



# Network Connected Audio Products

Measurements and Analysis of Network Standby Consumption

Prepared for IEA 4E EDNA

**JULY 2016**

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The Implementing Agreement on Energy Efficient End-Use Equipment (4E) is an International Energy Agency (IEA) Collaborative Technology Programme established in 2008 to support governments to co-ordinate effective energy efficiency policies. Twelve countries have joined together under the 4E platform to exchange technical and policy information focused on increasing the production and trade in efficient end-use equipment. However 4E is more than a forum for sharing information – it pools resources and expertise on a wide a range of projects designed to meet the policy needs of participating governments. Participants find that is not only an efficient use of available funds, but results in outcomes that are far more comprehensive and authoritative than can be achieved by individual jurisdictions.

Current members of 4E are: Australia, Austria, Canada, Denmark, France, Japan, Korea, Netherlands, Switzerland, Sweden, UK and USA.

Further information on the 4E Implementing Agreement is available from: [www.iea-4e.org](http://www.iea-4e.org)

Network connected devices, including the Internet of Things, are growing rapidly and offer enormous opportunities for improved energy management. At the same time, there is a responsibility to ensure that these devices use a minimal amount of energy to stay connected. 4E's Electronic Devices and Networks Annex (EDNA) works to align government policies in this area and keep participating countries informed as markets for network connected devices develop.

Further information on EDNA is available at: <http://edna.iea-4e.org>

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# 1 Network Connected Audio Products

## 1.1 Introduction

The way people consume music and other audio content has changed in the past few years. There is a desire to listen to music anytime and anywhere, without any limitations. This is made possible by streaming media from the Internet from providers like Spotify, Napster and Apple Music. Alternatively, streaming of stored media content from a central storage unit in the consumer’s home, e.g. a NAS (Network Attached Storage) is increasingly popular.

To play streamed media at home the consumer needs to have one or more network connected audio products (NCAP) like streaming clients, connected amplifiers and active speakers, which are mainly connected wirelessly. These components are often part of so called multi-room audio systems.

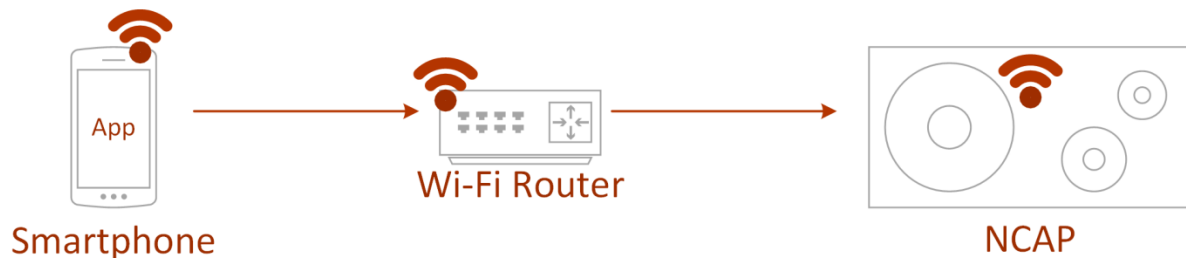
In the following sections it is explained how network connected audio products (NCAP) are used and how they are composed.

## 1.2 Explanation of terms

A network connected audio product is a device that is able to process and/or play audio content that is received as a stream from a source that is located in a Home Area Network (HAN) or in the cloud (the world wide web). The source in the HAN may be a mobile client (smartphone, tablet), a personal computer, a NAS or a Smart TV. The source in the cloud may be an internet radio station or, more often, a music streaming service like Spotify, Apple Music, Deezer, to name but a few.

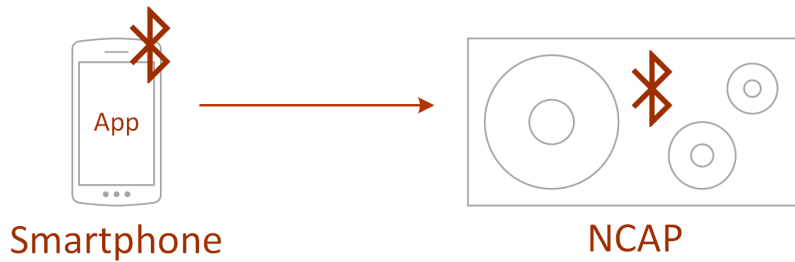
## 1.3 Use Cases

All investigated NCAPs for this study were required to be setup with the help of a smartphone app, usually provided by the manufacturer. In the simplest use case, the user only has to provide a Wi-Fi network. Once connected to this Wi-Fi network, the NCAP can be controlled by the smartphone app and music may be streamed from the smartphone to the NCAP. In this use case, not even an internet connection will be used (see Figure 1). Alternatively, the NCAP may be connected by wire (Ethernet) to the router.



**Figure 1: Basic use case for network connected audio products: Connection via Wi-Fi router**

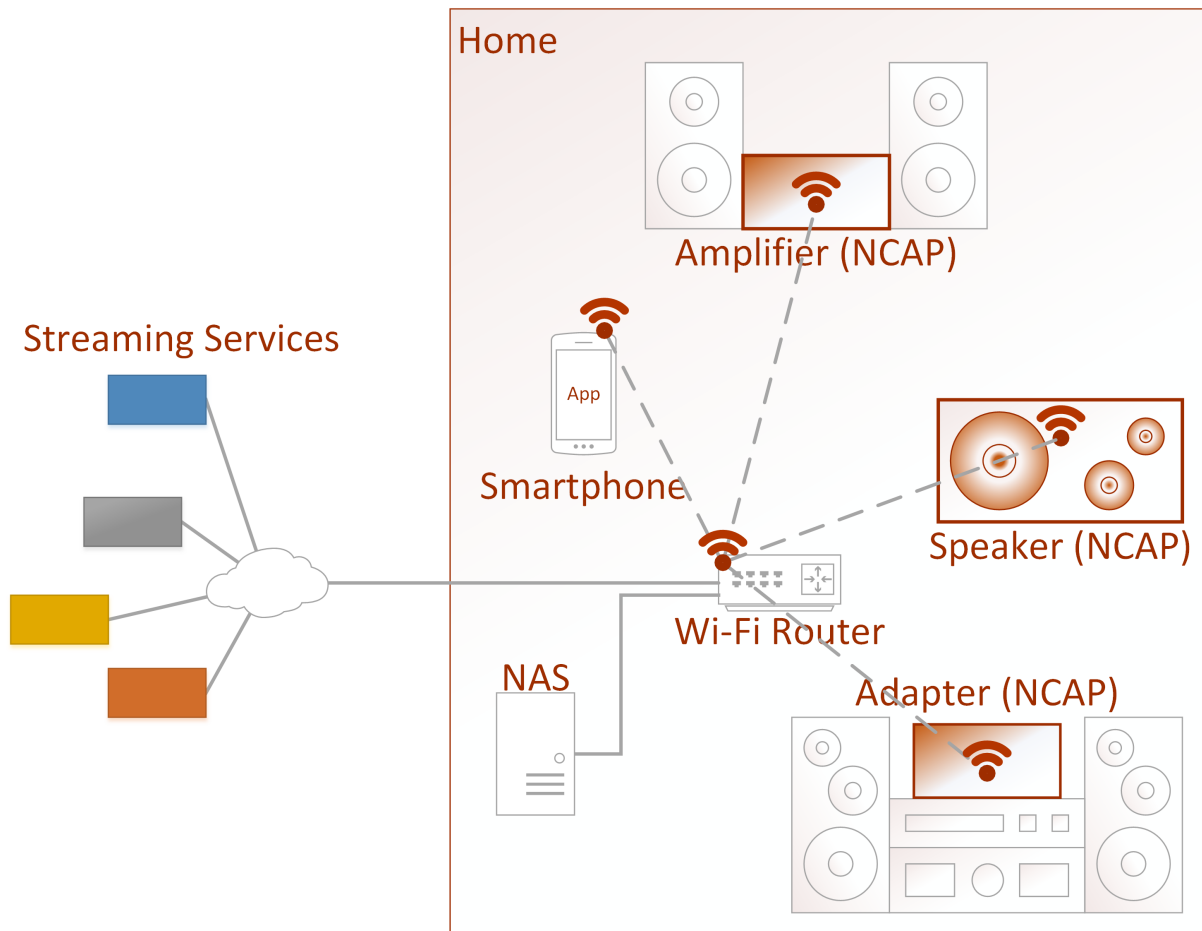
Some NCAPs offer the ability to directly connect to a smartphone or tablet using Bluetooth as shown in Figure 2. In this even simpler use case neither a Wi-Fi Router nor an internet connection is needed.



**Figure 2: Basic use case for network connected audio products: direct connection via Bluetooth**

In a more complex use case, multiple NCAPs are (wirelessly) connected together to build a multi-room audio system, which allows simultaneous playback of audio content in different rooms. The setup of a generic multi-room system is shown in Figure 3.

Inside a house or a flat, each room may be equipped with one or more NCAPs which are connected to the local Wi-Fi network. One or more smartphones/tablets can be used to control each of the NCAP and to stream audio contents. Sources of audio contents may be the smartphones/tablets, a NAS inside the same local network, a smart TV (not shown). If the network is connected to the worldwide web – which is often the case – it is possible to stream audio contents from various streaming services or from internet radio stations. Most systems allow playing the same audio content simultaneously in each room or playing different content in different rooms.



**Figure 3: Setup of a generic Multi-Rooming System**

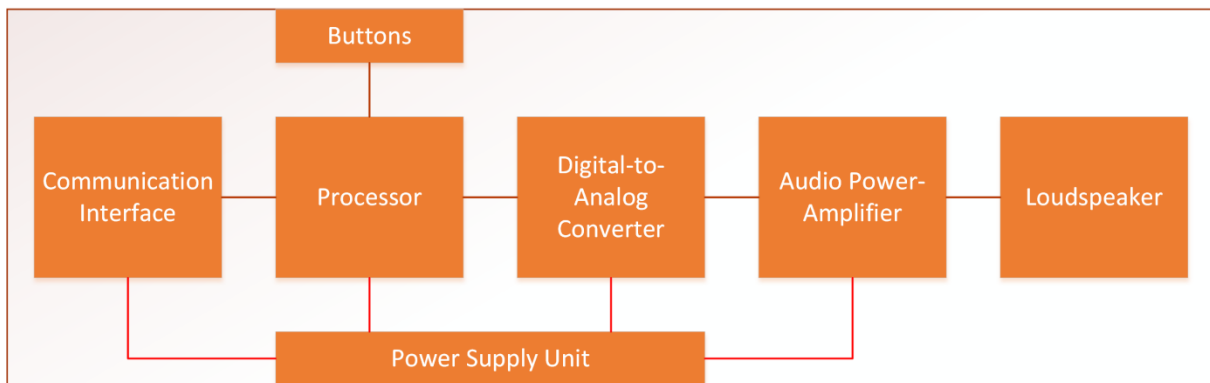
## 1.4 Device Types

### 1.4.1 Speaker

The most popular type of NCAP is the network connected speaker. Due to their ability to play audio content directly from a network without the need for additional components, network connected speakers are often called *network players*.

A speaker connects to a network and receives a digital audio stream from a network source. It continuously decodes the received audio stream and converts it to an analogue audio signal that will be amplified and played over the loudspeakers.

The typical design of a network connected speaker, as derived from a tear-down of some products, is shown in Figure 4. The subsystems shown in Figure 4 are described below.



**Figure 4: Typical design of a network connected speaker.**

#### *Communication Interface*

To connect to a network and receive digital audio contents, an appropriate interface is needed. All investigated speakers have at least a Wi-Fi interface to connect to the local network. The majority had an additional Ethernet interface to build a wired connection to the internet router. A minority of the investigated speakers have additional interfaces like Bluetooth or Near Field Communication (NFC) to connect directly to another Bluetooth or NFC enabled device without the need for a local network.

#### *Processor*

Each speaker needs a processor to control all other parts of the player and to process the digital audio stream. It is possible to split these functions into separate components: a control unit and a digital signal processor. But the majority of the products integrate these functions into one component.

#### *Digital-to-Analog Converter*

To convert the digital audio stream into a continuous analog audio signal, a digital-to-analogue converter (DAC) is needed. The DAC can be integrated into the processor. But some products, especially high-end products, may have a separate DAC to process the audio stream, which can result in better sound quality.



### *Audio Power-Amplifiers*

After converting the digital audio stream into an analog signal, it has to be amplified so it can be replayed by the loudspeakers.

### *Loudspeakers*

All speakers have one or more loudspeakers to replay the audio content. Loudspeakers are passive components which only draw power if they are driven by an amplifier.

### *AC/DC Power Supply*

Regarding the power consumption of a network speaker or NCAP in general, the power supply plays an important role. The power supply has to reliably deliver the needed DC-power to all components. Thus the higher the maximum power needed by the system, the larger the power supply has to be.

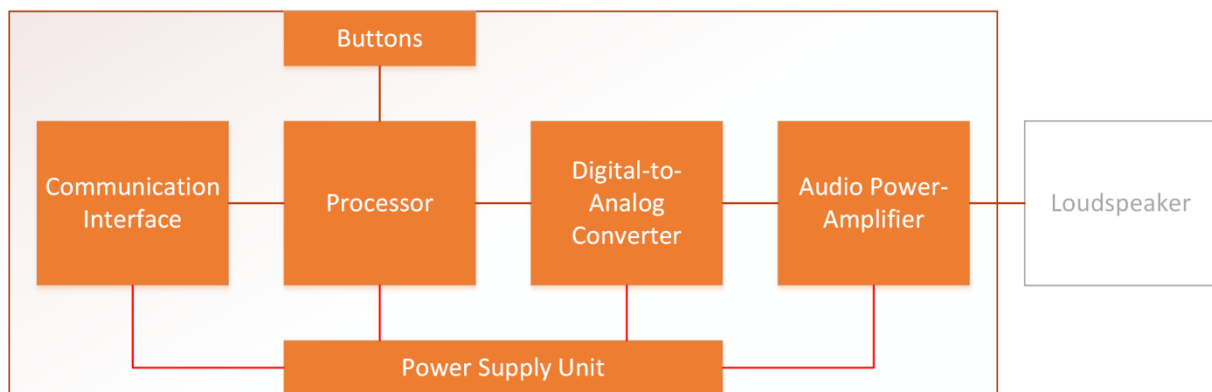
### *Buttons*

For basic controls, e.g. to turn on/off or to reset, all NCAPs have some buttons. Usually these are passive components which do not draw any power at any time.

## 1.4.2 Amplifier

Network connected audio amplifiers work the same as the above mentioned speaker, with the difference that they have no built-in loudspeakers. They are used to connect conventional loudspeakers to a multi-room system.

The typical design of a network connected audio amplifier is shown in Figure 5.

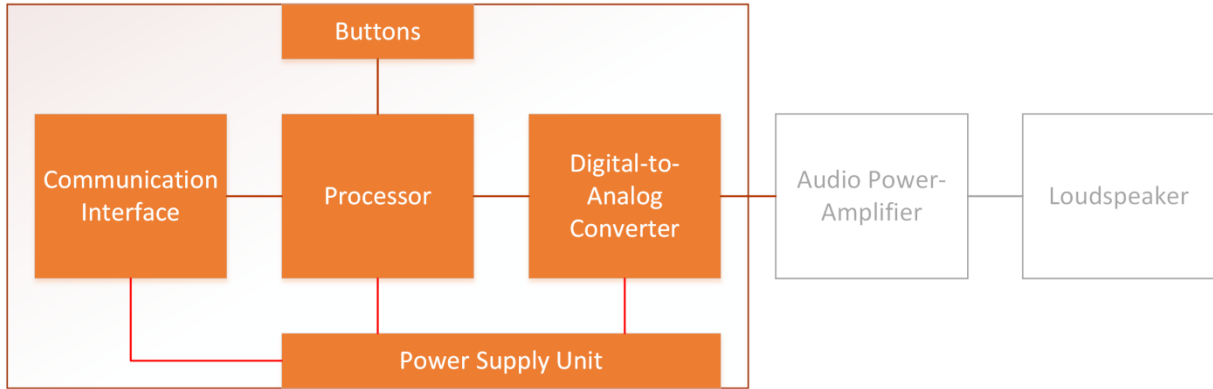


**Figure 5: Typical design of a network connected audio amplifier**

## 1.4.3 Adapter

Network connected audio adapters are used to connect conventional Hi-Fi systems to a multi-room system. They receive and decode a digital audio stream and convert it to an unamplified audio signal which then is replayed by the Hi-Fi systems.

The typical design of a network connected audio adapter is shown in Figure 6.



**Figure 6: Typical design of a network connected audio adapter**

## 2 Measurements and Analysis

### 2.1 Data Sources

Overall, 77 products from 13 manufacturers were evaluated regarding power modes and power consumption in each available modes.

Information about power modes and power data of the products can be found in datasheets, owner manuals and technical specifications provided on the webpages of the manufacturers. Since not all manufacturers publish the power data of their products, other resources like independent test reports had to be consulted. Fortunately a German computer magazine (c't) recently released a comprehensive test report on multi-room systems, including measured network standby power data of the products [1]. This information is also used in this report, courtesy of the author. If power consumption values for a product are provided by the manufacturer and c't, the values from c't are used since they are based on independent measurements.

To evaluate functions and designs of NCAPs, five products from three well known manufacturers were purchased, analyzed and measured in the laboratory (see Table 1). These products were chosen based on availability in Switzerland and on cost. At least one sample of each of the three device types was purchased.

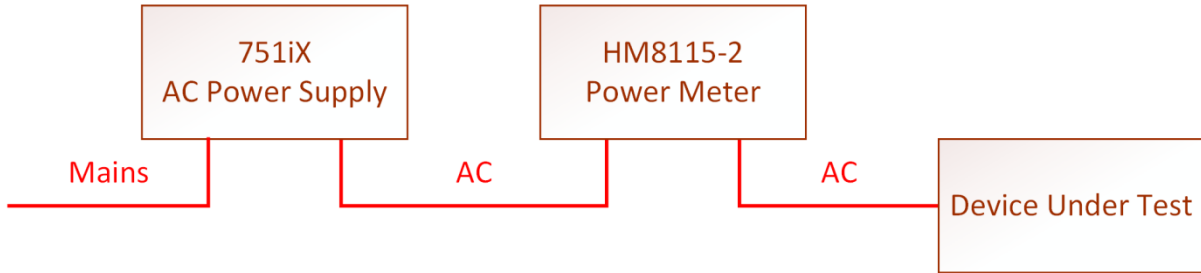
**Table 1: List of purchased products**

System	Product	Device Type
System 1	Product a	Speaker
System 1	Product b	Adapter
System 2	Product c	Speaker
System 2	Product d	Amplifier
System 3	Product e	Speaker

### 2.2 Measurement Setup

To measure the power consumption of the purchased products, a measurement setup as described below was used (see Figure 7).

The measurements were conducted in the premises of iHomeLab using a power meter HM8115-2 by HAMEG Instruments GmbH. To power the device under test an AC Voltage Source 751iX by California Instruments was used. The measurements were made in accordance to IEC 62301 for the measurement of standby power consumption. While most requirements of the standard were met, some could not be fulfilled with the available equipment. The detailed comparison of standard requirements and the actual conditions is listed in Table 2.



**Figure 7: Measurement Setup**

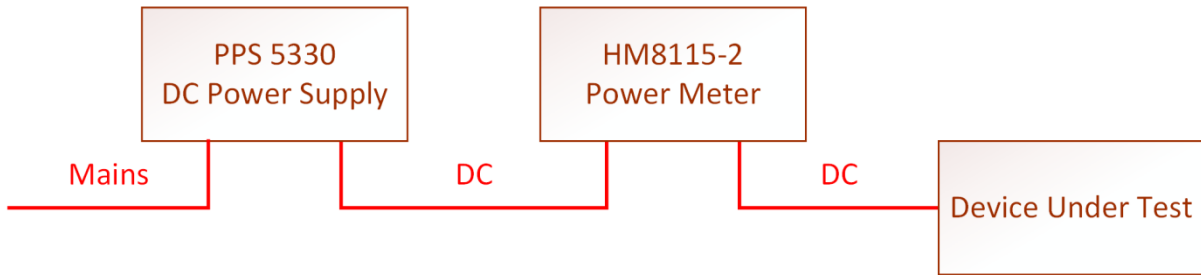
**Table 2: Comparison between IEC Standard 62301:2011 and the used measurement setup**

IEC 62301:2011	Measurement Setup
Ambient temperature: 23 ± 5°C	Yes
Warm-up time: 5 minutes	Yes
Voltage feed: 230V ± 1%	Yes
Frequency 50/60Hz ± 1%	Yes
Total harmonic distortion of voltage < 2%	Yes
Crest factor: 1.34 < CF < 1.49	Yes
Measurement duration ≥ 5 minutes and at least one measurement per second	Yes
If consumption fluctuates more than 5% during measurement period an average value must be determined	Yes
Measurement resolution better than 10mW for consumption up to 10W	Yes
Measurement accuracy 2% of the measured consumption for demand higher than 0.5W	Accuracy 0.1W
Bandwidth of power meter > 2.5kHz	Bandwidth 1kHz
Ability of the power meter measure direct current	Yes

All devices under test were first studied thoroughly to get an understanding of their functions and operation. In particular we had to determine the lowest power mode, for which the device stays responsive to commands sent over the network.

In these measurements, a smartphone was used to control the devices under test. Using the smartphone application, the devices were put in network standby mode (the communication module cannot be switched off via external control signals). After a waiting period of 5 minutes, the power consumption of the device was measured over a period of 5 minutes (300 measurements). Devices without the ability to enter network standby mode were left unused (in idle mode) for 5 minutes before beginning measurement. The 300 measurements were averaged to find the mean consumption of a device in network standby or idle mode respectively.

To examine the efficiency of AC/DC power supplies additional measurements were made. Since the products of manufacturer 2 have external power supplies, the power consumption without the AC/DC power supplies was measured as shown in Figure 8: Measurement setup for measurements without external power supplies.



**Figure 8: Measurement setup for measurements without external power supplies.**

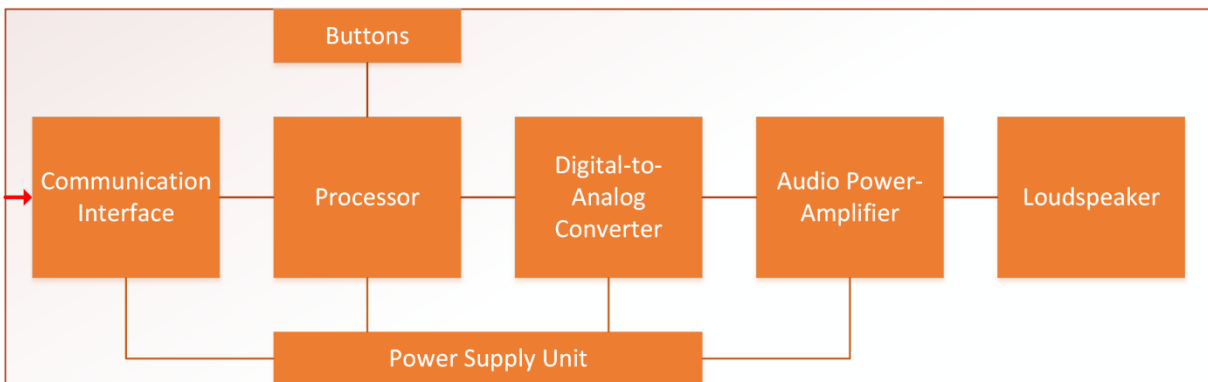
### 2.3 Analysis of Power Modes

The power consumption of an NCAP depends on use: An NCAP is expected to use more power while playing music than while waiting for user input. The analysis of datasheets, owner’s manuals and technical specifications has shown that in general we can distinguish four different power modes (five, if off mode is also considered).

The power modes are described in the following subsections using the example of a speaker. Note that very few products offer all of these power modes.

#### 2.3.1 Active Mode

When a speaker is playing music, all subsystems are active. The communication Interface receives an audio stream and relays it to the processor where it is decoded and then converted to an analog audio signal. The analog signal is amplified and then replayed by the speakers (see Figure 9).



**Figure 9: Speaker in active mode. All subsystems are active (indicated by orange coloring).**

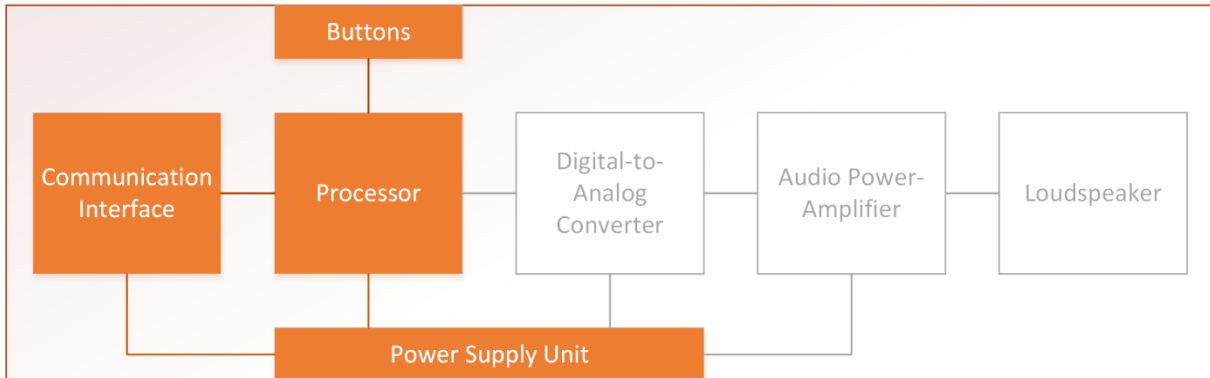
The power consumption in active mode is fluctuating and depends on the output power of the audio power-amplifiers: The louder the audio content is replayed, the more power is consumed.

In active mode, the power supply unit operates in the upper part of its nominal load range, where efficiency rates of 90% and higher can be achieved. This means that less than 10% of system power consumption is lost by the power supply unit.

#### 2.3.2 Idle Mode

In this study, idle mode is defined as the mode, where the speaker is not playing audio content, but is able to respond immediately to user input. This means that the Digital-to-Analog Converter, the audio power-amplifier and loudspeaker are not used and thus turned off (see Figure 10). The

processor has to stay active to ensure a fast response time. Network connection is active and communication is possible e.g. to send a digital audio stream or to change player settings.



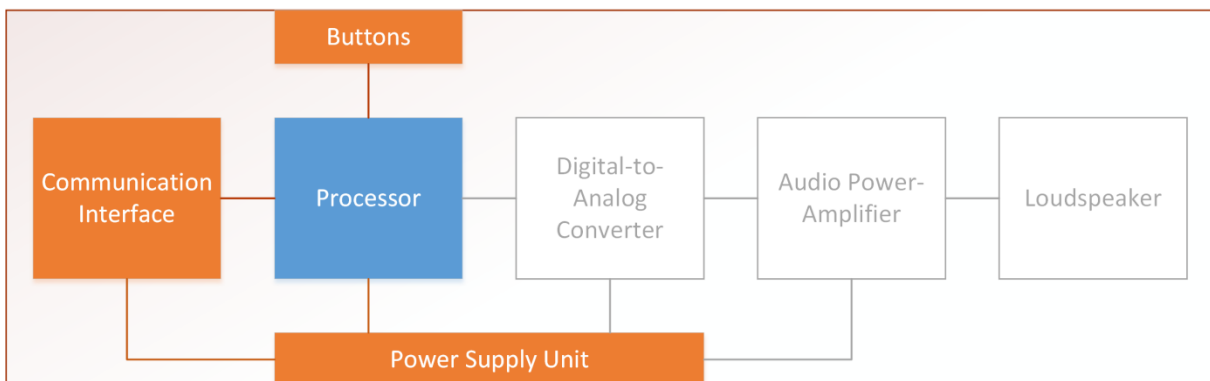
**Figure 10: Speaker in idle mode. Processor and communication interface stay active.**

Compared to active mode, the power consumption is stable and significantly reduced due to the inactive (or turned off) amplifier and DAC. Since no digital audio stream has to be processed, the power consumption of the processor is reduced also.

Due to reduced power needs, the power supply unit no longer operates in its high efficiency range, thus efficiencies of around 60% or lower are possible.

### 2.3.3 Network Standby

While the processor stays active in idle mode, it goes to a power save mode (also called standby or hibernation) while in network standby. Only the communication interface stays active. Like in idle mode, the system stays responsive to user inputs via network or button inputs however it may require more time to become activated since the processor may have to wake up from power save mode.



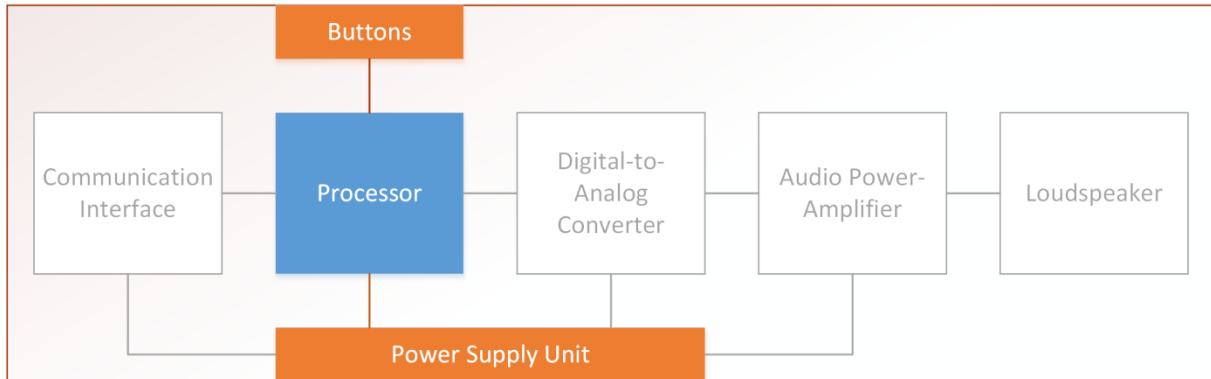
**Figure 11: Speaker in network standby. The processor is in a power save mode (indicated by blue color). Communication interface stays active.**

The system's power consumption is reduced compared to idle mode due to operating the processor in power save mode.

In this lower power range the efficiency of the AC/DC power supply unit usually further deteriorates and may drop below 50%. This means that the power loss of the power supply unit is greater than the power needs of the system.

### 2.3.4 Deep Standby

In deep standby, the speaker is only responsive to user inputs via button. All subsystems needed to receive and replay audio content are turned off, except the processor, which stays in power save mode (see Figure 12).



**Figure 12: Speaker in deep standby.**

The power consumption in deep standby mode is further reduced compared to the other power modes.

The efficiency of the power supply unit is typically decreasing further. For products that support the deep standby mode the loss of the power supply unit may be considerably higher than the power needed by the rest of the system.

### 2.3.5 Off Mode

If the speaker is in off mode it is completely turned off and no power is consumed. In most cases that means, that the connection to the mains was removed. This mode is not of interest in this study.

## 2.4 Modes of interest

Network connected audio products are supposed to be inactive most of the time but stay responsive to the smartphone app. Since not all products provide a real network standby as described previously, we had to introduce the term of the *lowest responsive power mode* to allow a comparison of the various products. This is the mode with the lowest power consumption for which the product stays responsive to the smartphone app.

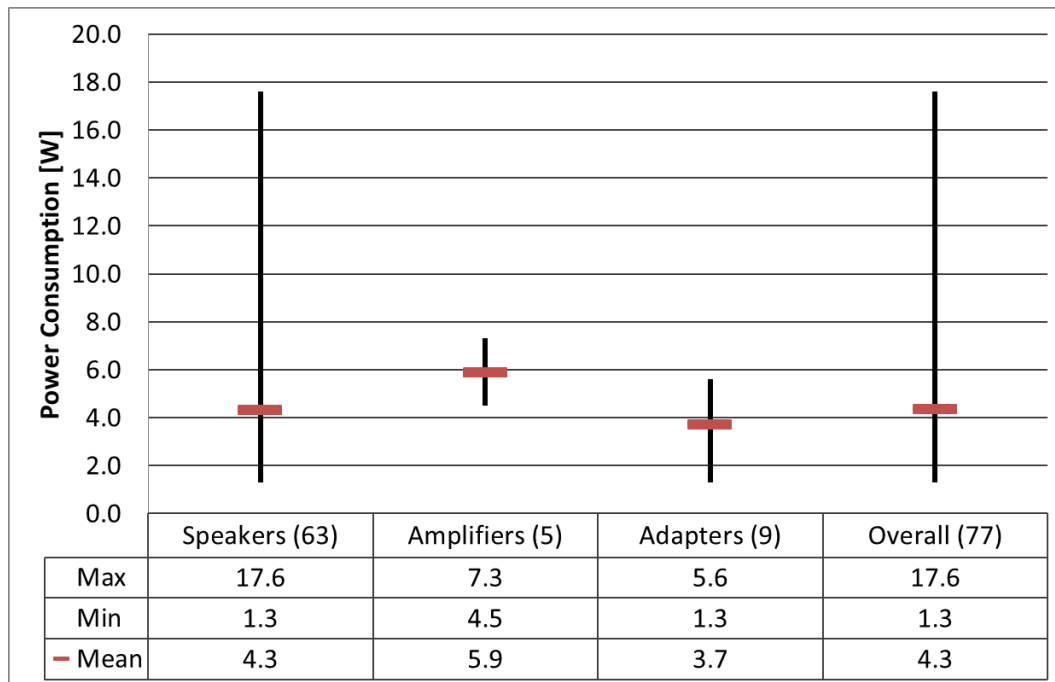
## 3 Results

### 3.1 Results of web-research

#### 3.1.1 Lowest responsive power mode

The graph in Figure 13 shows the power consumption in lowest responsive power mode of the investigated products sorted by device type (speakers, amplifiers, adapters) and overall.

While many manufacturers declare network standby mode for their products [2]–[20], one manufacturer explicitly declares that its products do not provide network standby but stay in idle mode to ensure fast response times [21]. For some products, power consumption data was not provided by the manufacturers. Therefore this information had to be taken from the test report of c't [1]. Nevertheless the nature of the lowest power mode is unknown for these products. On our inquiry, the author of the c't test report explained that power consumption was measured after leaving the products in idle mode for a while (some hours). As a consequence those products providing a network standby mode should have dropped into this mode, within this time period. The rest remained idle.



**Figure 13: Power consumption of investigated products in the lowest responsive power mode.**

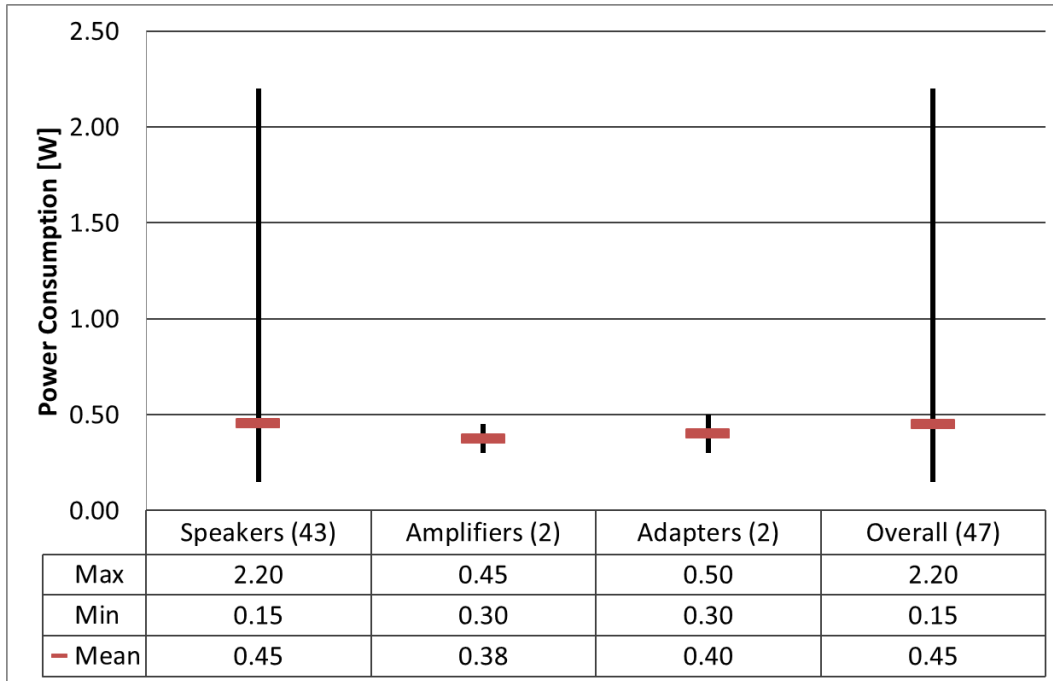
The speakers have the biggest spread: their power consumption ranges from 1.3W up to 17.6W while the mean power consumption is 4.3W. This means that most of the speakers have power consumption around the mean value, but a few have much higher power consumption.

The power consumption of the amplifiers stays inside a smaller range (4.5W to 7.3W). This is also the case for the power consumption of the investigated adapters (1.3W to 5.6W). In general, amplifiers consume more power than adapters, which may be explained by the power-amplifier part, which is not present in adapters.



### 3.1.2 Deep Standby Power Data

Additionally, the deep standby power consumption of the products was investigated. 47 of the 77 investigated products provide a deep standby mode, 43 of these are speakers, 2 are amplifiers and 2 are adapters. Figure 14 shows the deep standby power consumption of the investigated products sorted by device type (speakers, amplifiers, adapters) and overall respectively.



**Figure 14: Deep standby power consumption of investigated products.**

The power consumption of speakers in deep standby ranges from 0.15W up to 2.2W. Note that almost all (42) of these consume less than 1W in deep standby. The deep standby power consumption of amplifiers and adapters ranges between 0.3W and 0.5W.

## 3.2 Measurement results

Table 3 shows the result of our laboratory measurements. It shows that only one product provides deep standby mode (product e). As it is claimed by the manufacturer, system 2 does not even provide the network standby mode. In general, system 1 and system 3 are less power hungry than system 2.

**Table 3: Measurement results of purchased products.**

		Function	Power Consumption [W]			
			Active	Idle	Network Standby	Deep Standby
System 1	Product a	Speaker	3.1	1.6	1.3	n.a.
System 1	Product b	Adapter	3.0	1.5	1.3	n.a.
System 2	Product c	Speaker	6.0	5.0	n.a.	n.a.
System 2	Product d	Amplifier	19.5	6.1	n.a.	n.a.
System 3	Product e	Speaker	3.5	3.1	2.1	0.5

### 3.2.1 Behavior of purchased products

All of the purchased products are controllable via a smartphone app. When not streaming music, all of the products turn off the amplifiers (no audible noise anymore). Therefore they are in idle mode. When left in idle mode, the products of System 1 and System 3 fall into network standby within 10 to 20 minutes and thus consume less power if they are not reactivated. Only the products of system 2 stay idle and never reduce power consumption. To reduce power consumption of system 2 products, they have to be disconnected from mains. To further save energy, it is possible to set product e in a deep standby by pushing a specific button.

### 3.3 Worldwide Energy Impact

Figure 15 shows a forecast on shipments of network connected audio products published by IHS in March 2015 [22]. Based on this shipment forecast it is estimated that in 2018 around 300 million devices will be installed in homes worldwide. Based on this forecast, estimates about the total annual energy consumption of NCAP in lowest responsive power mode have been made.

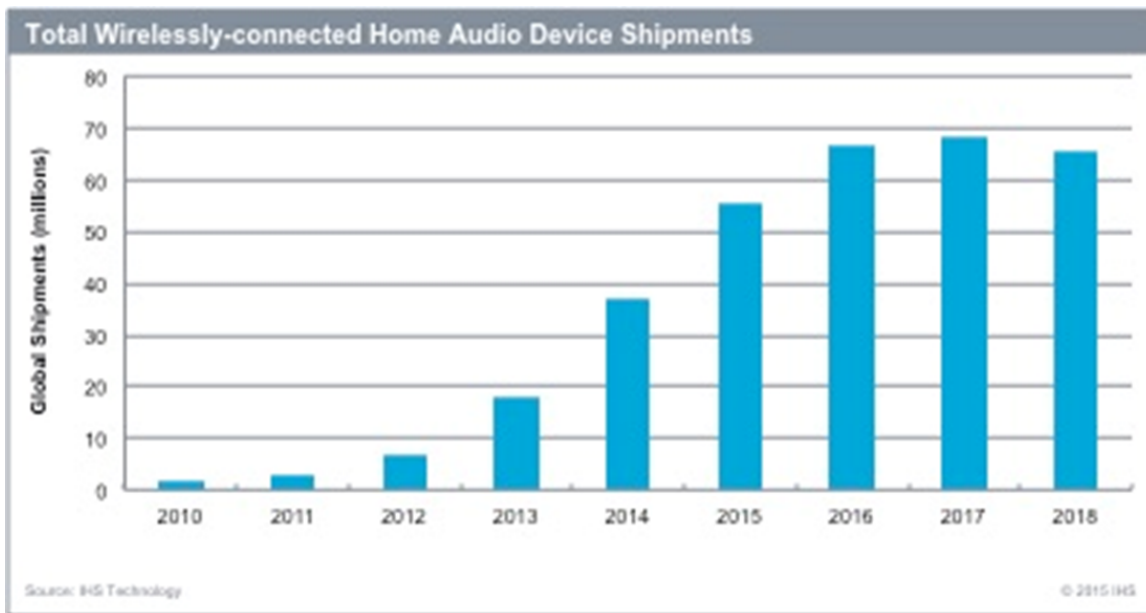


Figure 15: Shipments forecast of network connected audio products

Assuming that NCAP are not active for 95% of time, they stay for about 8322h per year in lowest responsive power mode. Table 4 shows the calculation of estimated total annual energy consumption for the year 2018. The calculation was made by using two different power consumption values: the average power consumption in lowest responsive power mode of all investigated products and the power consumption in network standby of the best product respectively.

Table 4: Estimated annual energy consumption of NCAP in network standby

Total Devices	Time p.a. in lowest responsive power mode	Value taken	Power Consumption	Total energy consumption p.a.
300 Mio.	8322h	average	4.3W	10.7 TWh
		best	1.3W	3.2 TWh

This rough calculation suggests that the annual energy consumption of NCAP in the lowest responsive power mode may rise up to almost 11 TWh in the year 2018. If all NCAPs would be on the level of the currently best available product it would be possible to save about 70% of energy or about 7.5 TWh.

Note: Since it is not clear, whether IHS' forecast also includes battery powered NCAPs, the installed base estimated above might be smaller.

### 3.4 Electricity costs per system

In the following, estimates about the annual electricity cost caused by a multi-room system in lowest responsive power mode will be made.

#### 3.4.1 Possible setup

The calculation is made based on a possible setup as it may be installed in a household. The setup is listed below:

##### *Living room*

- A soundbar and a subwoofer wirelessly connected to a Smart-TV.
- An adapter connected to a conventional Hi-Fi system.

##### *Home office*

- Two connected speakers in stereo mode. Here, the biggest available speakers of a system / manufacturer are taken.

##### *Kitchen*

- One connected speaker of medium format

##### *Bathroom*

- One small connected speaker. In this case, the smallest available speaker of a system / manufacturer are taken.

#### 3.4.2 Assumptions

For this calculation, following assumptions are made.

- All products stay in lowest responsive power mode for 95% of time (8'322h per year).
- The electricity price is 0.2855 € / kWh. This corresponds to the price of one of the biggest energy providers in Germany [23].

The calculation is made for four different device sets. First, the commercially available system with the lowest overall power consumption in lowest responsive power mode is taken. Secondly, the system with the highest overall power consumption in lowest responsive power mode is taken. Note that for these two calculations, systems which do not provide the necessary components, are not considered. Thirdly, one of the most sold systems is taken for the calculation. Fortunately this system provides all necessary components. Finally, a setup of components with the lowest power consumption is taken. It consists of products from different manufacturers, which might not be compatible with each other however.

### 3.4.3 Results

Figure 16 shows the results of the calculation of the annual standby related electricity costs of a multi-room system.

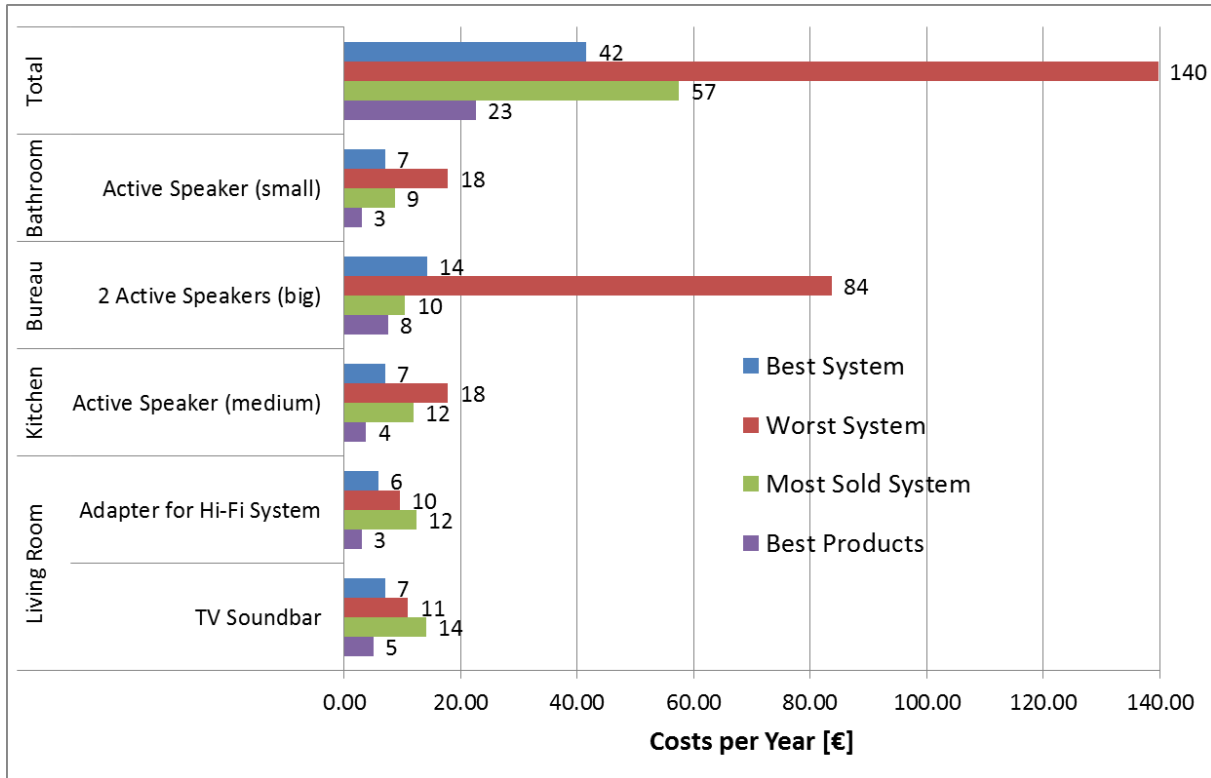


Figure 16: Annual network standby related electricity costs of a multi-room system.

### 3.4.4 Discussion

The system with the highest network standby power consumption has an annual standby energy consumption of 490 kWh in lowest responsive power mode. This results in annual energy costs of about 140 €, which makes a significant contribution to the energy costs of an average household in Germany (3100 kWh, 880 € [24]). Thus the energy costs for this system are six times greater than for a system containing only the most efficient products. By replacing these products with less standby power hungry devices, it would be possible to save energy costs of about 100 € a year.

It is obvious that the excessive network standby power consumption of the large speakers (of the worst system) makes a major contribution to the annual network standby energy costs in this example (60%). Since this may be an outlier, it makes sense to have a look at one of the most popular systems worldwide. It still consumes 2.5 times more network standby energy than the system with the best components. This very popular system is also the one for which the manufacturer claims to have no network standby mode, to enable fast response times.

Since two of the purchased products belong to this popular system (products c and d, see Table 3) there was the possibility to test these products to assess, whether they really have faster response times than the others which enter into a network standby mode. A short test has shown, that there is

no significant difference regarding the response times. But this result has to be treated with caution since it is not representative due to the small amount of samples.

## 4 Conclusions

Based on the analysis in this study, following conclusions can be drawn:

**All products use Wi-Fi as communication technology.**

Wi-Fi is the most common wireless communication technology for small, local networks. Thus it is used by all the investigated systems. The application layer (of the device communications system) varies however from manufacturer to manufacturer.

**Some products have no network standby mode, only an idle mode.**

The products of one of the most popular systems do not provide a network standby mode, claiming that this is required to ensure short response times. Preliminary investigations have shown no significant differences in response time between products with and without network standby mode.

**40% of the products have no deep standby mode.**

To save energy, e.g. when going on vacation, many products have to be un-plugged from mains.

**Considerable spread of power values in lowest responsive power mode.**

The best product has a power consumption of 1.3 W in network standby mode. The worst product consumes 17.6 W of power in its lowest responsive power mode. This is a huge amount of power considering that the only functionality in this mode is to wait and listen for commands coming from the smartphone app.

**The worldwide energy consumption in lowest responsive power mode of connected audio products is estimated to be up to 11 TWh in 2018.**

That is about 15% more than the annual production of a 1.3 GW nuclear power station (e.g. KKW Leibstadt in Switzerland: 9.5 TWh in 2014 [25]).

**By using the best available technology, the power consumption in lowest responsive power mode could be reduced by 70%.**

For most of existing systems which do not provide a network standby, possibly an update of the firmware could enable a network standby mode. This action could already result in a considerable reduction of power consumption.

**By using the best system, a household could save between 15 € and 98 € of electricity cost per year.**

This can be a significant share of the annual energy cost of an average household, which is about 900 €.

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