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# QUANTITATIVE ANALYSIS AND MODELLING OF ICT ENERGY IMPACT IN FRANCE

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## ABSTRACT

The energy demand of ICT (Information and Communications Technology) may be considered as an important topic of the 21st century. Today, at a country level, for example in France, there is a lack of credible estimates concerning ICT energy demand and concerning its evolution in particular in terms of network equipments. Our PhD work may be a contribution to the know-how on this topic. In this paper, we give first an overview of our study's framework. In a second time, we focus our investigations on a quantitative analysis and its results. In a third time we give a description of the energy model of the networks which is designed by FTR&D.

## 1. PRESENTATION OF THE STUDY'S FRAMEWORK

- The environmental impact of ICT: the complexity  
On one hand, ICT seems to be favourable to the environment through all immaterial activities and products it can generate. On the other hand, we have to take into account various negative consequences. They are coming from significant electric and electronic waste, proliferation of standby consumptions or full time electrical connections. In the same time and obviously, the energy demand is growing. Today, we cannot be sure that the ICT influence on the environment impact is positive. Nevertheless, ICT appears as a major actor for the contribution to the sustainable development. The interactions between ICT and sustainable development have given an emergent problematic, to the heart of numerous debates, forums and others initiatives [1].

- The ICT energy impact and the research  
We may consider that the first investigations have been held at the Lawrence National Berkeley Laboratory in United States (1987) with the first complete measurements on PC power consumption [2]. Then estimates on office equipments consumption [3, 4, 5] and evaluations on these devices energy efficiency [6, 7] have followed. All these works have enabled US-EPA (Environmental Protection Agency) to launch Energy Star Label [8]. Worldwide campaigns for low standby consumptions have been implemented in order to control and to reduce the growing energy

ICT demand. Having in mind the numerous actions throughout the world in this field, it is worth to underline that most of the works concerns the end-use equipments. Indeed, it is more difficult to have a global idea and precise information on the infrastructure and its energy demand.

## 2. TELECOM NETWORK CONSUMPTION AND MEASUREMENTS

In this section, we present some methods and we give some results of measurements in order to cope with the lack of data in this field. The question is: how to quantify the ICT energy demand at different level – user, operator and country – considering the network side?

### 2.1 The ICT energy demand at the user level

We have defined a methodology to quantify the energy cost of a telecom service, with FT operator example. We have implemented it to six main telecom services chosen in the residential access network: voice services (with fixed telephone, mobile telephone and IP network), the data service with mobile telephone network, the Internet access providing service, and the audiovisual service.

We resume our general approach by:

- identifying the network elements required for the considered service
- determining energy consumption of these network elements
- determining allocation keys when these elements are required for several services
- quantifying, for each element, the energy ratio allocated to one subscriber

For example, the network elements needed for the Internet access providing service are shown in table 1, with their annual energy consumption:

Network elements	Annual consumption (2006)
DSLAM (residential district ratio)	162 GWh
ATM / Ethernet / IP network equipments	26 GWh
Transverse elements: data centres,	704 GWh

transmission equipments, tertiary buildings	
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Table 1: First extract of energy balance led in FT

- DSLAM

DSLAM services are mainly required for Internet access providing, VoIP, and audiovisual services. According to DSLAM characteristics, two keys are chosen, to allocate energy consumption depending on the service:

- Per service subscribers number
- Average rate per subscriber

Considering these two factors for each service, we obtain for Internet access providing service ratio:

$$162 \text{ GWh} \times 64\% = 104 \text{ GWh}$$

This consumption has to be shared between all the subscribers (5.5 millions in 2006). Consequently, the ratio for one subscriber is about 19 kWh/year (2006).

- ATM / Ethernet / IP network equipments

In this part, three different telecom equipments are needed for Internet access providing service:

Equipment types	Annual consumption (2006)
ATM network equipments	14.9 GWh
BAS	3 GWh
RBCI equipments	2 GWh

Table 2: Second extract of energy balance led in FT

One key is chosen so as to allocate energy consumption depending on the different concerned services: the total annual rate volume. Finally, we obtain:

$$51\% \times 14.9 + 95\% \times 3 + 99.9\% \times 2 = 13 \text{ GWh}$$

The ratio for one subscriber is about 2 kWh in 2006.

- Transverse elements: data centres, transmission equipments, tertiary buildings

It is not possible to share precisely the transverse elements consumption between the different provided services because these elements are common. A proposed solution is a fixed energy ratio linked with one customer; we assume that this ratio is the same from one customer to another. Under this hypothesis, 10 kWh is allocated to each FT customer.

Finally, supplying the Internet access providing service generates a consumption equal to 31 kWh per subscriber and per year, from network side. The same approach has been used for the other main telecom services (see the results fig. 1).

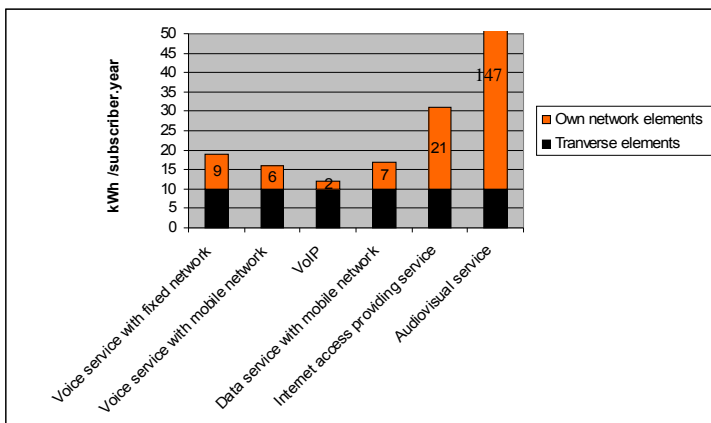


Figure 1: Quantification of telecom services energy cost, from network side

The required energy consumption varies significantly according to the service. Nevertheless, these results need a special attention. For example, calling with VoIP seems to consume less energy than calling with fixed network. It is not really true if we consider that the Internet access providing service is necessary to have access to VoIP.

It is interesting to compare the network energy load and the end-use equipments energy load. Let us underline without develop the controversy concerning this comparison. Once again and according to FT measurements, the ratio can vary significantly depending on the solicited service.

## 2.2 The ICT energy demand at the operator level

What about global energy demand of the infrastructure needed to make use the ICT end-use equipments? An energy balance has been carried out in the framework of FT to quantify its total consumption.

First of all, cartography of equipments has been defined and eleven sub sectors have been delimited (see table 3).

Public telephone network switches
Base station (BTS and Node B) and mini racks
Base station controller (BSC and RNC)
Network and Switching Sub-system (MSC, HLR, VLR...)
DSLAM
ATM and IP networks: NAS, BAS, router, switches, brewers
High data access network for companies
MDTN equipment
Data centres
Transmission Network
Tertiary sector

Table 3: Cartography of FT equipments

The global energy consumption of each sub sector has been quantified, from:

- Numerous measurements carried out in FTR&D
- Experts consultations
- Data bases consultations on network equipments list

For 2006, electric consumption of FT has been estimated to 1.9 TWh, that is to say 0.5% of total electric demand in France. The breakdown between sub sectors is given in figure 2.

## 2.3 The ICT energy demand at the country level

At the moment, two main results may be extracted from our study:

- Estimate of network power consumption allocated to residential district, by extrapolation of FT results
  - Estimate of total power consumption from French servers.
- Our attention has been focused on this area because the

amount of electricity used by servers and other Internet infrastructure has become an important issue these recent years.

### 2.3.1. French network power consumption allocated to residential district

The results which have been given in the case of FT subscribers can be extrapolated to other French subscribers. For that, we suppose that:

- Others French operators use the same equipments types.
- Equipments chain needed for a given service is the same from an operator to another.

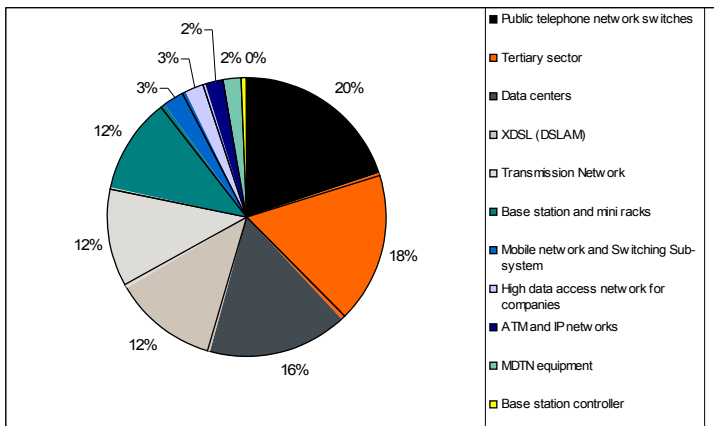


Figure 2: Energy breakdown of FT consumption by subsector

Under these hypotheses, extrapolation of FT data is made (see table 4).

Service type	Number of French subscriber (2006, residential district)	Power consumption
Voice service with fixed telephone network	38,7 millions	19 x 38,7 = 735 GWh
Mobile service	47,2 millions	23 x 47,2 = 1086 GWh
VoIP service	4,2 millions	12 x 4,2 = 50 GWh
Internet access providing service (ADSL)	10,5 millions	31 x 10,5 = 326 GWh
Audiovisual service	2,6 millions	157 x 2,6 = 408 GWh
<b>TOTAL</b>		<b>2.6 TWh</b>

Table 4: Extrapolation of FT data to others operators

Thus, concerning the residential district, the French network power consumption is estimated to 2.6 TWh in 2006. Let us notice that the only Internet access is considered here, and not Internet servers which hosted web sites.

### 2.3.2. Estimate of total power consumption by servers in France

Koomey [9] has estimated the total electric consumption used by servers in the U.S. and in the world, by combining measured data and estimates of power used by the most popular servers, with data on the server installed base from IDC (<http://www.idc.com>).

We have suggested applying the Koomey method to French case. We have focused our study on servers and the infrastructure energy use associated with those servers (cooling, fans, and UPSs etc.). The market share for each of the most popular servers has been used to calculate a weighted average power use per unit for each server class.

IDC's total installed base estimates for France are shown in table 5; they are split into three servers classes based on the cost of the system. These data include servers in both enterprise and scientific computing applications. Upgrades to existing servers are excluded. Volume servers are the most important in the installed base; nearly 1 million of servers were installed in France in 2006, which represents 4 % of the worldwide servers.

Year	Volume	Mid-range	High-end	Total
2004	736 196	52 839	2 630	791 665
2005	835 159	50 901	2 511	888 571
2006	939 084	49 234	2 375	990 693

Table 5: Installed base servers in France

After having imputed power data to this base, total power consumption for all servers in France in 2006 is estimated to 2.1 TWh. Including cooling and auxiliary equipment increases that total to 3.1 TWh (24% rise compared to 2004) or nearly 1% of total electricity demand in France (see figure 4).

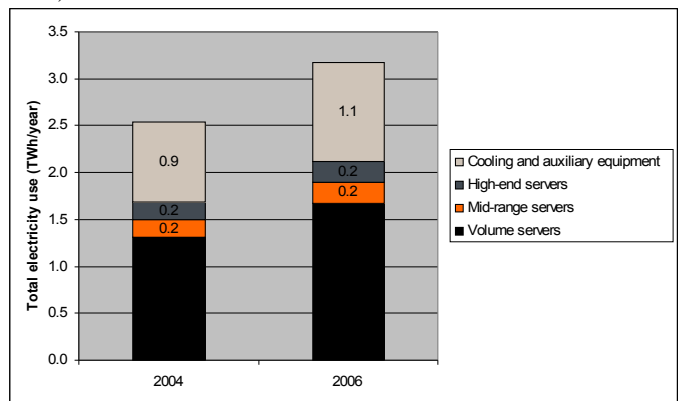


Figure 4: Total electric use for servers in France in 2004 and 2006, including cooling and auxiliary equipments

## 2.4 The ICT and the energy efficiency

Following recommendations from Energy Star Label in 1993, works on low standby devices consumption have been generalized. At the moment, experts are focusing all their attention on Data Centres whose energy demand has become an important issue. Numerous initiatives tend to reduce the

Data Centres power consumption. As some references: deployment of server virtualization, rightsizing of UPS, use of air conditioner economizer modes, installation of energy-efficient lighting...

If ICT energy consumption can be reduced, ICT has also an interesting potential to reduce global energy consumption, for example when it replace moves. Nevertheless, substitution effects are ambivalent and hardly quantifiable. Relationship between ICT and the environment is complex (10).

### 3. MODELLING AND METHODOLOGY

One of our PhD objectives consists in developing a tool which model FT network consumption. Two types of data are considered:

- Traffic data
- Equipments parks data related to devices power measurements.

This tool would enable to evaluate network consumption evolution, depending on traffic evolution or equipments parks modification over the next years. General approach is described in a first step. The second step which is under way consists on implementation software (Matlab).

#### 3.1 Network dimensioning step

The major difficulty is to well understand relation between traffic and power to model it. In a general way, network is sized from traffic matrix, tools which enable to flow traffic on the different network nodes and bonds. Network power consumption depends on this dimensioning stage corresponding to complex algorithms. The problem is that this stage cannot be easily designed in terms of energy.

That's why, in our tool, we choose to use already sized data in order to have a more easily manipulated tool. This choice implies to operate and think with "delta", as schematized on figure 5.

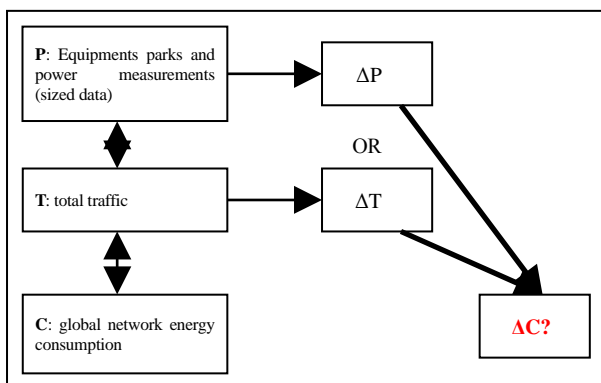


Figure 5: Model simplification

#### 3.2 Network segmentation

Another point has to be underlined. Because of different constraints from a network to another (architecture, topology, traffic quantity ...), we propose to operate network by network according to the following segmentation:

- Access network (star topology)
- Collect network (ring topology)
- Backbone network (mesh topology)

The approach consists in applying independently the scheme in figure 5 to each of network type.

Once these choices are made, the next step consists in modelling in terms of energy the evolution of each type of network depending on the traffic evolution, thinking with "delta".

In the current stage of the study, we can not develop this part yet; it will be set out at a later stage.

### 4. CONCLUSION

In this paper, we have given some results as a contribution to increase the know-how on ICT energy demand from network side, from a microscopic to a macroscopic point of view. We have presented the tool being developed in France Telecom to model energy consumption of its networks.

Whereas supplying the Internet access providing service involves 31 kWh consumption per subscriber per year from network side, total power consumption by servers in France reaches 3.1 TWh per year.

Global ICT energy footprint in industrialized European country is estimated to around 7% to 10% of the country demand (11). Over the next years ICT will become one of the most important electric consumption sectors. Consequently, we cannot ignore the energy impact and environmental impact of ICT area. Although the first research works are just 20 years old, we may notice that the awareness of energy issues has penetrated the consciousness of users recently. Unfortunately it is still not a priority for a lot of decision-makers.

#### GLOSSARY

ADSL	Asymmetric Digital Subscriber Line
ATM	Asynchronous Transfer Mode
BAS	Broadband Access Server
BLR	Radio Local Loop (Boucle Locale Radio)
BSC	Base Station Controller
BTS	Base Transceiver Station
DSLAM	Digital Subscriber Line Access Multiplexor
FT	France Telecom
GIX	Global Internet Exchange
HLR	Home Location Register
ICT	Information and Communications Technology
MDTN	Multiservice Digital Telephonic Network
MSC	Mobile Switch Centre
NAS	Network Access Server
Node B	3G Base Station
POP	Point of Presence
PLC	Power Line Communications
RBCI	IP Backbone Network in FT
RNC	Radio Network Controller
UPS	Uninterruptible Power Supply
VoIP	Voice over Internet Protocol
VLR	Visited Location Register

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