Assessment of electricity consumption in the ICT layer in Smart grids

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Technical coordination: *Bertholon Marion* – **Management\Service:** *DPED / SRER*

EXECUTIVE SUMMARY

ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

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Summary for the decision-makers

Issues and objectives

Faced with issues related to energy transition, the current electricity networks are confronted with several challenges. They must integrate new forms of renewable energy production that are decentralized and variable; prepare for the mass arrival of new consumption usages, while ensuring the maintenance of good quality electricity transportation. They also need to evolve towards offer and demand management methods that are more efficient and less energy consuming.

This change in electricity networks cannot be brought about without massive deployment of information and telecommunications technologies (ICT). ICT development responds to two major issues:

- Improving the overall knowledge about the electricity system, through multiplication of sensors and data;
- Monitoring the electricity system in a more responsive manner to make it more flexible at all levels between the production and consumption. What is equally important is that ICT's will enable more granular management of usages in order to obtain major benefits in terms of demand side management (DSM).

This growth of ICT's will differently concern all the strata of the electricity system: from the network core to the interior of the home. "Smart" solutions for energy integrate several information and telecommunications technologies (ICT): internet of things, gateways, wire and radio communication, data centres, smartphones, etc. This equipment represents an impact in terms of electricity consumption.

In this context, although ICT development in the smart electricity networks is taking place to improve the economic and environmental balance of the electricity system (growth of renewable energy and control over the electricity demand), ADEME wanted, through this exploratory study entrusted to Capgemini Consulting, to evaluate the electricity consumption resulting from their growth. It is a preliminary evaluation of the magnitude of the electricity consumption in the ICT layer in Smart grids for 2020 and 2030 at the France level. It is important to underline that this study:

- Is only an analysis of the annual electricity consumption; it does not calculate the net result or the cost-benefit analysis in terms of energy consumption. It also does not consider electricity consumption of monitored usages[1],
- Is not a life-cycle analysis. A significant, at times major share of CO_2 emissions in the life-cycle is related to the initial grey energy of manufacturing, not considered in the study,
- Produces a "photo" for 2020 and 2030 without looking to calculate a difference with the present.

Before analysing the results of the study below, it is necessary to keep the following points in mind:

- Today, what is observed across the world and in all sectors is a quick shift towards more data and communication
- Some of the objects whose consumption is taken into account in this study, like the Linky meter, don't have the only benefit of easing the flexibility of consumption, monitoring the connected objects or contributing towards the network's observability. They also provide several economic benefits that are not mentioned in this report. For the Linky meter, we can cite the benefits related to automated metering and consequently avoiding metering technicians coming home.

[1] For example, in the case of monitoring the load of an electric vehicle, the ICT consumption corresponds to the consumption of ICT equipment that enables smart monitoring of the vehicle load (sensor, data flow, IT server, etc.), but not the electricity consumed for powering the vehicle.

Domains handled and approach

To segment the study, the ICT layer was assessed in four domains of smart grids:

- **Smart metering (SM): smart metering infrastructure,** related to the Linky smart meter. The assessment is based on the complete metering chain: meters, concentrators, data centres, power line carriers (PLC) and mobile telephony, etc.
- **Smart home (SH): the infrastructure necessary for monitoring residential consumption** to offer flexibility for the network. We consider the entire chain related to an act of flexibility for a residential consumer: from the box in the house to the data centres managing it, via monitored objects and internet routers required for the transmission of information. The consumption related to the functioning of the domestic communication network, which enables ensuring the monitoring of machines, is also considered.
- **Smart charge of electric vehicles ("SVEL" in the graphs below): the infrastructure that enables monitoring the charge of electric vehicles** by taking into account the network constraints. It consists of analysing the consumption of a smart system that communicates between the vehicle, the terminal, the electricity network and the data centres of various players.
- **Smart public distribution network ("SRPD" in the graphs below): the technologies that enable better observability and medium and low voltage network monitoring**. We are interested in the feeder substation, the medium voltage line sensors as well as in the communication with the renewable farms and the distribution substations.

Two to four use cases were defined for each domain, during a workshop grouping various players from each chain. The use cases go from the simplest to the most technical. They are not exhaustive, but are representative in terms of data flows and processing. In all, 13 use cases were documented and modelled based on current technologies, to which were applied progress factors for 2020 and 2030 of the "Moore's law" type. Finally, an extrapolation on the France scale was obtained for the same timelines by combining proportions judged realistic in each of these use cases.

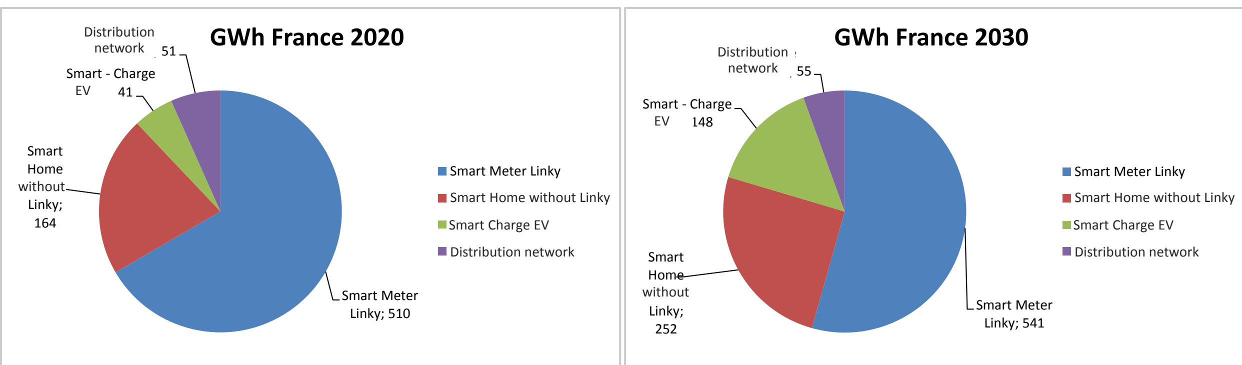
Main results

The combination of use cases leads to estimate that there will around **150 million connected objects in 2020 and 350 million connected objects in 2030** for the four domains studied as (meters, sensors, actuators, boxes, smartphones, etc.).

In 2020 as in 2030, a large part of the ICT consumption comes from metering (in blue in Figure 1). Once it is installed in 2020-2022, the Linky installed fleet will have a per-meter consumption that won't change much till 2030. The equipment for smart homes constitute a progressive, primo-installation market with stronger renewals, shorter life cycles and consumption per newly installed machine that will benefit from progress between 2020 and 2030 (in red in Figure 1).

The consumption share devoted to monitoring the charge of electrical vehicles is lesser on the whole (in green in Figure 1), but it is important for each user. The network monitoring and observation consume little energy, per client and on the whole (in violet in Figure 1).

Figure 1 –Total electricity consumption in the ICT layer for the 4 Smart Grid domains



If the information technologies were to remain as they are currently, the consumption in the ICT layer of smart grids would be 3.4 TWh in 2030 (Table 1) for the scope of Smart Grids studied: smart meter, smart home, monitoring the load of electric vehicles, distribution network. As technological progress has to be applied to this scope of ICT like to others, this leads to consumption being in a probable range of 0.8 TWh - 1.5 TWh between 2020 and 2030.

Table 1 – Key figures 2020 & 2030 – Total electricity consumption, with and without Moore's law[2]

Electricity consumption	Unit	2020	2030
Average hypothesis[3]	**GWh**	**766**	**996**
High hypothesis[4]	GWh	851	1535
Without technological progress (with current unitary consumption)	GWh	992	3 410

For comparison, 1 TWh represents only 0.6% of the 160 TWh of French residential electricity consumption. This can also be compared to the 6% and 20 TWh annual loss in the distribution network for 396 TWh of energy transported. **Consumption in the ICT layer of smart grids is reasonable when related to the advantages mentioned in the introduction**, particularly the increased flexibility in the management of the networks and of the offer & demand loads, as well as the potential for additional energy savings.

The Smart Grid sphere data volumes and flows will "only" account from 0.1% to 1% of the French datasphere. The data flows and their storage are small when compared to those generated by multimedia activities like video streaming, social networking, etc. There are only a few hundreds of terabytes per year indeed, corresponding to some thousands terabytes after ten years, and resulting in a number of MW of data centres devoted to energy usages, to be compared to the millions, even billions of terabytes annually managed in the total digital French sphere. The 1 to 3.4 TWh of the ICT layer of smart grids in 2030 compares to the 20.5 TWh of current IT and audio-visual residential consumption identified by the 2014 forecast report of the French transport system operator (TSO).

Table 2 – Annual kWh per client and domain in 2020 and 2030 (average and min-max within brackets)

Domain		2020	2030
SM - Smart Meter Linky[5]	**kWh annual / client**	17	15
SH – Smart Home (including Linky)[6]	**kWh annual / client**	31 (17-160)	31 (16-56)
SH – Smart Home (without Linky)	**kWh annual / client**	14 (0-142)	16 (0-40)
SVEL – Smart monitoring of the vehicle charge[7]	**kWh annual / client**	69 (0-114)	37 (3-61)
SRPD – Smart public distribution network[8]	**kWh annual / client**	2	2

Table 2 provides the average consumption for the mix of use cases. Within brackets, the minimum corresponds to the simplest use case; the maximum corresponds to the most advanced use case. The changes in minimum and maximum between 2020 and 2030 come from the technological progress of each use case. The average change depends upon the mix between use cases.

As per individual client, Linky and Smart Home induce an annual consumption of 15 kWh each, to be compared for example to the annual consumption of a television that could go from 100 to 300 kWh.

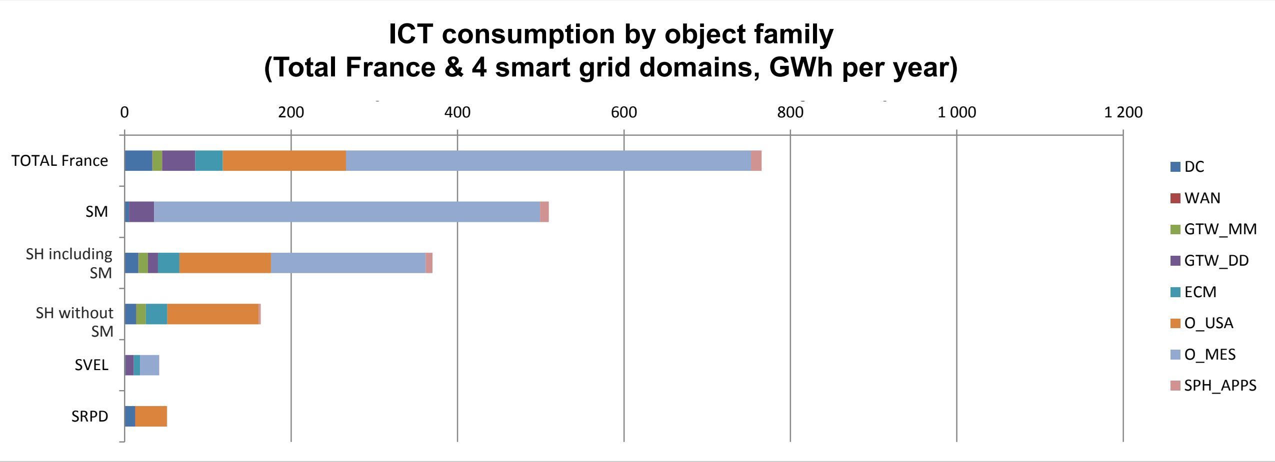
In 2020, the local level, which includes all the equipment located at the clients, represents over 90% of the total consumption of the ICT layer for the four domains. The median level relative to information transfer between local and central levels (WAN internet and telecom networks) consumes 4% of the total. The central level (DC data centres) consumes another 4% of the total. Within a box or a gateway, the consumption of the communication chip is negligible compared to the 24/7 consumption of the circuits. These indeed generally do not modulate their consumption in accordance with the low or high activity.

2 Moore's law states that the consumption of information and telecommunications technologies (ICT) are divided by two every N month, N depending upon each equipment type (exponential decrease).
3 For a 50% cannibalisation rate, See later in Figure 3 – Sensitivity of GWh France 2020 and 2030 at the cannibalisation rate of the Moore's law
4 For a 70% cannibalisation rate, See later in Figure 3 – Sensitivity of GWh France 2020 and 2030 at the cannibalisation rate of the Moore's law
5 For 30 million (2020) and 35 million (2030) low tension clients connected with the Linky meter,
6 For 12 million (2020) and 15.75 million (2030) connected smart home clients (from monitored hot water for sanitary use till the most advanced smart home with a large number of connected equipment in the house),
7 For 0.6 million (2020) and 4 million (2030) electric or hybrid, rechargeable vehicles,
8 For 35 million (2020 and 2030) low tension public distribution clients

The following figure provides the consumptions for the following equipment families:

- DC: Data centre
- WAN: consumption in the Wide Area Network
- GTW_MM: family multimedia gateways/boxes, taken into account for 10% of their consumption,
- GTW_DD: dedicated gateways, taken into account for 100% of their consumption,
- ECM: energy & charge manager boxes,
- O_USA: objects controlling usages,
- O_MES: objects that only measure,
- SPH_APPS smartphones, taken into account for 5% of their consumption

Figure 2 - Consumption of the ICT layer by object family in 2020



Technological progress, Moore's law and cannibalisation through functional and applicative inefficiency

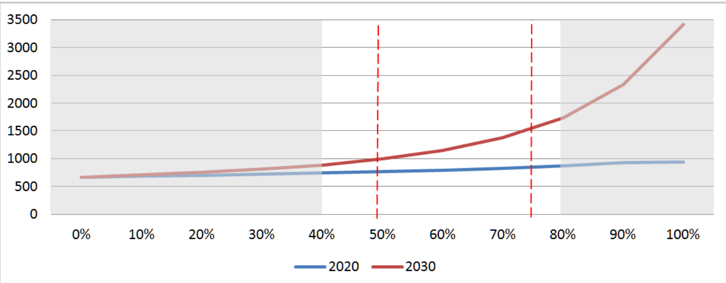
When it comes to the improvement of consumptions, the proposed magnitude of 1 TWh in electricity consumption presupposes that technological progress has been made and benefits to the reduction in ICT consumption. The study has the merit of offering a preliminary modelling of technological progress in ICT not only through the Moore's law, but also through an additional "cannibalisation" ratio of Moore's law progress by functional and applicative inefficiency.

- Moore's law states that the consumption of information and telecommunications technologies (ICT) are divided by two every N month, N depending upon each equipment type (exponential decrease).
- The cannibalisation ratio translates the progressive heaviness of applications and the multiplicity of standards. These eat into the progress in additional storage and calculation capacity such that technological progress does no translate into benefits for the client or reduction in consumption.

Figure 3 shows that this is the major sensitivity factor of the study. In the absence of objective elements, it is estimated that the cannibalisation range lies reasonably between 40 - 80 % (white area).

The central hypothesis of the study is based on a 50% rate. A high variant is presented in the results of Table 1 with a 75% rate (dotted red lines).

Figure 3 – Sensitivity of GWh France 2020 and 2030 at the cannibalisation rate of the Moore's law



Watch-points

Several factors lead to qualifying the statement of a reasonable consumption level:

- **In some use cases, the ICT consumption seems high when compared to the total consumption of their domain**:
  - Some very advanced Smart Homes could consume up to 150 kWh per client and per year, i.e. 1 - 5% of the consumption of the homes.
    - ➔ The functioning of the ICT layer could consume 9% - 23% of the annual energy savings related to demand side management[9]
  - Monitoring the charge of the electric vehicle is significant since it represents 2 - 5 % of the amount of energy effectively charged[10].

- **A more comprehensive approach in life cycle analysis may clarify the statements and remains to be detailed**:
  - Based a fast approach that remains to be backed by additional studies, the grey energy could multiply energy costs by a factor of 1.2 - 4.4, but the carbon return on investment remains in nearly all studied cases positive
  - The energy and CO_2 return time are average in 2020. The probability that there will not be a positive return in this timeline is low. The return time is between average to good in 2030 (less than 1 year to 5 years, for an equipment life cycle duration of 5 - 10 years)
  - 35 - 70 million of waste electrical and electronic equipment will be generated annually by the ICT's linked to the smart grids (WEEE): the issue is at least as important as that of electricity consumption

Recommendations

Electricity consumption in the ICT layer will depend on the manner in which maximum profit is derived from technological progress expressed through Moore's law. The implementation (or not) of functional, software and technical eco-design best practices aiming at sobriety, efficiency and adequate solution mix are particularly at stake.

A certain vigilance is still necessary, which leads to the formulation of the following recommendations.

The focus for the development of new solutions will be on the following key points:

- Priority reduction in consumption and equipment downsizing, particularly those deployed on a large scale at individual residences. Optimal sizing of boxes, equipment and devices, avoiding the over-sizing or over-powering observed in the multimedia world
- Develop "communicating" boxes that can modulate their activity
- Develop software, application and technical ecodesign to exit from the logic of inflating software ("bloatware", "fatware")
- Develop know-how in algorithms that auto-adapt to locally available time, calculation and memory capacities
- Promote knowledge transfer in terms of ultra-low consumption from Energy Harvesting objects towards objects with batteries as well as towards objects that are plugged in
- Encourage open standards, interoperable at each level of the OSI[11] model, compatible from end to end with the logic of internet of things with few "translations" to minimise the number of proprietary standards and therefore the required power of calculation
- Make profit of the interest of households in boxes related to security or health, and add energy related services. Pool the equipment, particularly for individuals. Gain not only by pooling the ICT consumption, but also in capturing additional potential customer base for flexibility and demand side management,
- Motivate clients and operators to use their equipment as best as possible, not only for flexibility but also to generate energy savings

As a general rule, this study constitutes a first step, that should be deepened and completed, particularly in terms of : understanding the effect of cannibalisation of Moore's law improvements; considering the park effect; new smart grid

[9] Based on whether the 2020 or 2030 timeline is considered; based on whether are considered all the households that have a smart meter or only those who also have smart home equipment. Hypotheses of 0,5% to 10% energy savings depending upon the use cases.

[10] This result must be balanced with the fact that the number of electric vehicles in 2020 is still quite low. The scale effects could enable better amortising the energy costs of the ICT installations. These key figures must also be put into perspective in terms of the very high impact that a development of electric vehicles would have without load monitoring.

[11] The **OSI** (***O**pen **S**ystems **I**nterconnection*) model describes the functionalities necessary for communication between IT systems and their organisation in 7 layers.

use cases enabled by the long range, low frequency, SIMless technologies; energy and carbon footprint including manufacturing; raw material footprint from the point of view of the WEEE.

Conclusion

A deployment of smart grid technologies compatible with the energy transition will lead, according to the results of this first study, to an annual consumption of around 1 terawatthour in 2030, for the ICT layer of all use cases related to smart metering, smart home, smart network and smart EV charge. This calculation is highly dependent upon the hypotheses on the actual efficiency of technological progress related to the ICT. This consumption is mainly related to the objects that will be massively deployed at local level, and to a lesser degree, to the centralized big data infrastructures. In comparison with the losses in the distribution network (20-30 TWh annually), this consumption is relatively low. It seems important however, to remember that the objects considered in this study, like a charging point for an electric vehicle or the smart meter Linky for example, certainly consume energy, but in return, provide a wide range of services for the energy transition. They contribute to important functioning improvements, particularly in the electricity distribution and transport networks, as well as in better control of the demand for energy through more granular monitoring.

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ABOUT ADEME

The French Environment and Energy Management Agency (ADEME) is a public agency under the joint authority of the Ministry of Ecology, Sustainable Development and Energy, and the Ministry for Higher Education and Research. The agency is active in the implementation of public policy in the areas of the environment, energy and sustainable development.

ADEME provides expertise and advisory services to businesses, local authorities and communities, government bodies and the public at large, to enable them to establish and consolidate their environmental action. As part of this work the agency helps finance projects, from research to implementation, in the areas of waste management, soil conservation, energy efficiency and renewable energy, air quality and noise abatement.

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