-G700	2 W	6 W
IAD System 1	Infineon chipset	5,86W	8,13W
IAD System 2	Infineon chipset	9,14W	10,26W
IAD System 3	Infineon chipset	10,21W	11,28W
IAD System 4	Infineon chipset	8,70W	9,88W

Annex A.2: Profiles from appliances of manufacturers outside the project

Profiles for appliances of manufacturers not participating in the project have been found indirectly through the Code of Conduct agreements.

These agreements are documents worked out together by the EC and the Industry in an effort to control the CO_2 footprint of industrial products.

In the field of household appliances technology, the EC has set in force CoC agreements for "Digital TV Service Systems" [14], "Broadband Equipment" [13].

The table below summarizes the energy consumption thresholds of appliances compliant to these CoCs.

Appliance type	**Consumption in active mode (in Watts)**	**Consumption in standby mode (in Watts)**
Home gateways central functions plus WAN interface		
ADSL/ADSL2/ADSL2+	5	4,2
VDSL2	7,5	5,5
Fast Ethernet WAN (100Base-T)	4,2	2,9
Gigabit Ethernet WAN (1000Base-T)	7	4
Fibre Ptp Ethernet WAN (100/1000Base-BX or FX)	7,1	3,4
DOCSIS 2.0	5,5	5,5
DOCSIS 3.0	8	8
WiMAX	11	8,2
Fast Ethernet switch, up to 4 ports	1,8	0,6
1 Fast Ethernet port	0,4	0,3
Gigabit Ethernet switch, up to 4 ports	3,7	1,2
1 Gigabit Ethernet port	1,3	0,3
Wi-Fi interface single IEEE 802.11b/g or 11a radio	2	0,7
Wi-Fi interface single IEEE 802.11n Draft 2 radio (and other	2,5	1

proprietary pre-n solutions)		
Wi-Fi interface dual (2.4GHz and 5GHz) IEEE 802.11n Draft 2 radio (and other proprietary pre-n solutions)	5	2
Alternative LAN technologies (HPNA, MoCA, POF…)	2,5	2
Powerline	3	2,5
FXS	1,5	0,5
FXO	0,9	0,4
DECT GAP	1,65	0,75
DECT Cat-iq	2	0,75
Central functions + ADSL WAN interface	5	2,6
4 port Ethernet switch	2,2	0,6
Wi-Fi Access Points with single band IEEE 802.11b/g or 11a	3,6	2,3
Wi-Fi Access Points with single band IEEE 802.11n Draft 2 radio (and other proprietary pre-n solutions)	5	3,5
Optical LAN adapter (fiber converter) 10/100/1000 Mbit/s	3,5	3,5
ATA / VoIP gateway	2,2	1,5
VoIP telephone	3,7	3
Audiovisual equipment		
simple digital TV converter - Cable	7	2
simple digital TV converter – Terrestrial	7	2
simple digital TV converter – Satellite	10	2
simple digital TV converter – IP	7	2
simple digital TV converter for high definition TVs-Cable	11	2
simple digital TV converter for high definition TVs – Terrestrial	11	2

simple digital TV converter for high definition TVs – Satellite	14	2
simple digital TV converter for high definition TVs – IP	11	2
STBs -Cable	7	3
STBs –Terrestrial	6	3
STBs –Satellite	8	3
STBs -DSL	6	3
TVs with Cable connection	n/a	1,5
TVs with Terrestrial connection	n/a	1,5
TVs with Satellite connection	n/a	1,5

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[13] European Commission, “Code of Conduct on Energy Consumption of Broadband Equipment”, November 2008.

[14] European Commission, “Code of Conduct on Energy Efficiency of Digital TV Service Systems”, January 2008.