# A SIMPLIFIED ENERGY CONSUMPTION MODEL FOR FIBRE-BASED NEXT GENERATION ACCESS NETWORKS

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## Introduction

- **Reducing energy consumption** is one of the main goals of Europe.
- **ICT-based opportunities** (smart buildings, smart grids and smart transportation systems among others) can lead to emission reductions 5 times the size of the sector’s own footprint.
- **Next Generation Networks (NGN)** are considered as the most relevant upcoming ICT developments.
- **Major blocks of energy consumption in ICTs**: telecommunications networks, data centres and consumer equipment.
- **A significant degree of innovation is still required.**

## Objectives

- Deriving a **simplified model** for energy consumption of diverse types of fiber-based NGANs.
- **Enable comparisons** across technologies.
- Estimate the **impact** of the energy consumption in the life-cycle cost of NGNs and the implications of new NGAN deployments on the ICT carbon footprint.
- Contribute to a constructive and **open discussion** on the benefits of deploying NGAN from an energy efficiency point of view.

# 2. Foundations of the model

## Access Technologies

- The model for energy consumption in NGANs departs from a review of all of the technologies suited for NGANs in the short and middle term
- Broadband access technologies can be classified by the physical medium into two major groups: wired (or fixed line) technologies and wireless technologies.

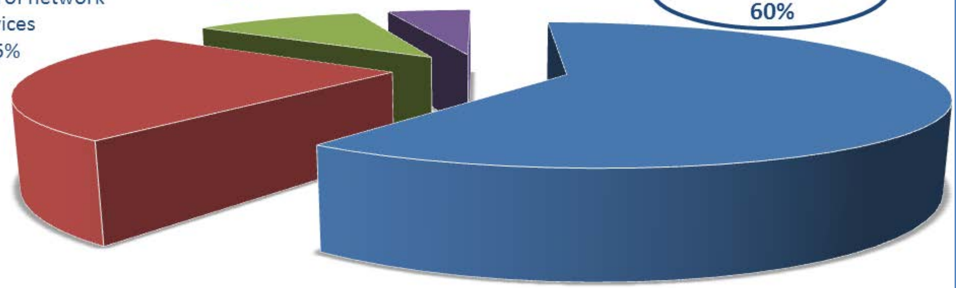
Access Technologies

- Fixed line
  - Fibre
  - Copper wire
  - Coaxial
  - PLC
- Wireless
  - Terrestrial
  - Satellite

- In the following discussion, only **fixed fibre-based NGANs** (*PON and PtP variations of FTTH and FTTx/VDSL*) and their energy requirements are taken into account.

## Energy assumptions

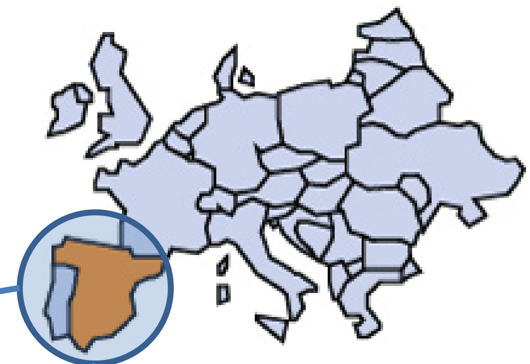
- Different phases of **energy consumption in the life cycle** of a NGAN.



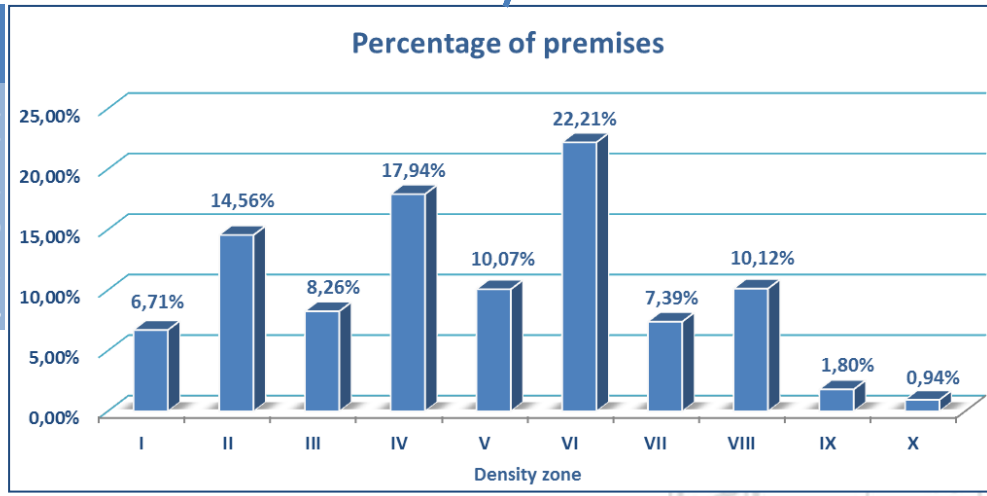

- **Wide variety of devices** that take part in the energy consumption of a NGAN.
  Focus on the main **active components** of the network and the **end-user facilities** (CPEs and ONTs).
- Energy consumption of the **customers' own house equipment** is defrayed excluded from the economic balance presented below.
- Calculations using the **maximum power allowances** stated for each technology provided by the standards listed in the regulatory initiatives section.
- The reference price/KWh set for the cost calculations is **0.14 €/KWh**.

## Demographic data

- Classification in **10 geographical zones** with **population density** as the basic parameter.
- The nation of **Spain** is used as a case study. The model described in the paper would be applicable without major modifications to most European countries.



| SPAIN | |
|---|---|
| Number of municipalities | 8.112 |
| Total population | 46.745.807 |
| Population per municipality | 5.763 |
| Total surface (km2) | 504.677,19 |
| Surface per municipality | 62,21 |
| Number of households and businesses | 17.950.398 |



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## Traffic and Demand assumptions

- Energy consumption **highly dependent on the traffic patterns** of the users.
- The interfaces **100% duty cycle constantly** (24 hours per day). Total energy consumed in one year= [power consumption of each device per hour] x [power **factor of 8760** (24 hours times 365 days a year)].
- **Demand** is also an important factor for a general view of the complete Spanish scenario.
- The study on the energy consumption during the network usage presented in this paper defines the **behaviour of the network once deployed**.
  - **Take-up ratio of 80%**
  - **Churn ratio 20%**
- It would be **interesting to study** the implications of energy in cost balancing **during the network deployment phase**.

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## Network sizing assumptions

- Energy consumption model would be incomplete if only isolated access networks are analysed.
- As not every municipality make a 100% efficient use of the access area even fully deployed, a extrapolation for the complete density zone is done in order to take into account these not used parts of the access areas that also consume energy. (Not linear deployment)
- The **correction factor** is used with the intention of alleviating this effect. Affects the energy required by **cabinets and OLTs** that are not fully used. Do not affect **customer premises equipment.**

$$correction\ factor = \frac{maximum\ premises\ covered\ by\ the\ access\ area}{average\ premises\ per\ municipality}$$

In the zones where this number is lower than 1 no correction is needed as the full network is exploited, so in those cases the factor used is 1 .

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## Economic repercussions

- Large repercussions on the costs of network operation. Can represent a strong barrier towards the economic viability of NGAN deployments.
- Energy consumption could become an important criterion taken into account in the design process of active devices.

## Regulatory initiatives

- European Commission: Code of Conduct on Energy Consumption of Broadband Equipment (EC 2008).
- ETSI: TS 102 533: EE - Energy consumption in BB Telecom Network Equipment.
- Verizon NEBS Compliance: Energy Efficiency Requirements for Telecommunications Equipment (Verizon 2009).

# 3. Model description

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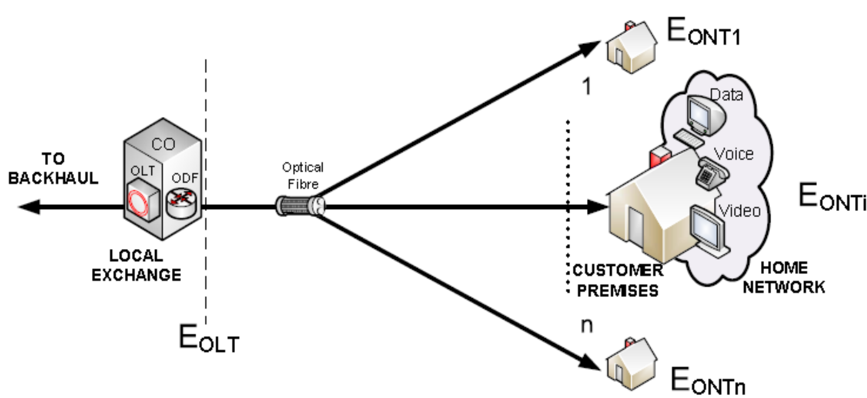
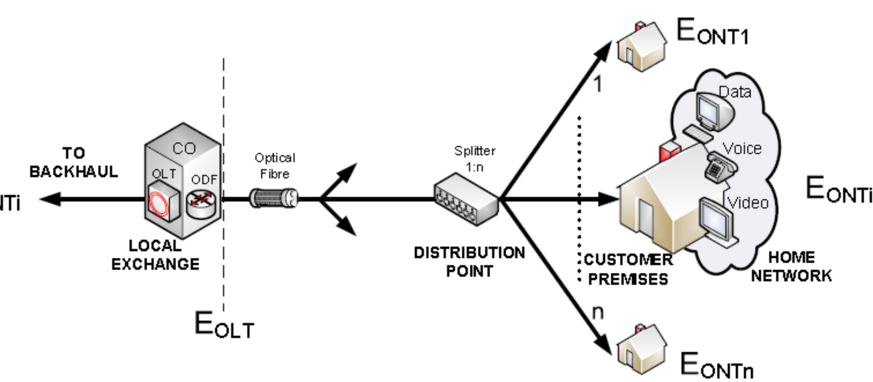
## Fiber-to-the-home (FTTH)

Different FTTH network architectures, *single fibre is used for a subscriber* in a **point-to-point configuration (PtP)** or *some portion of the fibre is shared among customers* (point-to-multipoint); here presented as a **Passive Optical Network (PON)**.

**Point-to-point network architecture**




**Passive Optical Network architecture**



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Fiber-to-the-home (FTTH)

## PtP architecture

- **No passive elements** placed in between Local Exchange and Customer Premises.
- **Customers without service do not need to be connected.**
- **Total local exchange offices** depend on connected users, the network penetration and the percentage of subscribed users.
- The **cost per user is constant** and the **energy consumption is directly related to the number of users**.
- Extra factor because of the **cooling requirements** ($\alpha_{cooling}$=60% ). ONT cooling factor approaches zero (passive way).

$$P_{\text{cooling}} = P_{\text{Opt DSLAM}} \times 0{,}6$$

- Equations for the energy balance of an access area:

$$E_{\text{OLT}}\ (W) = (P_{\text{OLT}} + P_{\text{cooling}}) = P_{\text{OLT}} \times \left(1 + \alpha_{\text{cooling}}\right) = P_{\text{OLT}}\ (1 + 0{,}6)$$

$$E_{\text{Total}} = E_{\text{OLT}} + E_{\text{ONT}}$$

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Fiber-to-the-home (FTTH)

## PON architecture

- After the local exchange, **one level of passive optical splitters** is used to distribute the signal before it reaches the optical network terminal (ONT) placed in the customer premises.
- Splitting process increases the power required for signal transmission. The insertion loss depends on the splitting factor *n* (**17 dB for a 32-fold splitter )**.
- Focus placed in the **OLT and ONT stages**.
- The key difference with PtP model is that the **homes passed are now considered to be subscribed**. (resource allocation)
- The calculations can be made using the next equation:

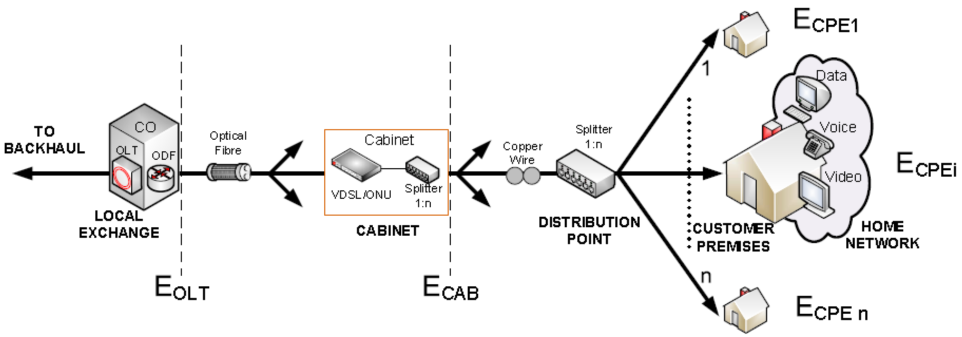
$$E_{OLT} = E_{Uplink} + E_{Downlink} + E_{cooling} = (n_{up} \times p_{uplink} + n_{down} \times p_{downlink}) \times (1 + \alpha_{cooling})$$

## FTTx/VDSL

- FTTx bring fibre from the CO closer to the subscriber and the final distribution is made via an alternative means. FTTB (Fibre To The Building/Basement), FTTC (Fibre To The Curb/Cabinet) and FTTN (Fibre To The Node).
- VDSL/xDSL can be considered equivalent from a network architecture perspective.
- **Active devices**: OLT and CPE (calculated similarly to the FTTH-PON), VDSL/ONU and the DSLAM (Cabinet).
- Power consumption per **cabinet** is set at **1334 W**.
- Total power demand

$$E_{TOTAL} = E_{OLT} + E_{CPE} + E_{CABINET}$$

**FTTx/VDSL access area architecture**



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## Results introduction

- Two main results: to determine which deployments will result into **more energy efficient solutions** and to obtain estimations of the **economic costs** due to the power consumption.
- Next topics are discussed: the **analysis of the relative importance of each energy consumer element** in the access network, the **average premise cost** for access areas according to the specific network sizing used, the study of the **factors affecting the total energy and cost calculations** for the complete demographic framework and the study of the **power consumption in the different density zones** for FTTx/VDSL .

# 4. Results discussion

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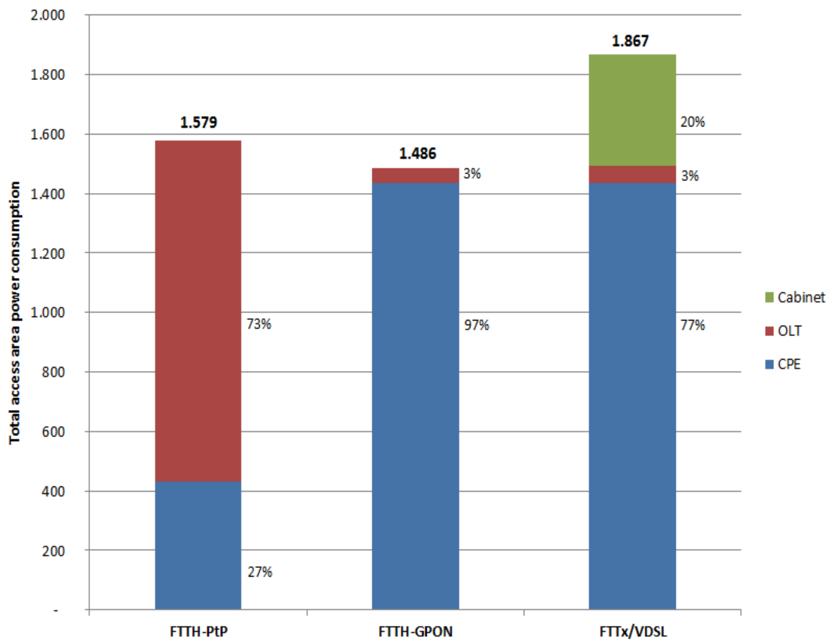
## Analysis of the relative importance of each energy consumer element

- *FTTH-PtP* networks, the share of the active element power consumption is **constant** throughout the ten zones.
- *FTTH-PON and FTTx/VDSL* networks, the **non-direct relation** of the energy on the number of users connected to the local exchange translates into a **variation of the power share** of the active elements.
- The higher output required by the laser diodes in FTTH-PON and FTTx/VDSL is a **critical fact**. Weaken the advantage of PON over PtP networks, but on the whole power consumed $E_{PtP} > E_{PON\&FTTx}$.




Percentage of power consumption for each active element of the fibre-based networks vs. the total power consumption in the access area (according to the sizing for density zone VI).

# 4. Results discussion

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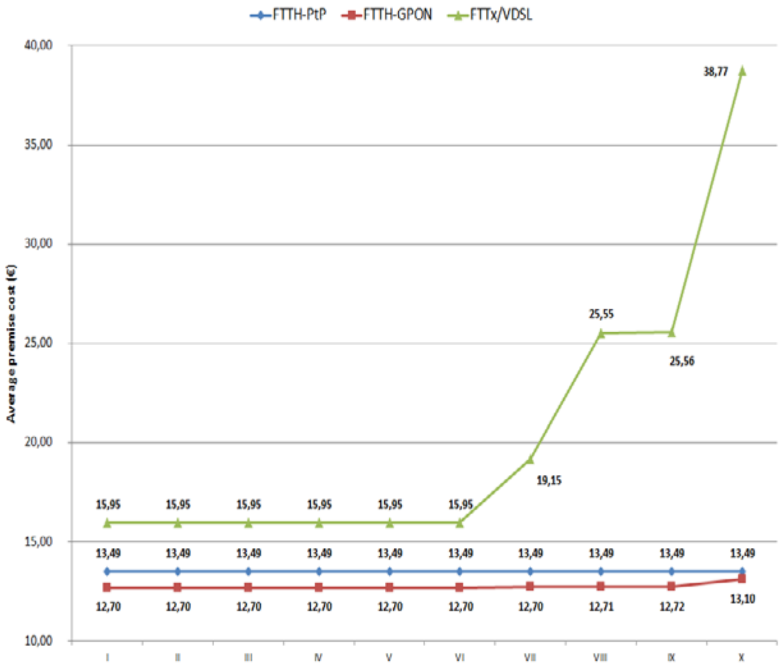
## Average premise energy cost for each access area

- **PtP** networks **constant and independent** of the area, because each **resource is allocated** to the customer only **when the premise is connected** to the network.
- In low density areas the importance of **OLT and cabinets power consumption increases.**
- Importance of the **sizing** of the network.



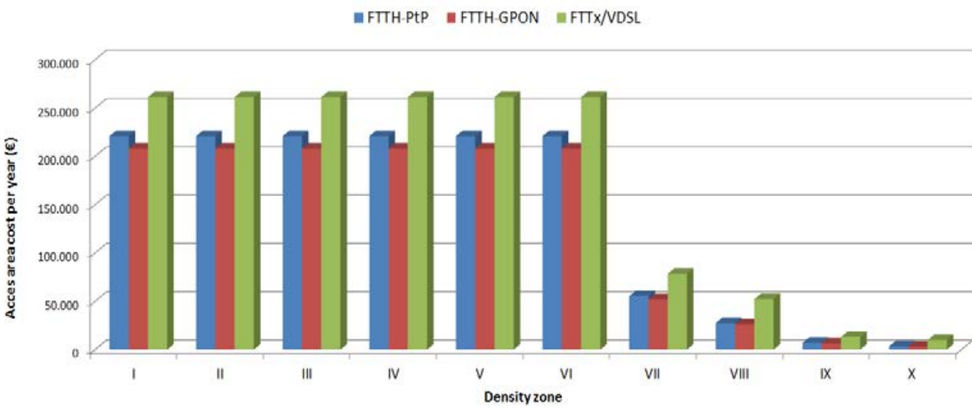

Average premise cost (€) in each access network.

# 4. Results discussion

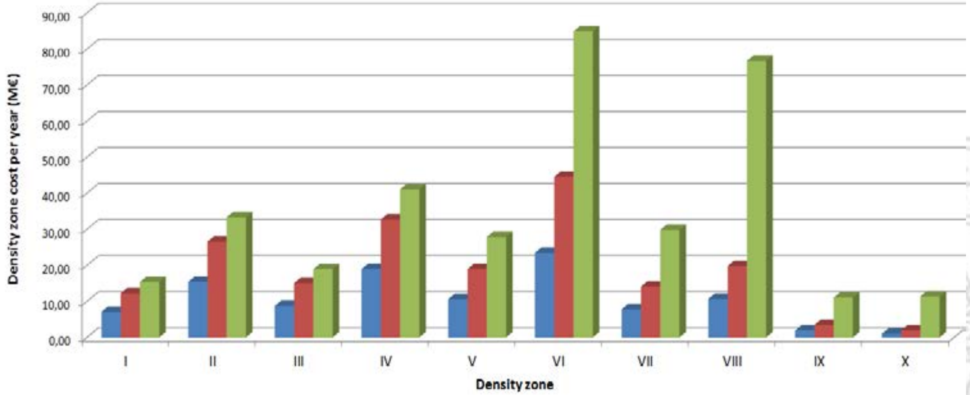


## Factors affecting the total energy consumption

- Factors affecting **cost calculations**:
  1. Access area average energy cost per premise
  2. Sizing of the network
  3. Premises involved in each density zone
  4. Number of areas required to cover each density zone
  5. Network correction factor
- For the **access areas** only the two first factors affected the power and cost calculations. For the **density zones** the three other factors are used and as the access area data is used as reference for the calculations the first two factors affect indirectly as well.




Access area cost per year (€)




Total cost of each density zone per year (M€)

# 4. Results discussion

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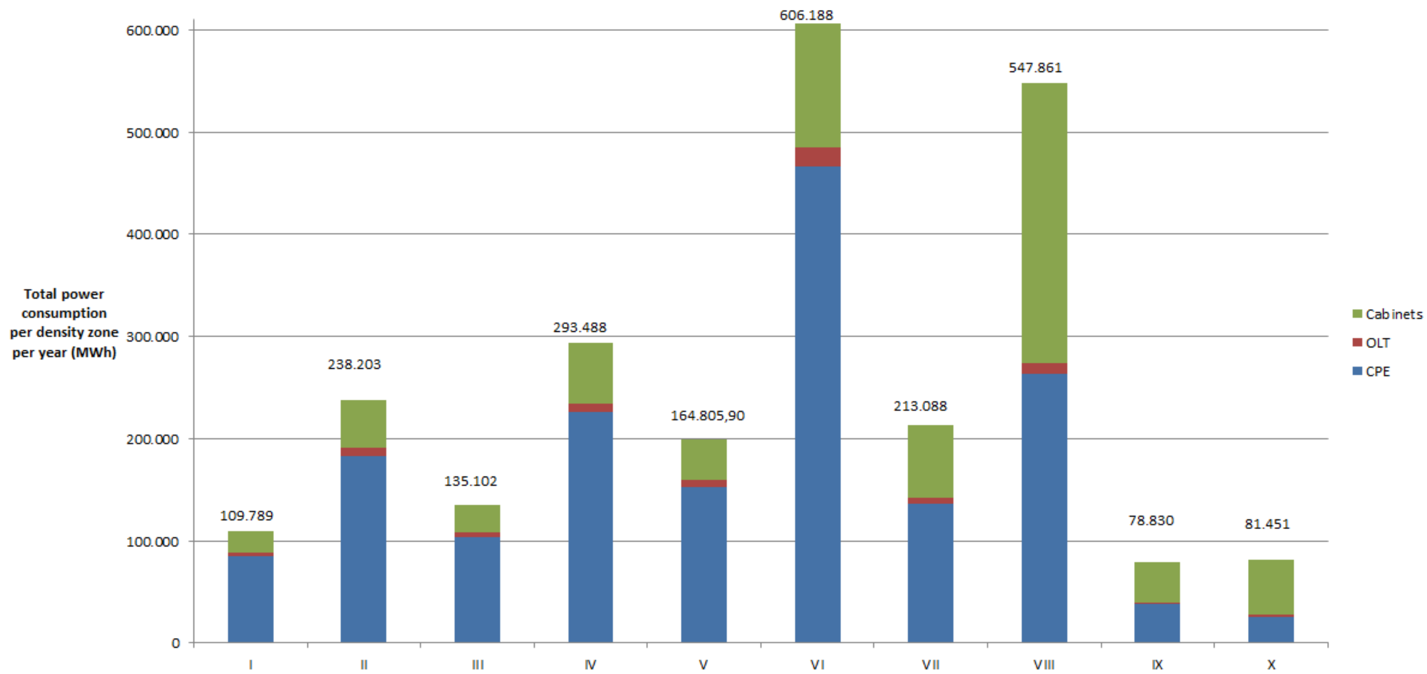
## Factors affecting the total energy consumption

- Power consumption: **correction factor applied** (both OLT and cabinets)
- In density **zone VII** reaches a **peak**.




Total power consumption per density zone (MWh) of the FTTx/VDSL architecture and participation of each network active element.

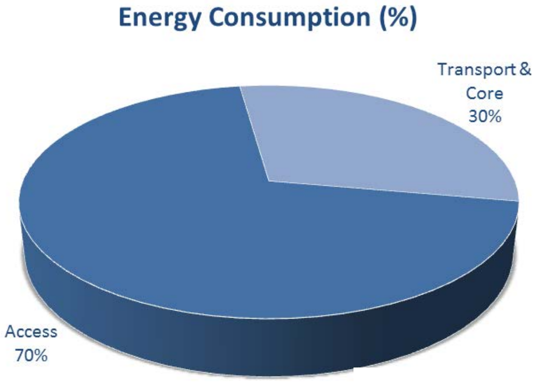
## Results summary

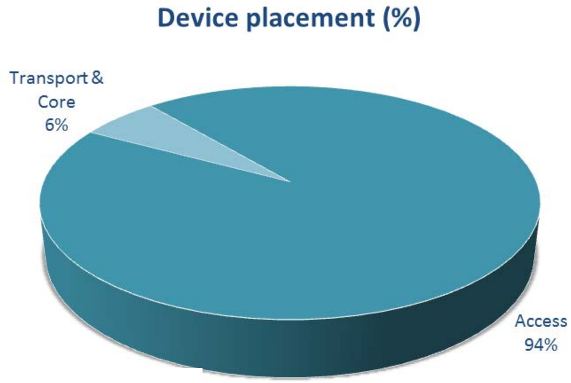
- To conclude this section, the following table summarizes the results obtained for the whole territory of Spain, given all the data and assumptions explained in the previous sections.

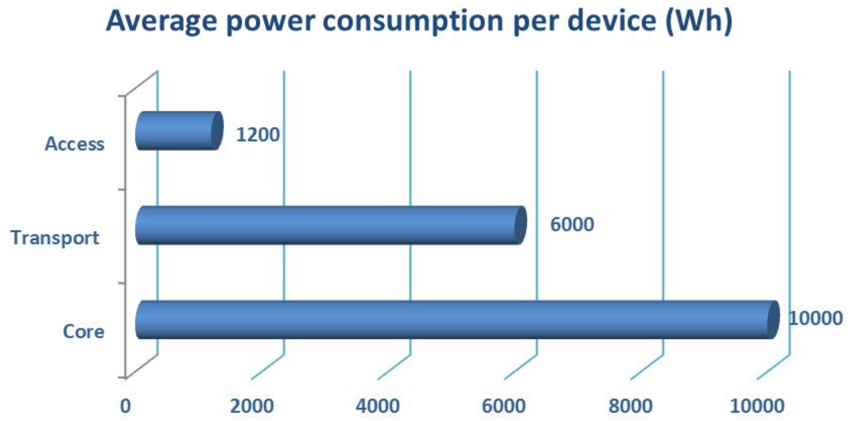
| Technology | FTTH-PtP | FTTH-PON | FTTx/VDSL |
|---|---|---|---|
| Total energy consumption for the Spanish territory (GWh) | 755 | 1.352 | 2.503 |
| Total cost per year for the entire Spanish territory (M€) | 106 | 189 | 350 |

# Conclusions (I)

- Importance of the **Access layer** in the power consumption analysis of NGNs



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# Conclusions (II)

- **Distribution of energy consumption** among the active elements of the access network is rather **dependant on the technology.**
- **Energy consumption** mainly depends on the **architecture and on the sizing** of the access coverage area, but is **also affected by other particularities**.
- Importance of framing the study in **a specific scenario**.
- Analysis of the single access area **cannot be extrapolated** to the **general deployment** of each access networks along the demographic framework because it **entails some implications**.
- Energy consumption and deployment investment costs behaves the same way when the areas are **aggregated**.
- **PtP** access networks are **more expensive to deploy** but implies lower overall energy consumption than that of PON
- In **low density areas**, while **VDSL** networks have an advantage in economic terms (reuse of existing network), consume more energy due to the required equipment.

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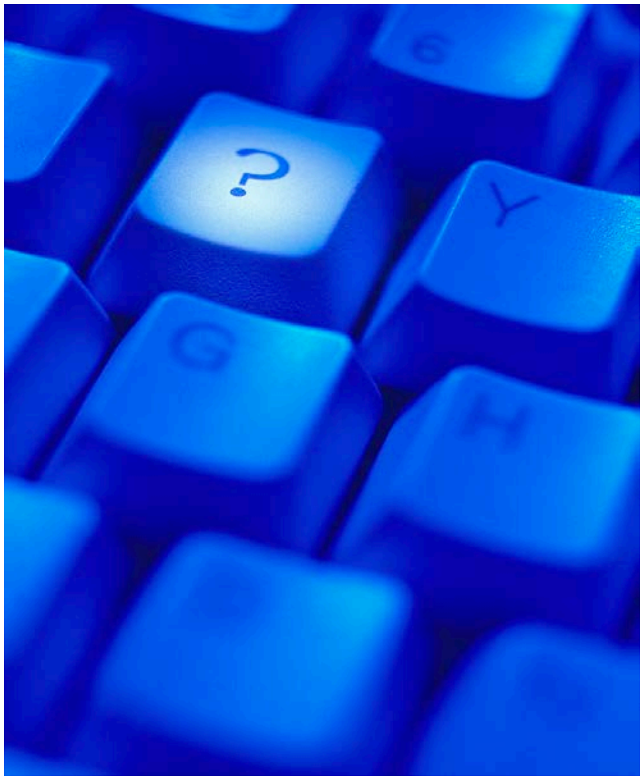
## Next steps

- DOCSIS and Mobile NGANs energy consumption models development for **technology comparison** in order to obtain further conclusions on the suitability of one or other technology for each population scenario. This would add one more variable in the comparison among different technologies for an optimal roll-out aside for the simple economic one.
- Detailed **demand assumptions** over time to determine the rolling-out period energy consumption and the afterwards usage energy level.
- Exhaustive **traffic assumptions** for energy consumption frame in the different equipment and scenarios.
- Implication of the energy consumption on the OPEX of the NGANs for an **economic comparison** on the level of expense this factor implies.

# Questions and Ideas





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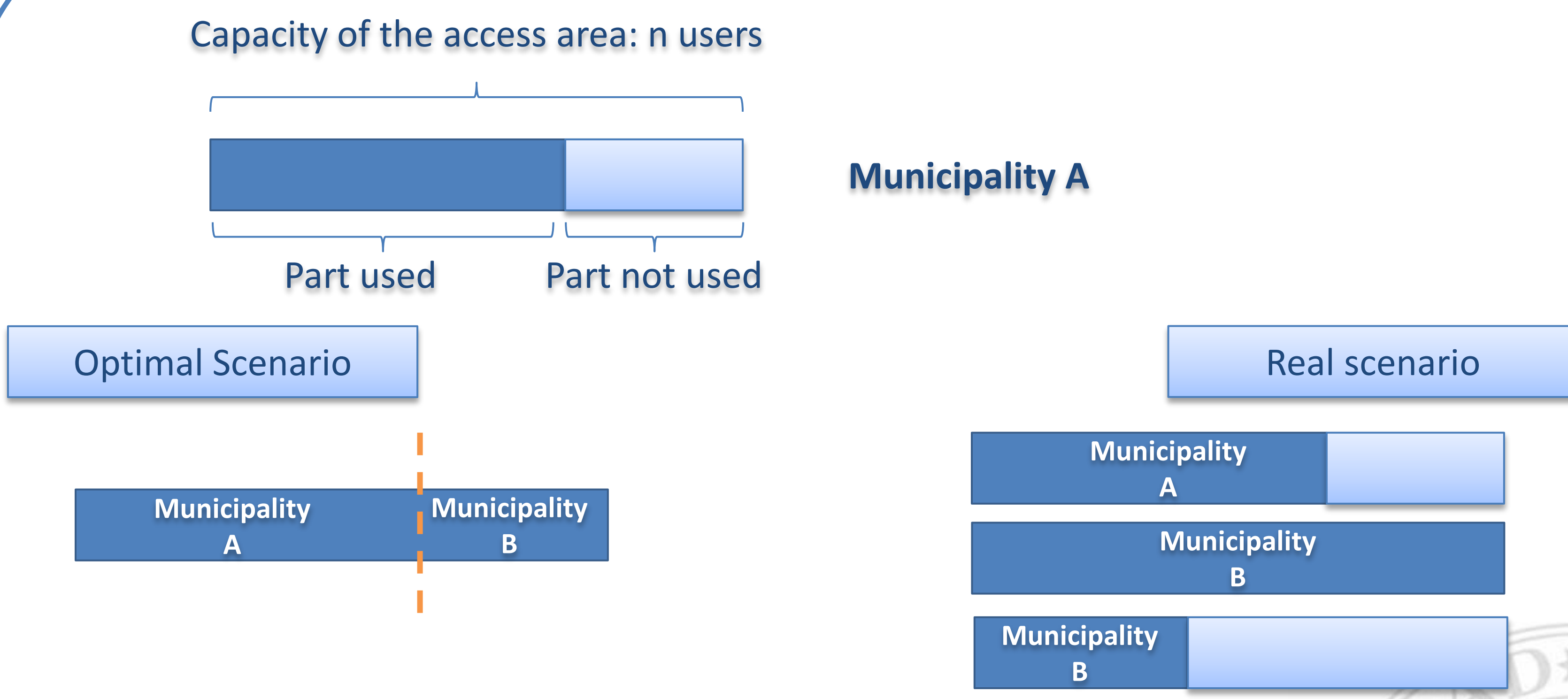
# 2. Foundations of the model

## Network sizing assumptions

Back




Due to the distant locations of the different municipalities of the same density zone the optimal scenario is not real and therefore an access network has to be deployed alone for a single municipality (in many of the cases ), even if the population of the municipality (or the remain population not covered by other access network) is lower than the total capacity of the access area