CONVINcE
D1.2.2

Business Cases for IPTV and OTT

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1 EXECUTIVE SUMMARY

The purpose of the deliverable is to provide an analysis of the energy consumption savings obtained by introducing CONVINcE research results, comparing the State Of The Art (SOTA) reference scenario with the scenarios studied by the project: Edge Cloud, Software Defined Networks, (SDN), Network Functions Virtualization (NFV) and Content Delivery Network (CDN). This should allow positioning quantitatively possible savings in the End-to-End (E2E) chain, including the service supplier and the customer.

In this second study, the analysis focuses on the IPTV and OTT service, which is becoming more and more popular. OTT services are more energy consuming than IPTV. We define the "average hour of video" as the reference unit for supporting costs. Thus, the key performance indicator is the average consumption of energy for one hour of IPTV and OTT. We then evaluate for the European market what represent in economic terms the energy savings that should be realized by implementing the project results.

We use a top-down approach, analysing globally the impact of the project results on the various consumption elements (headend, network and terminal).

Savings that could be obtained by the CONVINcE project for IPTV and OTT service remain small at the European level. We can obtain an order of magnitude of some hundreds of millions of Euros savings per year in Europe. In regards to the energy expenses of all participants (video service sellers and users) we obtained 86M€ for IPTV and 659M€ for OTT savings.. However, at the level of the service, it represents about 14% for IPTV and 15% for OTT savings for the delivery of the service which is not negligible.

The energy consumption for IPTV and OTT service is a small portion of the total energy that operators use in their networks. But nowadays is very hard to reach spectacular savings. Operators are looking for even small cost cutting measures. However, this must not be considered as a final work showing all the business value of the project. This final work will be reported in deliverable D1.2.3 where we will take in to account cloud (NGPoP solution).

Table of Contents

1 Executive Summary 2
2 Document history and abbreviations 5
2.1 Document history 5
2.2 Abbreviations 5
3 Introduction and presentation of the approach 7
3.1 IPTV and OTT 7
4 Energy consumption models in reference scenario (sota) 9
4.1 Simplified end to end architecture for IPTV and OTT: 9
4.2 Methodology to calculate the energy consumption of an average video in SOTA scenario: 9
4.3 Terminals (including sharing with other services) 10
4.3.1 Smartphones and tablets 10
4.3.2 Personal computers 11
4.3.3 Set-Top Boxes 11
4.3.4 TV sets 11
4.3.5 Average consumption per terminal 11
4.4 Network 11
4.5 Headend 13
5 Dedicated architecture for on demand video service 14
5.1 Proposed improvements (new architecture) 14
5.1.1 Terminals 15
5.1.2 Network 15
5.1.3 Headend 15
5.2 Evaluation of Convince proposal for terminals 15
5.3 Evaluation of CONVINcE proposal for the network 16
5.3.1 Edge cloud 16
5.3.2 SDN/NFV 17
5.3.3 Content distribution architecture 18
5.3.4 Cumulative improvements for networks 18
5.4 Global evaluation of potential savings 18
Table 8 Average consumption of energy of an OTT service 19
6 Economic model: how to pass from energy to euros 19
6.1 Calculation of forecast of volume of IPTV and OTT per country 19
6.2 Cost of energy per country 20
6.2.1 Analyse of the impact on the cost of energy (purchase, production and distribution) .. 20
6.2.2 Cumulated savings for all actors within the chain 21
6.3 The project's economic assessment 22
7 Conclusion 23

Table of Figures

Figure 1 Architecture model for IPTV and OTT 9

Figure 2 - Daily profile of traffic in the IP core network 17

Table of Tables

Table 1 Basic energy consumption for 1 GByte downloaded (target year 2018) 13

Table 2 IPTV Total headend consumption 14

Table 3 Consumption of headend for a video 14

Table 4 Basic energy consumption for 1 GByte downloaded with an edge cloud architecture 16

Table 5 Basic energy consumption for 1 GByte downloaded with a SDN/NFV architecture 17

Table 6 Basic energy consumption for 1 GByte downloaded when cumulating edge cloud and SDN/NFV architectures 18

Table 7 Average consumption of energy of an IPTV service 19

Table 8 Average consumption of energy of an OTT service 19

Table 9 Elements of calculation of number of IPTV and OTT per country 20

Table 10 Economic savings in terms of costs of energy and supply for IPTV 21

Table 11 Economic savings in terms of costs of energy and supply for OTT 21

Table 12 The total savings in terms of fee for energy for IPTV per year (energy and euro) 22

Table 13 The total savings in terms of fee for energy for OTT per year (energy and euro) 23

2 Document history and abbreviations

2.1 Document history

Version	Date	Description of the modifications
0.0	01/03/2017	Table of content
0.1	02/08/2017	Completed by OTT results and updated results for IPTV
1.0	03/08/2017	Final version
1.1	01/09/17	Cosmetic modifications to final version

2.2 Abbreviations

CPU	Central Processing Unit
DSLAM	Digital Subscriber Line Access Multiplexer
E2E	End to End
EPC	Evolved Packet Core
GB	GigaByte
GE	Gigabit Ethernet
GPU	Graphics Processing Unit
HD	High Definition
IP	Internet Protocol
IPTV	Internet Protocol Television
MPLS	Multiprotocol Label Switching
IPTV	Internet Protocol Television
LTE	Long Term Evolution
Mbps	Mega bit pre second
MPEG-DASH	Dynamic Adaptive Streaming over HTTP
MSAN	multiservice access node
NGPoP	Next Generation Point of Presence
OTT	Over The Top technology
PC	Personal Computer
SD	Standard Definition
SDN/NFV	Software Defined Networking/Network Functions Virtualization
SM	Smartphone
SOTA	State of the Art
STB	Set-Top Boxe

TV	Television
VPN	Virtual Private Network
W	Watt - a unit power in the International System of Units (SI)
Wh	Watt per hour

3 INTRODUCTION AND PRESENTATION OF THE APPROACH

The purpose of the deliverable is to provide an analysis of the energy consumption savings obtained by introducing CONVINcE research results, comparing State Of The Art (SOTA) reference scenario with scenarios including CONVINcE proposals. This should allow positioning possible savings with the total energy consumption and give relative savings per component of the End-to-End (E2E) chain. The content of this deliverable is thus an economic assessment of the stakes of the project results. In this second document, the analysis focuses on IPTV service and OTT.

The objective is to give an order of magnitude of the possible savings (not to make mistakes in a ratio of 10!) and to have an idea of the savings relatively to the consumption on the whole chain. Experience on historical cost calculations shows some stability, even if the figures may vary by country depending on the network architecture and the volume of the traffic. By analogy, we conjecture a similar trend for energy consumption.

To reach this objective, we propose to analyze the impacts of the project proposal on a unit of video service (for example, an average downloaded video in the case of a IPTV service and OTT). The idea is to compare incrementally the results of the project with the current scenario (SOTA).

By analogy with studies on costs, we aim at using a top down model. Starting from the observed energy consuming of a unit of video, rebuilt from basic elements of energy consumption, the main steps are:

1) To share it on the network elements of the chain, including terminals, network – and typically, for the network[1]: core network, backhaul and access – and headend,
2) To analyze globally the impact of the project results on each of these elements,
3) To decrease or increase the energy consumption for each one,
4) To sum again on the whole chain.

As energy cost deeply depends on the energy tariffs within the country, transformation of kWh into Euro will be done at the end.

The analysis is done for an architecture which is already in place (SOTA or proposed scenarios). Details on transition between the existing scenario (SOTA) towards proposed ones is not part of this work.

In this second version of the study, we focus on two services: IPTV and OTT.

One of the difficulties of the exercise is to define the perimeter of the analysis:

- What size for the network: country wide, European wide, worldwide?
- What topology?
- Supporting which services (network elements are always shared among a lot of services)?

To avoid this difficulty, we reduce the problem to a unit of service supposed to support the consumption of energy. From the experience at Orange in calculating cost of gigabyte of data in the European affiliates of the Orange group - which have certain stability despite the differences in scale, network architecture or customer usages - we assumed the same stability applies to energy consumption in the network supporting the same units of traffic– at least in the same proportions. Thus, we suppose that the resulting consumption of energy is quite stable for European countries (we attempt to give bounds). The calculations are based on energy consumption of basic elements including implicitly network topology, engineering rules, sharing with other services (for example by using an average energy consumption to download a gigabyte of data in the core network). The assumption is that these basic consumption figures have the same order of magnitude, independently of the size and topology of the network. As the considered figures correspond to the network of a specific operator, we aim to have a precision lower than a ratio 10.

3.1 IPTV and OTT

For IPTV and OTT, we define an average video by its duration, and by its average volume in terms of downloaded data (in Giga Byte). The calculations take the form below, where items in italic characters are assumed to be data observed from measurements.

[1] We use aggregated model of energy consumption by element of the chain: for example for the national wide core IP/MPLS network calculation could be based on the energy consumption to download one gigabyte of data, idem for aggregation and access networks, including the contribution of all layers below IP (WDM).

$$VolumeVideo\,[GB] = VolumeVideoTV\,[GB] * percentTV + VolumeVideoPC\,[GB] * percentPC + VolumeVideoSM[GB] * percentSM$$

Where

VolumeVideoXX $[GB]$ represent the volume in Gigabyte of an average video on terminal *XX* [XX: TV set (*TV*), personal computer (*PC*) or smartphone or tablet (*SM*)]

percentXX $[GB]$ is the frequency of usage by customers.

Note that: $percentTV + percentPC + percentSM = 100\%$

The average duration of a video may also depend on the terminal:

- *DurationVideoTV[hour]* for TV sets,
- *DurationVideoPC[hour]* for personal computers,
- *DurationVideoSM[hour]* for smartphones and tablets.

$$\mathrm{DurationVideo[hour]} = \mathrm{DurationVideoTV[hour]} * \mathrm{percentTV} + \mathrm{DurationVideoPC[hour]} * \mathrm{percentPC} + \mathrm{DurationVideoSM[hour]} * \mathrm{percentSM}$$

We suppose VolumeVideoXX, BitrateVideoXX and percentXX are the available input data.

In the following calculations, we make the following assumptions for IPTV and OTT. It reflects practical usage experience.

$VolumeVideoTV[GB] = 1$
$VolumeVideoPC[GB] = 0{,}5$
$VolumeVideoSM[GB] = 0{,}25$

$DurationVideoTV[hour] = 1$
$DurationVideoPC[hour] = 0{,}5$
$DurationVideoSM[hour] = 0{,}25$

In OTT we take in to account way of watching free YouTube videos, that why for IPTV and OTT we take different percentage of usage.

For IPTV:

$percentTV = 50\%$
$percentPC = 25\%$
$percentSM = 25\%$

For OTT:

$percentTV = 20\%$
$percentPC = 45\%$
$percentSM = 35\%$

We thus obtain for an average video:

IPTV

$\mathrm{DurationVideo[hour]} = 0.7$
$\mathrm{VolumeVideo[GB]} = 0.7$

OTT

$\mathrm{DurationVideo[hour]} = 0.5$
$\mathrm{VolumeVideo[GB]} = 0.5$

4 ENERGY CONSUMPTION MODELS IN REFERENCE SCENARIO (SOTA)

4.1 Simplified end to end architecture for IPTV and OTT:

The analysis is based on the simplified reference architecture (Figure 1), mainly:

- Headend located within the video data center,
- Network composed of an IP-based national core network,
- Fiber IP/GE aggregation network,
- Wireless and wired accesses,
- Terminals.

At head-end, videos for IPTV service are generally only coded once in a format HQ. For OTT videos, on the contrary, many formats are encoded (until 150) adapted to each kind of terminals.

In practice, videos are downloaded via two access networks, fixed and mobile, on different kinds of terminals (some of them reached by both types of accesses).

For OTT video, the IP core network is the Internet network carrying the data traffic from the Internet (unmanaged IP network). For IPTV, the core network is a specific network (dedicated to traffic in connected mode) that provides a level of traffic protection and a level of quality of service higher than in the IP transport network of the Internet. This network generally overlaps the IP transport network (directly used to carry Internet traffic) over which it is created; it is based on VPN dedicated to the connected mode traffic involving VPN routers, it is operated with traffic engineering different from those operating the IP network in background.

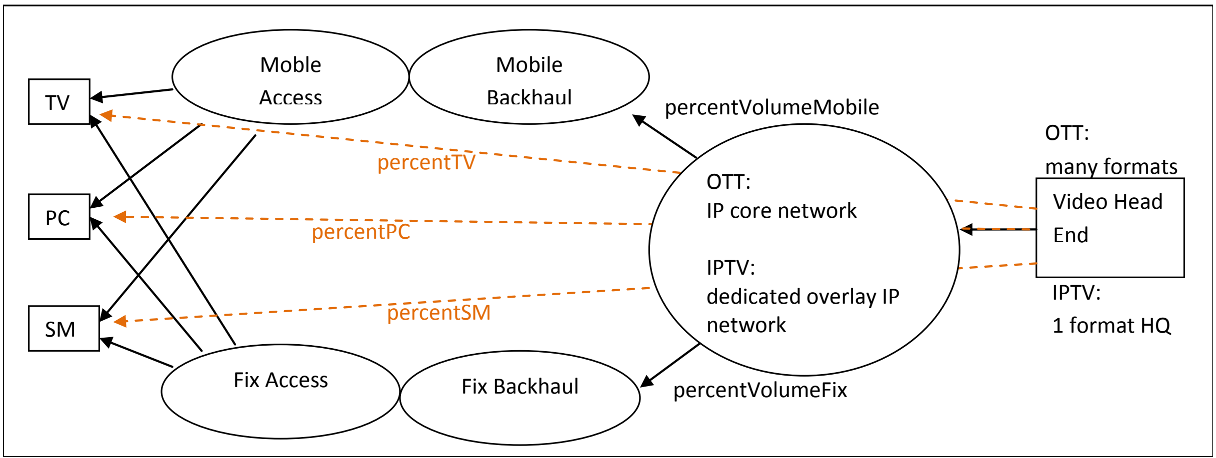

Figure 1 Architecture model for IPTV and OTT

4.2 Methodology to calculate the energy consumption of an average video in SOTA scenario:

The average consumption of a video is calculated from the average consumption in the different elements of the end to end chain (headend, network, terminals). The calculation method differs according to these elements. For the network elements, it depends on consumption units related to volume of downloaded data (in networks, costs are typically supported by gigabytes of data and minutes of voice). The calculation is thus carried out from the average consumption to download a gigabyte of data, weighted by the usage to download a video (which may differ for IPTV and OTT video). For terminals and headends it depends on consumption units related to durations of use (one hour of video seems the most natural unit to compare different technologies of terminals). For the various network elements, the calculation is thus carried out from the average consumption to download a gigabyte of data, weighted by the usage to download a video. For the terminals and headends, the calculation is carried out from the average consumption of processing one hour of video.

$$\text{ConsoVideo [Wh]} = \text{VolumeVideo [GB]} * \text{Conso1GBNetwork} \left[\frac{\text{Wh}}{\text{GB}}\right] + \text{Conso1hourTerminal[Wh]} * \text{DurationVideo [hour]} + \text{Conso1hourHeadEnd [Wh]} * \text{DurationVideo[hour]}$$

$$\begin{aligned}\text{Conso1hourTerminal [Wh]} &= \text{Conso1hourTV [Wh/hour]} * durationVideoTV[hour] * percentTV \\ &+ \text{Conso1hourPC [Wh/hour]} * durationVideoPC[hour] * percentPC \\ &+ \text{Conso1hourSM [Wh/GB]} * durationVideoSM[hour] * percentSM\end{aligned}$$

Where *VolumeVideo* is the average volume of a video downloaded by all kind of terminals given in section 3.1.

Basic energy consumptions of the elements of the chain (Conso1hourXX, Conso1GBNetwork and Conso1GBHeadend) are made explicit respectively in subsections 4.3, 4.4 and 4.5).

4.3 Terminals (including sharing with other services)

4.3.1 Smartphones and tablets

A smartphone or a tablet is usually used for a large amount of use cases. Hence, such terminals have an average power consumption even when it is not used for video services. We denote this power consumption as "background consumption". This background consumption could be the result of using the terminal for voice calls, messaging, social networking, gaming, web browsing etc. However, on top of the background consumption we consider here specifically the usage of smartphones and tablets for video usage.

For downloading a video on mobile terminals we consider the data to be delivered either over a cellular network (e.g. LTE) or local area network (WiFi). The available data rates over the radio interface for these network types are typically in the same order of magnitude, e.g. ~100Mbps. However, the available data rate of a single mobile phone at a given time slot could be different, depending, among others, on the radio environment and on the radio access load. The video download can utilize a dynamic rate selection protocol, e.g. MPEG-DASH to adapt the selected media data rate / quality to the available link data rate. Codec H265 and H264 are typically used for video, where the h.265 codec needs in the order of 50% less data than H264 for the same video quality.

Within CONVINcE state of the art, we consider different power consumptions for smartphones and tablets respectively, mainly due to larger average display sizes of tablets. We can consider the consumptions of energy to incrementally process one hour video, on top of the background consumption for a smartphone or a tablet, are:

$$\text{Conso1hourSmartPhone[Wh]} = 1.23$$

$$\text{Conso1hourTablet[Wh]} = 3.5$$

Assuming a penetration ratio between smartphones and tablets of 25% for video we obtain (for the sake of simplicity we assumed the same ration for IPTV and OTT:

$$\text{Conso1hourSM[Wh]} = 1.8$$

Note that the capacity of a Smartphone battery is about 11 Wh[2]. This means that a smartphone when watching video works during 9 hours (simply by dividing 11 Wh by 1.23 W), which corresponds to the experience of everyone.

[2] A typical smartphone battery size is centered around ~3Ah which corresponds to ~11Wh.

4.3.2 Personal computers

The power consumption of PCs differs a lot, based on hardware specifications such as CPU, GPU, screen technology and size, hard disk drive, etc. However, we can here typically focus on a state of the art laptop, targeting mainstream performance. Similar as for smartphones and tablets, the average usage is widespread on many different use cases besides video usage. We here consider the additional power consumption on top of such background usage. Basic consumption of energy to incrementally process 1 hour video on a PC supposed to be already connected is assumed to be:

$$\text{Conso1hourPC[Wh]} = 27$$

4.3.3 Set-Top Boxes

Just like other terminals, the power consumption of the Set-Top Boxe (STB) varies depending on the CPU, GPU and other parameters of the hardware used. In this project, a specific terminal is used as reference STB which is equipped with a Broadcom 7250 chipset. The average power consumption can be assumed to be 30 Wh.

Analyses made by Orange reveals that a given number of customers (15%) do not switch off their STB after watching TV. The STB is set in sleeping mode. The consumption is then reduced to 3 Wh (10% of the consumption in activity). For these STB, we only count the incremental cost of activity, let say 27 Wh. The final figure is hence given by:

$$\text{Conso1hourSTP[Wh]} = 29.6$$

4.3.4 TV sets

The consumption of TV sets (the terminal is supposed to be on at the beginning of the video and off at the end) to process 1 hour video is:

$\text{Conso1hourTV [Wh]} = 63$ for HD 40” TV Sets

$\text{Conso1hourTV [Wh]} = 93$ for 4K HEVC 40” TV Sets

We propose the following sharing: 67% for HD 40” TV Sets and 33% for 4K HEVC 40” TV Sets. The average energy consumption is thus:

$$\text{Conso1hourTV [Wh]} = 72.9$$

4.3.5 Average consumption per terminal

The average consumption of terminals can be easily calculated from the average usage in time (see formula in section 4.2):

IPTV:

$$\text{Conso1hourTerminal[Wh]} = 77$$

OTT:

$$\text{Conso1hourTerminal[Wh]} = 52.1$$

And for an average video:

IPTV:

$$\text{ConsoVideoTerminal[Wh]} = 52.9$$

OTT:

$$\text{ConsoVideoTerminal[Wh]} = 26.7$$

4.4 Network

For the analysis of energy consumption, the network has been divided into macro elements compatible with the block diagram of Figure 1.

For mobile networks:

- Radio access network (including 3GPP macro and micro cells, WiFi),
- Mobile backhaul,
- Mobile core platforms (EPC).

For the wired networks:

- Copper and optical local loop,
- DSLAM, MSAN access equipment for data services,
- Backhaul (based on GE routers and fiber).

IP core transport network is common to both wired and wireless networks.

$$\mathrm{Conso1GBNetwork}\left[\frac{\mathrm{kWh}}{\mathrm{GB}}\right] = \mathrm{Conso1GBCoreIP}\left[\frac{\mathrm{Wh}}{\mathrm{GB}}\right]$$
$$+\left(\mathrm{Conso1GBMobileBackhaul}\left[\frac{\mathrm{Wh}}{\mathrm{GB}}\right] + \mathrm{Conso1GBMobileAcces}\left[\frac{\mathrm{Wh}}{\mathrm{GB}}\right]\right) * \mathrm{percentVolumeMobile}$$
$$+\left(\mathrm{Conso1GBFixBackhaul}\left[\frac{\mathrm{Wh}}{\mathrm{GB}}\right] + \mathrm{Conso1GBFixAccess}\left[\frac{\mathrm{Wh}}{\mathrm{GB}}\right]\right) * \mathrm{percentVolumeFix}$$

Where:

- *Conso1GBXX* defines the energy consumption to download one Gbyte of data in the network element XX (XX = Core IP, Mobile access and backhaul, Fixed [wired] access and backhaul) (values are given in column "energy consumption to download 1 Gbyte" of Table 1),
- *percentVolumeMobile* and *percentVolumeFix* are respectively the percentage of data traffic downloaded by wireless and wired users (respectively 20% and 80%, as it appears in column "percent of concerned traffic" of Table 1).

Energy to carry 1 Gbyte of data was calculated using real measurements in Orange France Network, extrapolated for year 2018. The scope is data networks, including 3G and 4G technology for mobile access network and DSL copper or optical access for the wired network. The equipment dedicated to voice services or legacy data services is not involved. This information is obviously confidential. To give an idea of the distribution of energy consumption in a network among its main elements, the consumptions are given in Table 1 as a percentage of the total consumption. The energy consumption is quite stable during the year. The conclusion to be drawn from these assessments of energy consumption is the trend to stability, regardless of traffic growth (new technologies consume less, which counterbalances the traffic growth).

For every part of the network, the consumption has then been divided by the traffic forecasted during the period. Of course, the traffic volume involved is different for each of the network segments as expressed in column "percent of concerned traffic". Traffic towards wireless users is forecast to represent 20% of the total data traffic (about 10% in 2014, meaning a yearly increase of about 60% for mobile users).

Traffic for IPTV is routed through a VPN overlay network. This network requires additional routers. The traffic engineering and dimensioning rules induce an average usage of the VPN 20% lower than in the IP network systems. We concluded that the consumption for carrying a gigabyte of IPTV requires 20% more energy than the equivalent in the IP network.

To summarize trends, energy consumption of the involved network elements between 2014 and 2018 is forecasted to be relatively constant, including changes in technology and evolution of usage. However, data traffic is sharply increasing during the same period with an overall growth of 40% per year. This means that a large part of the energy consumption is quite independent of the usage and the consumption of energy of a video directly decreases as the number of video increases.

Consumption for 1 Gbyte is given in Table 1, column "energy consumption to download 1 Gbyte".

network element	variable	energy consumption forecast for 2018 on a basis 100	energy consomption observed in 2014	percent of concerned traffic	energy consomption to download 1 Gbyte Wh
radio access network 3G and 4G	Conso1GBMobileAccess	33	32	percentVolumeMobile = 20%	122
mobile packet core and backhaul	Conso1GBMobileBackhaul	9	10	percentVolumeMobile = 20%	32
fixed access (copper and fiber)and backhaul	Conso1GBFixAccess + Conso1GBFixBackhaul	40	39	percentVolumeFix = 80%	37
IP core network	Conso1GBCoreIP for videos from OTT	18	18	percentVolumeMobile + percentVolumeFix = 90%	13
	Conso1GBCoreIP for videos on demand			percentVolumeMobile + percentVolumeFix = 10%	16

Table 1 Basic energy consumption for 1 GByte downloaded (target year 2018)

It should be noted that energy is rather used in the access, particularly for wireless access. The core network represents only 18% of the full network consumption (see column "energy consumption forecast for 2018 on a basis 100" .

Note that for an average Gigabyte of downloaded video network usage is different for IPTV and OTT (IPTV is most often viewed on television sets and therefore relatively uses more fixed access and less mobile access than OTT).

With the given assumptions, using the model above, the energy consumption for one Gigabyte of video is:

IPTV:

$$\text{Conso1GBNetwork} = 76.5\ \text{Wh}$$

OTT:

$$\text{Conso1GBNetwork} = 79.6\ \text{Wh}$$

The energy consumption in the network for an average video is:

IPTV:

$$\text{ConsoVideoNetwork} = 52.6\ \text{Wh}$$

OTT:

$$\text{ConsoVideoNetwork} = 40.8\ \text{Wh}$$

4.5 Headend

Basic energy consumption models for video headends have been introduced in CONVINcE deliverable D2.1.1. For IPTV and OTT services, we supposed that videos are mainly delivered by IPTV headend.

The model proposed by D2.1.1 and presented in Table 2 calculates an energy consumption per transcoding unit. Fixed costs related to redundant units, management systems, scramblers, etc. represent about 15% of the total headend consumption.

For IPTV:

$$HEcons_{(Wh)} = FixedPartCons_{(Wh)} + (ChannelCons_{(Wh)} \times NumberOfChannels)$$

Taking into account the nature of video channels, a more accurate model is:

$$HEConsumption_{(Wh)} = FixedPartCons_{(Wh)} + (SDChannelCons_{(Wh)} \times NumberOfSDChannels) + (HDChannelCons_{(Wh)} \times NumberOfHDChannels)$$

	Nb units	W/unit	Total W
SD transcoder units (1RU)	20	460	9200
HD transcoder units (1RU)	18	460	8280
Redundant units (1RU)	4	460	1840
Mangement system	1	460	460
CAS	1	200	200
Scramblers	4	140	560
Total consumption (W)			**20540**

Table 2 IPTV Total headend consumption

Finally, considering that we use a single transcoder for a video, we obtain the amount of energy consumption presented in Table 3. The energy consumption is supposed to be quite linear with the time of encoding. For IPTV, only one high quality format is encoded. For OTT, the same video is transcoded several times to have versions corresponding to the various kinds of terminals (typically 150 versions for the same video). Considering that a video is watched by a certain number of users, we obtain the average consumption of energy related to a video usage by customer.

We note that this consumption is negligible compared with network and terminals consumptions.

consumption for coding 1 hour video	541 Wh
Video on demand	
consumption for coding 1 average video	372 Wh
number of versions coded for a single video	1
average popularity of a video on demand	100 000 users
consumption for 1 hour video per user	0,005 Wh
consumption for 1 video per user	0,004 Wh
Video OTT	
consumption for 1 average video	197 Wh
SOTA or storing several copy in the edge cloud	
number of versions coded for a single video	150
average popularity of a video on demand	500 000 users
consumption for 1 hour video per user	0,162 Wh
consumption for 1 video per user	0,059 Wh

Table 3 Consumption of headend for a video

5 DEDICATED ARCHITECTURE FOR ON DEMAND VIDEO SERVICE

5.1 Proposed improvements (new architecture)

In this section, we attempt to describe the main impact of the proposed architecture and proposition of CONVINcE for the energy consumption of a IPTV and for a OTT service.

5.1.1 Terminals

The energy consumption savings analyzed within the CONVINcE project for terminals are being conducted within CONVINcE WP4, including, for instance, more efficient utilization of the wireless radio interface in the communication between network and terminals.

WP4 studies [Refer to D4.2.1] show that the reduction of power consumption for video usage over a cellular radio access network such as LTE could be achieved by a collaborative architecture sharing information between terminals and the mobile access network. The savings on total terminal energy consumption level are for this study typically in the order of 5% (smartphones and tablets).

For the fixed terminals, namely the PCs, STBs and TV Sets, not only power consumption in the radio interface but also the decoders on the hardware and the screens are two major components responsible for power consumption. Furthermore, the effective usage of the operating modes is one of the factors of reducing the average power consumption. Overall, the achived power consumption reduction in PCs are from 43% up to 65%, STBs are about 10% and in the TV Sets are about 15%.

5.1.2 Network

Three scenarios of network evolution have been proposed in CONVINcE project (see Deliverable D1.1.1 - *Application Scenarios*), namely an edge cloud based architecture, a SDN/NFV based architecture and a content distribution architecture.

We explain below what brings each scenario in terms of energy savings for an IPTV and an OTT service.

- Edge cloud allows storing contents nearby the user, saving capacity of transport in the IP/MPLS core network. For the IPTV and the OTT service, the edge cloud architecture should allow saving capacity (and thus energy consumption) within the core IP and backhaul networks by downloading fewer videos.
- SDN/NFV allows switching on/off routers according to the volume of traffic to download. There is thus a possible saving in IP/MPLS core network, during the off-peak hours. This architecture is expected to optimize network resources and could allow switching off the under-loaded routers (or interfaces) in the core network.
- Content distribution architecture: for the IPTV and the OTT service the impact is supposed to be similar to edge cloud (same storage function closer to users of the most requested data)

5.1.3 Headend

For the IPTV and the OTT service, the consumption of energy is very small compared to the other elements of the chain, so we have not analyzed here, for this service, the impact of possible improvement proposed by WP2 (Power saving in the headend). It is intended to take into account in further studies the influence of the headend in the end to end consumption

5.2 Evaluation of Convince proposal for terminals

For the business case analysis, we estimate that the potential savings due to mobile terminals and PCs could be in the order of 5% to 65%, 10% for STB and 15% for TV sets, considering the total terminal average power consumption during active video usage.

The energy consumption for an average hour of video becomes:

IPTV:

Conso1hourTerminal = 63.9 Wh

OTT:

Conso1hourTerminal = 39 Wh

The energy consumption due to terminal for an average video is:

IPTV:

ConsoVideoTerminal = 43.9 Wh.

OTT:

ConsoVideoTerminal = 20 Wh.

5.3 Evaluation of CONVINcE proposal for the network

5.3.1 Edge cloud

The edge cloud architecture allows storing contents nearby the user and consequently decreases the data traffic in the IP/MPLS core IP network. For IPTV service, the edge cloud architecture should allow saving capacity (and thus energy consumption) within the core IP and backhaul networks by downloading fewer videos.

The decrease of traffic volume depends on several factors, among them the popularity of the requested contents, the possibility to catch and store them, and the performance of the caching algorithms. In practice, today, the performance observed of transparent cache in Orange affiliate networks is about 30% of traffic saved upstream of the cache, concerning in particular OTT video, and the figure rises to 40% for IPTV. This scenario should multiply the number of storage sites and the total volume of stored data. Today, we have no realistic value of energy consumption for storing data in a cloud. Nevertheless, most of energy used in delivering contents is consumed when downloading the video and in both scenario (SOTA and Edge Cloud) the number of downloading will be the same. So, in this first analysis we neglect the difference between both scenarios.

Supposing that globally 30% of the traffic is saved (all services), this may have an impact on the dimensioning and topology of the core packet network. Due to modularity of transport systems, the impact on the network dimensioning is not exactly linear, but due to the high volume of traffic impacted it should tend nearby a linear trend. As we are looking for an order of magnitude in energy saving, we suppose that decreasing by 30% the traffic volume in the core network induces a decrease of same ratio in network dimensioning and consequently a decrease of 30% in energy consumption in the core IP network. This corresponds to a decrease of 30% for OTT videos and to a specific decrease of 40% for IPTV more impacted by caching.

Considering these possible savings, the energy to download 1 Gigabyte of data in the IP core network is given by the Table 4:

network element	variable	energy consomption to download 1 Gbyte Wh
IP core network	Conso1GBCoreIP for **IPTV**	11
IP core network	Conso1GBCoreIP for **OTT**	9

Table 4 Basic energy consumption for 1 GByte downloaded with an edge cloud architecture

Energy consumption for an average Gigabyte of video becomes:

IPTV:

Conso1GBNetwork = 71.7 Wh

OTT:

Conso1GBNetwork = 75.6 Wh

Energy consumption due to the network for an average video is :

IPTV:

ConsoVideoNetwork = 49.3 Wh.

OTT:

ConsoVideoNetwork = 38.7 Wh.

5.3.2 SDN/NFV

The SDN/NFV architecture applied to router control should allow optimizing the network transport resources by switching off routers when the network is under loaded outside of the busy period. Figure 2 gives the trend of the daily data traffic profile in the IP core network of Orange France. The carried volume of traffic is under 2/3 of the volume reached at the busy period at least during 12 hours during the day, half of the volume of the busy period during 10 hours, 1/3 of the volume of the busy period during 5 hours. We suppose that during this period of time, by reconfiguring the network, we are able to switch off equipment until 2/3 of the core IP systems (no more due to problems of connectivity within the network), linearly with the decrease of traffic, what consequently leads to a 30% saving of energy consumed in IP transport network during the day..

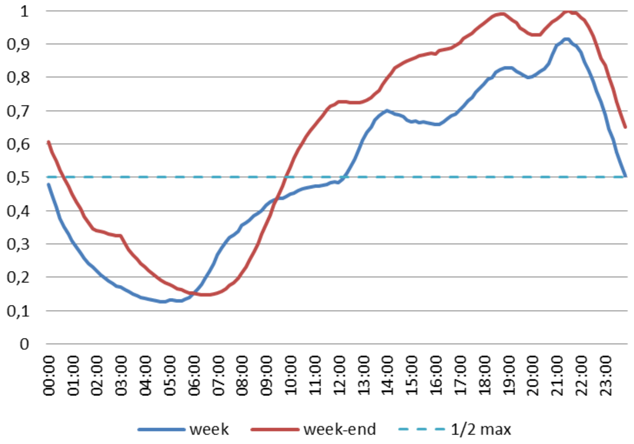

Figure 2 - Daily profile of traffic in the IP core network

Considering these possible savings, the consumption of energy to download 1 Gigabyte of data in the IP core network is given by Table 5:

network element	variable	energy consomption to download 1 Gbyte Wh
IP core network	Conso1GBCoreIP for **IPTV**	11
IP core network	Conso1GBCoreIP for **OTT**	9

Table 5 Basic energy consumption for 1 GByte downloaded with a SDN/NFV architecture

Energy consumption for an average Gigabyte of video becomes:

IPTV:

Conso1GBNetwork = 71.7 Wh

OTT:

Conso1GBNetwork = 75.6 Wh

Energy consumption due to the network for an average video is :

IPTV:

ConsoVideoNetwork = 49.3 Wh.

OTT:

ConsoVideoNetwork = 38.7 Wh.

5.3.3 Content distribution architecture

It is considered that the CDN has the same impact on power consumption as the edge cloud architecture. We suppose CDN are located in the same place where edge cloud could be deployed. For IPTV and OTT service the role of edge cloud and CDN will be exactly the same: to store the video closer to the saving carrying data in the core network.

5.3.4 Cumulative improvements for networks

Note that the impacts of introducing the new network architectures (edge cloud or CDN and SDN/NFV) are cumulative. By introducing simultaneously an edge cloud architecture or a content distribution architecture and an SDN/NFV architecture, the energy consumption to download 1 Gigabyte of data in the IP core network becomes:

network element	variable	energy consomption to download 1 Gbyte Wh
IP core network	Conso1GBCoreIP for **IPTV**	8
IP core network	Conso1GBCoreIP for **OTT**	6

Table 6 Basic energy consumption for 1 GByte downloaded when cumulating edge cloud and SDN/NFV architectures

Energy consumption for an average Gigabyte of video becomes:

IPTV:

Conso1GBNetwork = 68.4 Wh

OTT:

Conso1GBNetwork = 72.8 Wh

Energy consumption due to the network for an average video becomes:

IPTV:

ConsoVideoNetwork = 47.0 Wh.

OTT:

ConsoVideoNetwork = 37.3 Wh.

5.4 Global evaluation of potential savings

The average energy consumption of an average IPTV is illustrated in Table 7 and for OTT in Table 8 the SOTA scenario and for the various improvements proposed by CONVINcE on network (including SDN/NFV and CDN [or edge cloud]) and on terminals. Results are given with components for each one of the end to end segments (terminals, network and headend), for 1 hour of video (Conso-1hour) and for an average video (Conso_Video) as defined in section 3.1.

Applying all CONVINcE proposals together for network and for terminals will lead to a 14% decrease of energy consumption in the end to end chain for IPTV and to a 15% decrease for OTT. Note that most of this energy consumption comes from the terminals (50%), 49% comes from the network and the energy consumption in headends is relatively insignificant (1%).

The difference in energy consumption between one hour of IPTV and one hour of OTT (higher for IPTV) is mainly due to the difference in volume of data needed to encode the video (significantly higher for IPTV). IPTV more often uses television sets which consume more energy than mobile devices. However, OTT more often use the mobile access network which consumes more than the wireline access.

Relative savings from terminals are eventually limited (17% for IPTV and 25% for OTT). Most of the savings in the network (11% for IPTV and 8,5% for OTT) comes from the core network which remains 2nd order compared to wired and wireless accesses.

	SOTA	Network improvements		terminal improvements	All
		including SDN/NFV	*including CDN*	*~17% on terminals*	
Conso_Video	**106,0 Wh**	**102,8 Wh**	**102,8 Wh**	**97,1 Wh**	**91,5 Wh**
Conso_Terminal	52,9 Wh			43,9 Wh	43,9 Wh
Conso_Network	52,6 Wh	49,3 Wh	49,3 Wh		47,0 Wh
Conso_HeadEnd	0,56 Wh				0,56 Wh

Table 7 Average consumption of energy of an IPTV service

	SOTA	Network improvements		terminal improvements	All
		including SDN/NFV	*including CDN*	*~25% on terminals*	
Conso_Video	**67,9 Wh**	**65,9 Wh**	**65,9 Wh**	**61,2 Wh**	**57,7 Wh**
Conso_Terminal	26,7 Wh			20,0 Wh	20,0 Wh
Conso_Network	40,8 Wh	38,7 Wh	38,7 Wh		37,3 Wh
Conso_HeadEnd	0,42 Wh				0,42 Wh

Table 8 Average consumption of energy of an OTT service

6 ECONOMIC MODEL: HOW TO PASS FROM ENERGY TO EUROS

The objective of this section is to quantify the economic gain realized when results of the CONVINcE project will be implemented. A European perimeter integrating the main European countries was selected.

From an estimation of IPTV and OTT downloaded per country, we aim at estimating the corresponding savings in terms of energy. Considering the average cost of energy per country, we deduce savings in term of cost, per country, and globally.

For the number of videos considered, the approach was the following. Assumptions about the number of IPTV and OTT was made for France, as Orange had the best statistics for this country. Figures were then extrapolated to other European countries, using demographics and standard of living indicators.

Average earnings in energy by video are assumed to have the same order of magnitude for all the concerned countries. We consider applying altogether the propositions of CONVINcE project, as evaluated in section 5.4 of this document.

Cost of energy was derived from public sources accessible on the Internet.

6.1 Calculation of forecast of volume of IPTV and OTT per country

We suppose IPTV represent 10% and OTT 80% of the total traffic in the core network of Orange France. Supposing that Orange France has 40% of the market share, the number of IPTV calculated for France is in the order of scale of 4.4 x10^9 videos in 2018 and the number of OTT videos 96,1 x 10^9 videos

The total consumption of videos in other countries is supposed to be proportional to the population and proportional to the "purchasing power parities" factor representing the standard of living within the country (figures from OECD). Results of this calculation are given in Table 9.

country	population	Purchasing Power Parities	weighting factor	number of video IPTV (Giga)	number of video OTT (Giga)
Germany	81 174 000	115	1,41	6,2	66,51
France	66 352 469	100	1,00	4,4	47,27
United Kingdom	64 767 115	103	1,01	4,4	47,53
Italy	60 795 612	89	0,82	3,6	38,55
Spain	46 439 864	87	0,61	2,7	28,79
Poland	38 005 614	63	0,36	1,6	17,06
Netherlands	16 900 726	122	0,31	1,4	14,69
Belgium	11 258 434	109	0,18	0,81	8,74
Greece	10 812 467	66	0,11	0,47	5,08
Czech Republic	10 538 275	76	0,12	0,53	5,71
Portugal	10 374 822	71	0,11	0,49	5,25
Hungary	9 849 000	63	0,09	0,41	4,42
Sweden	9 747 355	118	0,17	0,76	8,19
Austria	8 584 926	117	0,15	0,67	7,16
Denmark	5 659 715	114	0,10	0,43	4,60
Finland	5 471 753	103	0,08	0,37	4,02
Slovakia	5 421 349	72	0,06	0,26	2,78
Ireland	4 625 885	129	0,09	0,40	4,25
Total	466 779 381			30	321

Table 9 Elements of calculation of number of IPTV and OTT per country

6.2 Cost of energy per country

The objective is to take into account the difference of cost of energy possibly variable in the different countries in Europe.

A difficulty arises when defining the cost/price of energy. Energy in the end to end chain will be consumed by various actors: companies like operators, domestic customers, …, with different tariffs corresponding to the different market segments. Moreover the price of energy includes a number of taxes, depending on the market segment.

For these economic assessments of energy, we evaluated two aspects of the problem:

- Economic savings in terms of costs of energy and supply (column "estimation cost of energy" and "economic savings Convince" in Table 10 for IPTV and Table 11 for OTT).
- The total savings in terms of fee for energy to pay by all participants within the chain: enterprises for content delivery and network, final consumer for terminals (columns "price of energy …" in Table 12 for IPTV and Table 13 for OTT).

Values used in these evaluations are extracted from European statistics (Eurostat website and more specifically http://ec.europa.eu/eurostat/web/energy/data/database).

6.2.1 Analyse of the impact on the cost of energy (purchase, production and distribution)

Unfortunately, on the Internet, we can easily find prices of energy addressed to different classes of customers, but costs of production are not so easily available. We suppose that wholesale prices of energy and supply for the highest volume of energy without any taxes are nearer from production cost. Evaluated basic cost of energy can be found in column "estimation of costs of energy". They refer in Eurostat prices of energy and supply for the greatest volumes.

Except some specific countries, the value of a kWh ranges from 4 cents of euro to 9 cents.

country	number of video (Giga)	savings energy convince MWh	estimation cost of energy (€/kWh) 2020	economic Savings convince M€
Germany	6,2	89 996	0,064	5,77
France	4,4	63 968	0,052	3,34
United Kingdom	4,4	64 313	0,101	6,49
Italy	3,6	52 164	0,094	4,93
Spain	2,7	38 951	0,089	3,45
Poland	1,6	23 083	0,053	1,21
Netherlands	1,4	19 878	0,060	1,18
Belgium	0,81	11 831	0,063	0,75
Greece	0,47	6 880	0,071	0,49
Czech Republic	0,53	7 721	0,051	0,39
Portugal	0,49	7 101	0,066	0,47
Hungary	0,41	5 982	0,069	0,41
Sweden	0,76	11 089	0,051	0,56
Austria	0,67	9 683	0,057	0,55
Denmark	0,43	6 220	0,085	0,53
Finland	0,37	5 433	0,052	0,28
Slovakia	0,26	3 763	0,053	0,20
Ireland	0,40	5 753	0,067	0,39
Total	30	433 809		31

Table 10 Economic savings in terms of costs of energy and supply for IPTV

country	number of video (Giga)	savings energy convince MWh	estimation cost of energy (€/kWh) 2020	economic Savings convince M€
Germany	66,5	677 508	0,064	43,41
France	47,3	481 567	0,052	25,14
United Kingdom	47,5	484 163	0,101	48,86
Italy	38,5	392 701	0,094	37,09
Spain	28,8	293 231	0,089	26,00
Poland	17,1	173 775	0,053	9,13
Netherlands	14,7	149 646	0,060	8,91
Belgium	8,74	89 064	0,063	5,63
Greece	5,08	51 793	0,071	3,66
Czech Republic	5,71	58 128	0,051	2,96
Portugal	5,25	53 461	0,066	3,54
Hungary	4,42	45 033	0,069	3,09
Sweden	8,19	83 477	0,051	4,23
Austria	7,16	72 899	0,057	4,16
Denmark	4,60	46 827	0,085	3,99
Finland	4,02	40 904	0,052	2,12
Slovakia	2,78	28 330	0,053	1,50
Ireland	4,25	43 310	0,067	2,92
Total	321	3 265 816		236

Table 11 Economic savings in terms of costs of energy and supply for OTT

6.2.2 Cumulated savings for all actors within the chain

The prices involved in the evaluation of the amount of money paid by the energy consumer in the chain include the prices of energy, of network and taxes (they correspond to what the customer pays for its energy). Values used in this evaluation refer to electricity prices for domestic for terminals and industrial customers for network and headends. Corresponding values can be found respectively in columns "price of energy households" and "price of energy enterprises" of Table 12 and Table 13. Note the price for household customers is significantly higher than the price for enterprises. The order of scale is more than 2 times the costs of production.

6.3 The project's economic assessment

Taking into account these energy costs and the forecast volume per country for the year 2020 (we may consider this an order of size of the saving per year), we obtain the energy savings in Table 12 for IPTV and in Table 13 for OTT (column "savings energy convince" for the savings in MWh, and column "savings network + headends" and "savings terminals" for the savings in energy price for the energy consumption in the whole end to end chain within the cloud).

In both cases, the total energy savings at the scope of the main European countries is some tens of millions of euros for IPTV and in a few hundred millions euros for OTT, which is little compared to the energy consumption of network operators in Europe.

The assumptions taken for this analysis (IPTV and OTT in the global traffic, consumption of energy of the elements of the chain) have been chosen to give upper bounds to the energy savings.

In our methodology, results or measurements obtained for one operator have been generalized to others operators in other countries. The objective of these calculations is to give an order of scale about possible savings and not a precise evaluation. We develop our methodology after comparing the evaluation of pricing costs of data gigabyte in various European affiliate of the Orange group. The range of value is in a ratio less than 5, mainly depending of the usage of traffic. We made the assumption that the trend should be similar for the consumption of energy per gigabyte as for the cost.

These methodology may thus induce errors of evaluation let say in a ratio until 5 times more. Suppose thus the energy savings 5 times higher, the final trend of the evaluation remains unchanged: the economy of energy related to the service IPTV and OTT is small compared to the total energy consumed by networks and terminals.

country	number of video (Giga)	savings energy convince MWh	price of energy households 2020	price of energy enterprises 2020	savings network + head-ends	savings terminals
Germany	6,2	89 996	0,2976	0,1811	6,24	16,53
France	4,4	63 968	0,1661	0,1208	2,96	6,56
United Kingdom	4,4	64 313	0,2423	0,1787	4,40	9,62
Italy	3,6	52 164	0,2672	0,1930	3,85	8,61
Spain	2,7	38 951	0,2290	0,1408	2,10	5,51
Poland	1,6	23 083	0,1409	0,1058	0,93	2,01
Netherlands	1,4	19 878	0,1940	0,1097	0,83	2,38
Belgium	0,81	11 831	0,2407	0,1290	0,58	1,76
Greece	0,47	6 880	0,1877	0,1550	0,41	0,80
Czech Republic	0,53	7 721	0,1261	0,0926	0,27	0,60
Portugal	0,49	7 101	0,2227	0,1368	0,37	0,98
Hungary	0,41	5 982	0,1064	0,1040	0,24	0,39
Sweden	0,76	11 089	0,1777	0,0746	0,32	1,22
Austria	0,67	9 683	0,2009	0,1247	0,46	1,20
Denmark	0,43	6 220	0,2945	0,1079	0,26	1,13
Finland	0,37	5 433	0,1502	0,0848	0,18	0,50
Slovakia	0,26	3 763	0,1506	0,1351	0,19	0,35
Ireland	0,40	5 753	0,2564	0,1700	0,37	0,91
Total	30	433 809			25	61
					86	

Table 12 The total savings in terms of fee for energy for IPTV per year (energy and euro)

country	number of video (Giga)	savings energy convince MWh	price of energy households 2020	price of energy enterprises 2020	savings network + head-ends	savings terminals
Germany	66,5	677 508	0,2976	0,1811	41,58	133,30
France	47,3	481 567	0,1661	0,1208	19,72	52,87
United Kingdom	47,5	484 163	0,2423	0,1787	29,32	77,55
Italy	38,5	392 701	0,2672	0,1930	25,68	69,38
Spain	28,8	293 231	0,2290	0,1408	13,99	44,39
Poland	17,1	173 775	0,1409	0,1058	6,23	16,18
Netherlands	14,7	149 646	0,1940	0,1097	5,56	19,20
Belgium	8,74	89 064	0,2407	0,1290	3,89	14,17
Greece	5,08	51 793	0,1877	0,1550	2,72	6,43
Czech Republic	5,71	58 128	0,1261	0,0926	1,82	4,85
Portugal	5,25	53 461	0,2227	0,1368	2,48	7,87
Hungary	4,42	45 033	0,1064	0,1040	1,59	3,17
Sweden	8,19	83 477	0,1777	0,0746	2,11	9,81
Austria	7,16	72 899	0,2009	0,1247	3,08	9,68
Denmark	4,60	46 827	0,2945	0,1079	1,71	9,12
Finland	4,02	40 904	0,1502	0,0848	1,18	4,06
Slovakia	2,78	28 330	0,1506	0,1351	1,30	2,82
Ireland	4,25	43 310	0,2564	0,1700	2,50	7,34
Total	321	3 265 816			166	492
					659	

Table 13 The total savings in terms of fee for energy for OTT per year (energy and euro)

7 Conclusion

Savings that could be obtained by the CONVINcE project for IPTV and OTT service remain small. We can only obtain savings in order of magnitude of some hundreds of millions of Euros per year in Europe. In regards to the energy expenses of all participants (video service sellers and users) we obtained 86M€ for IPTV (Table 12) and 659M€ for OTT (Table 13) savings. However, at the level of the service, it represents about 14% for IPTV and 15% for OTT savings for the delivery of the service which is not negligible for the stakeholders.

The energy consumption for IPTV and OTT service is a small portion of the total energy that operators use in their networks. But nowadays is very hard to reach spectacular savings. Operators are looking for even small cost cutting measures. However, this must not be considered as a final work showing all the business value of the project. This final work will be reported in deliverable D1.2.3 where we will take in to account cloud (NGPoP solution).