# ON THE ECONOMICS OF ENERGY CONSUMPTION IN 4G NETWORKS: THE CASE OF SPAIN


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## Research question

Reducing energy consumption is one of the main challenges in most countries. For example, European Member States agreed to reduce greenhouse gas (GHG) emissions by 20% in 2020 compared to 1990 levels (EC 2008). Considering each sector separately, ICTs account nowadays for 2% of total carbon emissions. This percentage will increase as the demand of communication services and applications steps up. At the same time, the expected evolution of ICT-based developments - smart buildings, smart grids and smart transportation systems among others - could result in the creation of energy-saving opportunities leading to global emission reductions (Labouze et al. 2008), although the amount of these savings is under debate (Falch 2010).

The main development required in telecommunication networks –one of the three major blocks of energy consumption in ICTs together with data centers and consumer equipment (Sutherland 2009) – is the evolution of existing infrastructures into ultra-broadband networks, the so-called Next Generation Networks (NGN). Fourth generation (4G) mobile communications are the technology of choice to complete -or supplement- the ubiquitous deployment of NGN.

The risk and opportunities involved in NGN roll-out are currently in the forefront of the economic and policy debate. However, the issue of which is the role of energy consumption in 4G networks seems absent, despite the fact that the economic impact of energy consumption arises as a key element in the cost analysis of this type of networks. Precisely, the aim of this research is to provide deeper insight on the energy consumption involved in the usage of a 4G network, its relationship with network main design features, and the general economic impact this would have in the capital and operational expenditures related with network deployment and usage.

## Remarks on methodology

The model displayed in the research will be used for the calculation of the energy consumption in the two main 4G technologies: Long Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WIMAX). Just the access part of the network will be included in the calculations as the backbone is similar to other broadband technologies. However further considerations will be made in order to obtain some rough figures on the consumption of the transport and core parts, and on the energy consumed along the complete life-cycle of the network.

The approach in the project will use data from Spain as the demographic and geographic framework for what could be considered an average European scenario. The model will use a classification in zones based in population density. Thus some differences in energy consumption between different area types and technologies could be identified. The network deployment model has already been used in research works and publications (Feijóo and Gómez-Barroso 2010; Coomonte et al. 2011; Feijóo et al. 2011).

All the data for the energy consumption of the network elements is obtained from different standards and industry suppliers' specifications.

**Expected results**

The research aims to provide a model for the estimation of the energy consumed by 4G networks, in particular by LTE and WIMAX architectures, as a function of general geo and demographic parameters. This would allow a reasonably accurate estimation of the economic impact of the energy consumed and enables a sensitivity analysis regarding the variation of some architectural (i.e. network design) and connectivity parameters (i.e. data rates).

The analysis of the figures obtained leads to energy consumption cost comparisons between technologies and with regard to the CAPEX, OPEX and total expenditure involved in the roll-out and maturity stage of the networks. With some additional assumptions, it is possible to estimate also the total life-cycle energy consumption and the total cost of 4G networks.

Moreover, as energy consumption could become an important criterion to take into account in the design of networks and network devices, it is hoped that this work could contribute to a constructive and open discussion on the full implications of deploying 4G networks.

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*Disclaimer: This study has been developed under the European Investment Bank (EIB) STARBEI funding program.*

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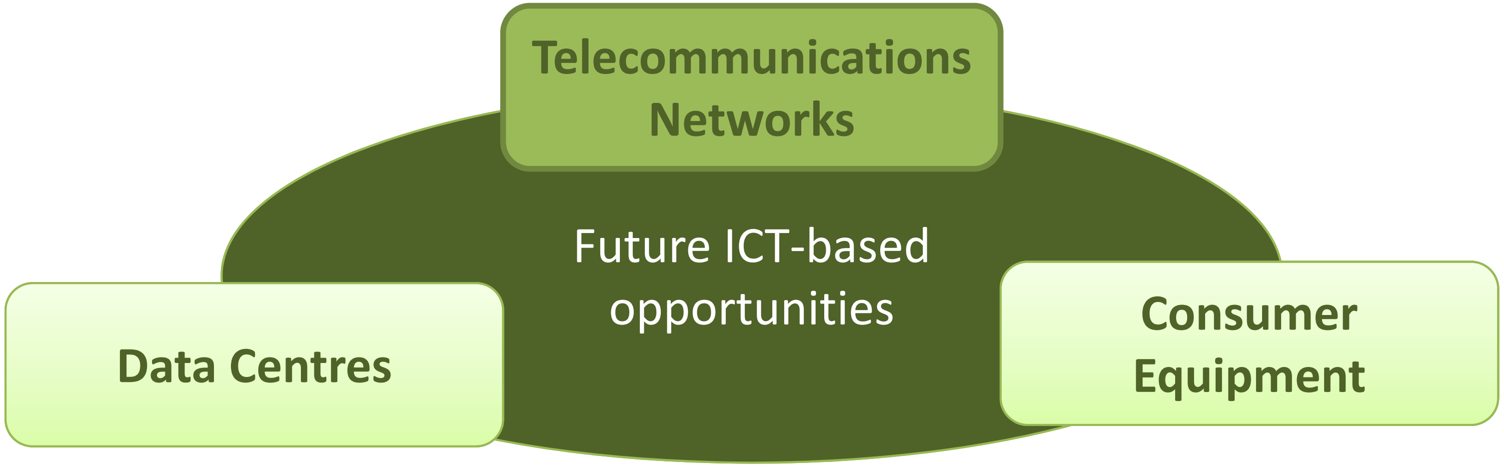
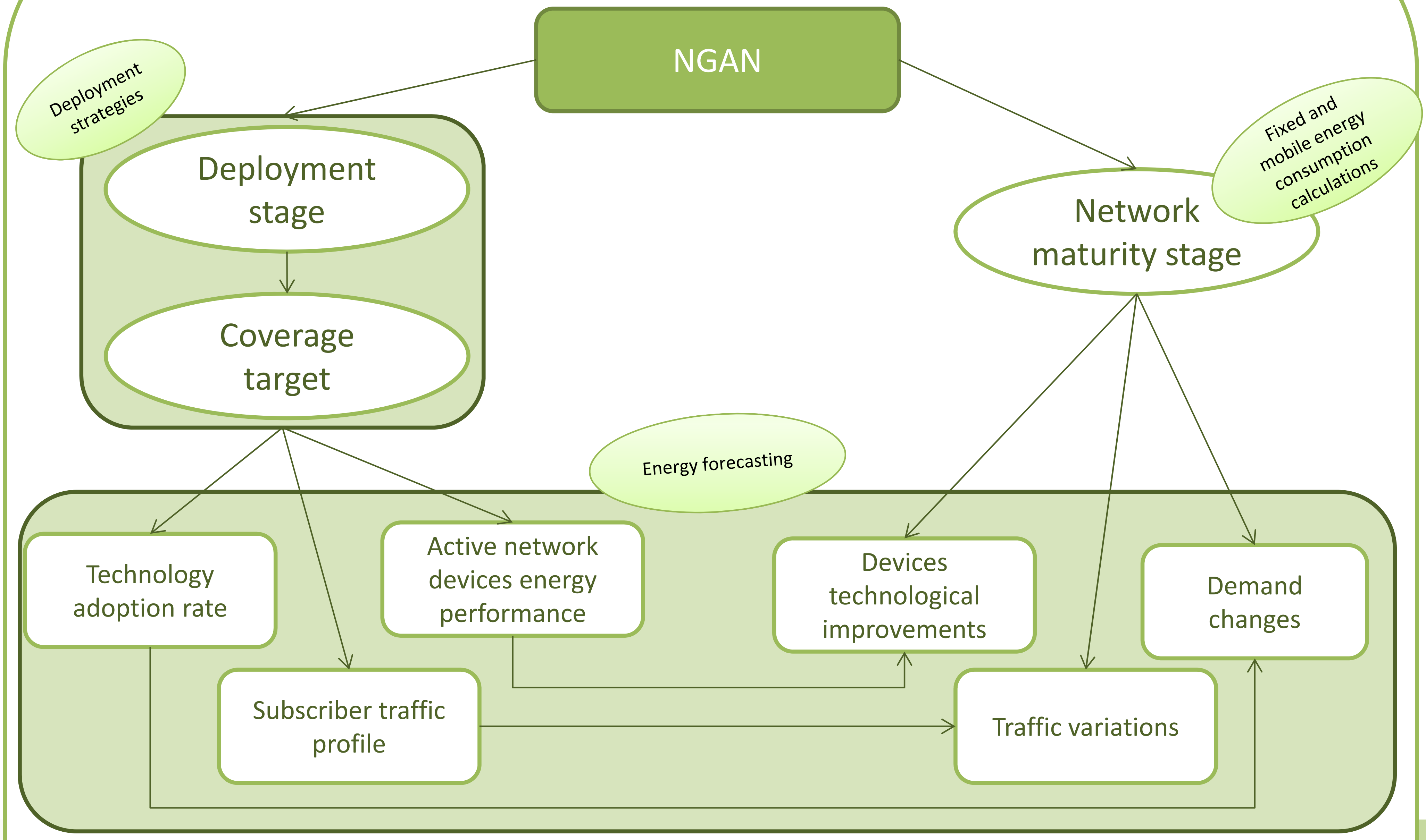
# Introduction

- **Reducing energy consumption** is one of the main goals of sustainability planning in most countries. For instance in Europe, the EC established the objectives in the Communication "20 20 by 2020 Europe's climate change opportunity".




- Next Generation Networks (NGN) → **One of the most relevant upcoming ICT development**
- The role of energy consumption seems mostly **absent** from the main analysis and the debate on NGN deployment.

# Overview of the complete project

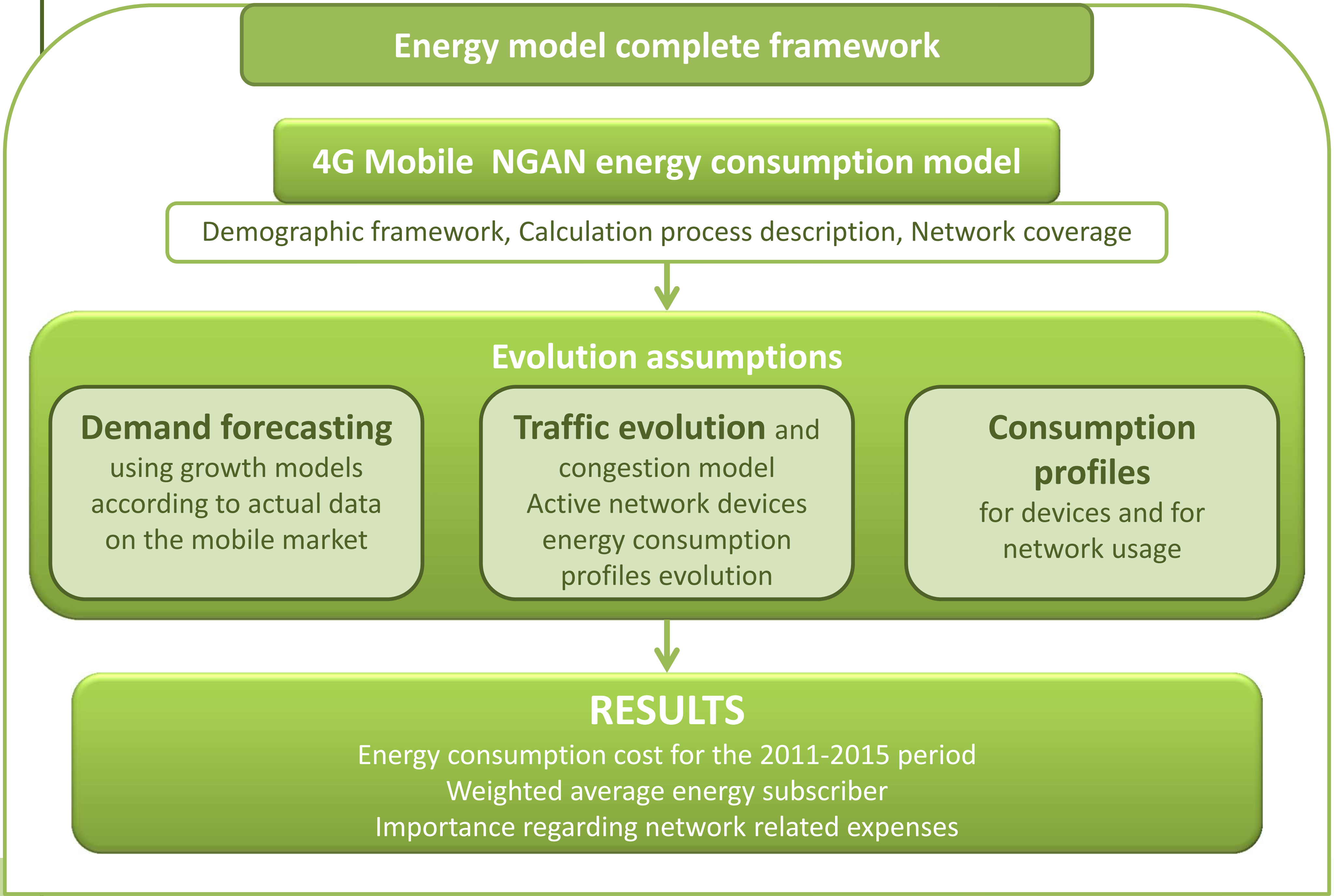


## Research questions

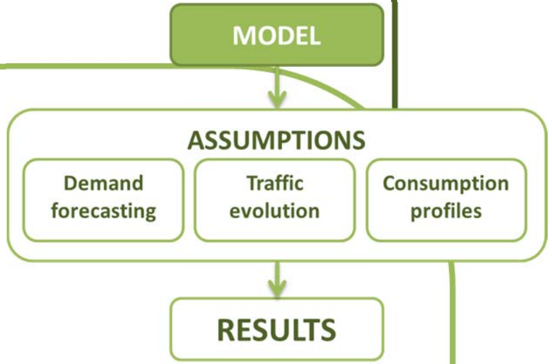
- What design parameters could affect the levels of cost/energy consumption of the network?
- How the variation of these parameters affects these levels?
- How is the cost of the energy consumption related to network CAPEX and OPEX?

# Motivation

- 4G Networks → Alternative to fixed networks
- Variation of the design parameters through the years (2011-2016 period):
  - ***Demand***
  - ***Traffic***
  - ***Usage during the day***
  - ***Device energy consumption***
- The complexity lies on the proper **definition and proper combination** of those parameters in the model proposed.
- The analysis of the results would help us determine the **relative importance** of each factor and the need of improving the accuracy on the calculation of each of them.

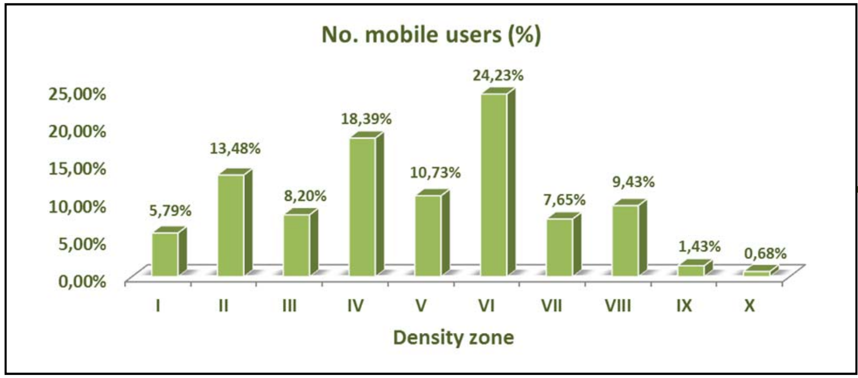

Energy model complete framework
4G Mobile NGAN energy consumption model
Demographic framework, Calculation process description, Network coverage
Evolution assumptions
Demand forecasting using growth models according to actual data on the mobile market
Traffic evolution and congestion model Active network devices energy consumption profiles evolution
Consumption profiles for devices and for network usage
RESULTS
Energy consumption cost for the 2011-2015 period
Weighted average energy subscriber
Importance regarding network related expenses

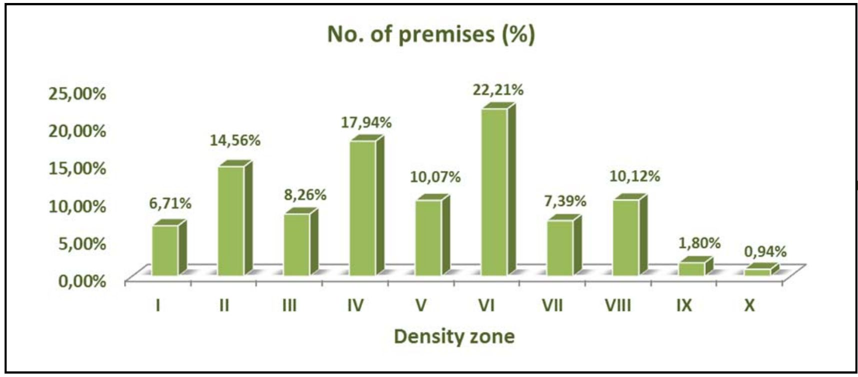
# Demographic framework

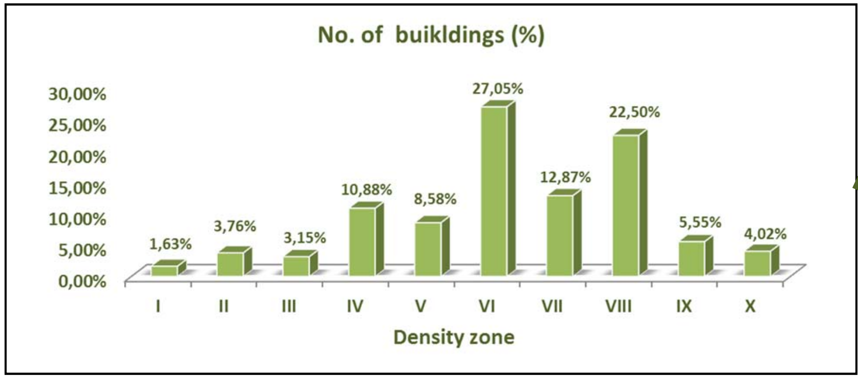


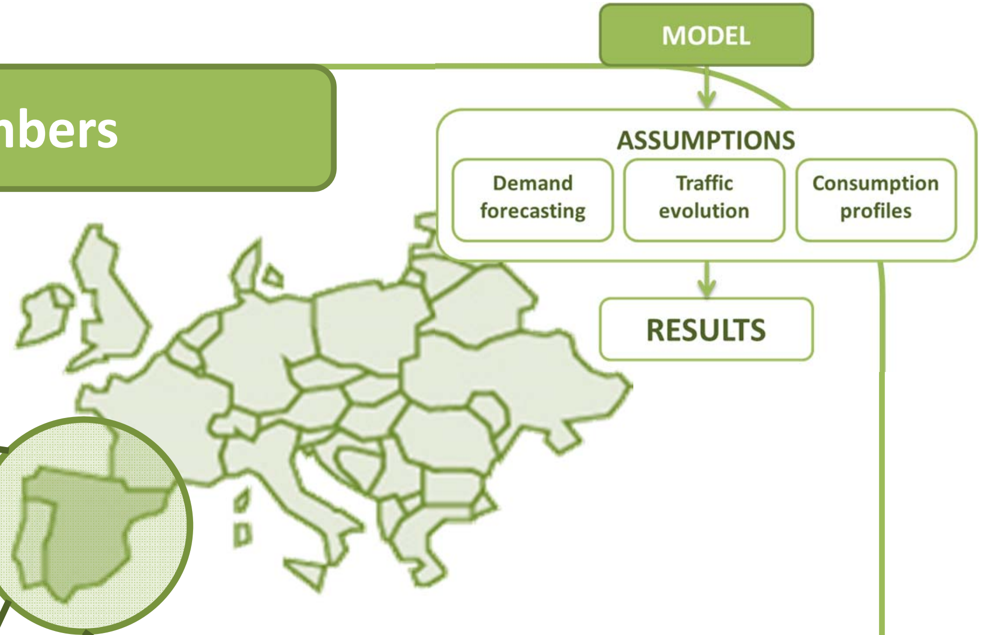

- **Spain** is used as a case study (applicable without major modifications to other countries).
- Classification in **10 geographical zones** with **population density** as the basic parameter.
- The model allows for more precise **estimations in the areas where only one broadband network operator is present**
- **To improve the lack of information on buildings clustering**, mainly for suburban and rural areas → Division of each zone in **2 different geotypes "A" & "B"**

# Demographic framework in numbers



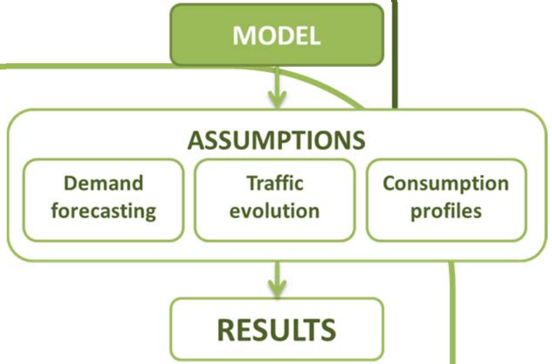



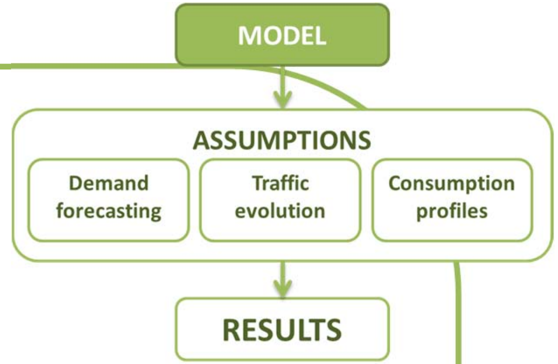

| SPAIN | |
|---|---|
| Number of municipalities | 8112 |
| Total population (inhabitants) | 46.745.807 |
| Mobile penetration rate (CMT, October 2010) | 121% |
| Total number of mobile users | 56.562.426 |
| Number of households an businesses | 17.950.398 |
| Global average mobile users per premise | 3,15 |
| Number of buildings | 9.285.007 |
| Global average mobile users per building | 10,08 |
| Average population (inhabitants per municipality) | 5.763 |
| Total surface (km2) | 504.677 |
| Average surface per municipality (km2) | 62,21 |

# User allocation

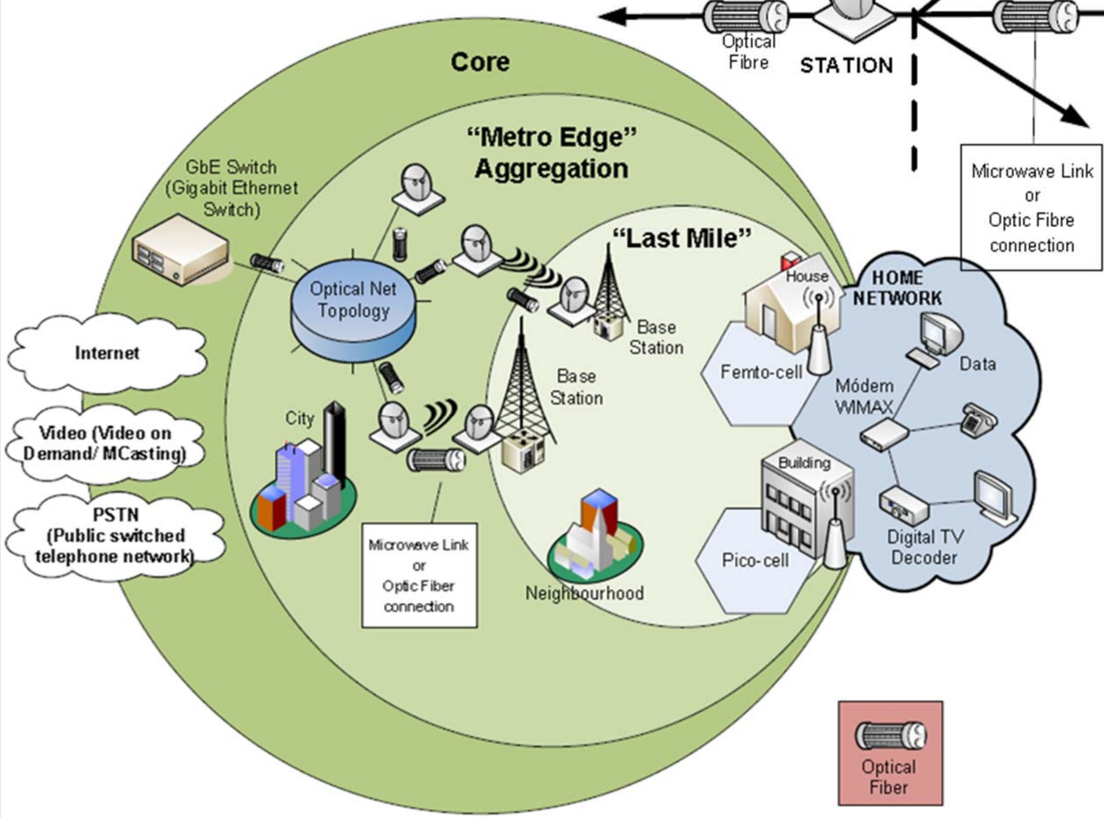


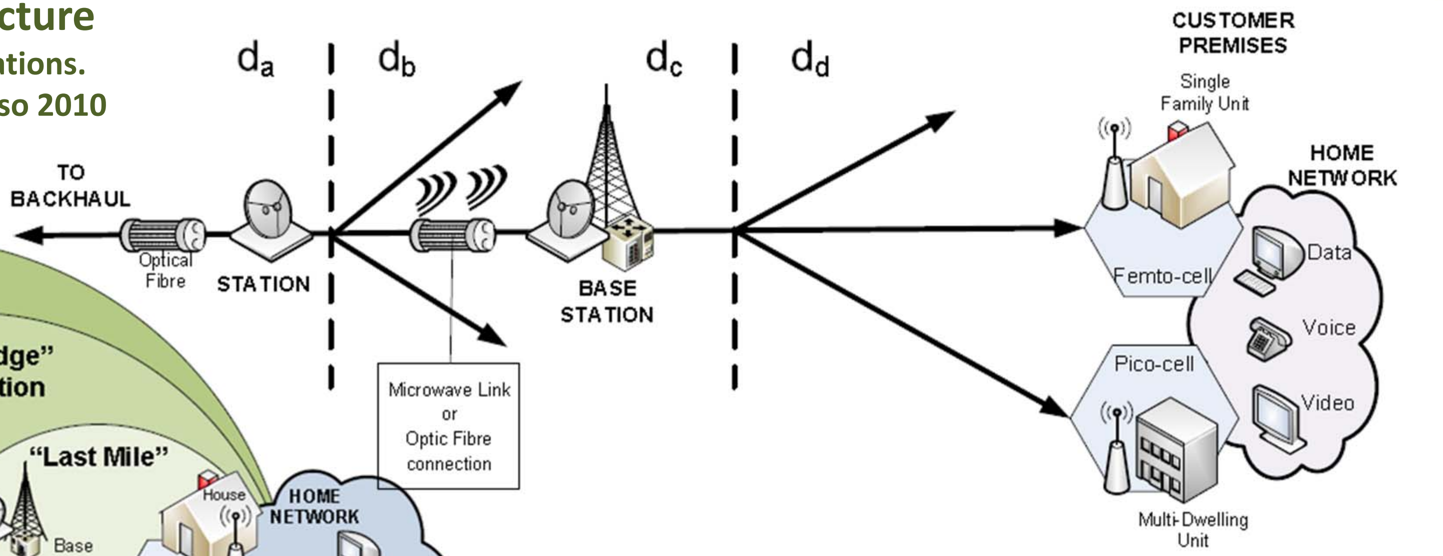

- Some principles are established for potential subscriber allocation:
  - Some zones would be the first to be deployed and therefore all the potential subscribers goes to these zones until the penetration reaches the established level.
  - At the end of the period not all the zones will be fully deployed, in fact depending on the strategy  some would even be without any deployment at all.
  - **Base scenario** assumes deployment from **higher density zones** to lower ones (operators perspective). The alternative scenario considers the opposite, from lower to higher density zones (due for instance to license or regulatory conditions).

# 4G Access network architecture




**Mobile network architecture**
**for energy consumption calculations.**
**Source: Feijóo and Gómez-Barroso 2010**



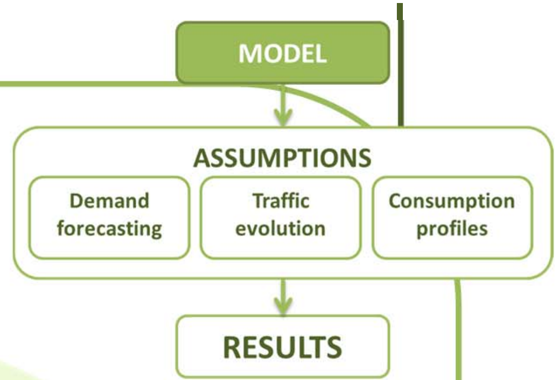

*Initial assumption*

**Guaranteed data rate per user: 1 Mbps**

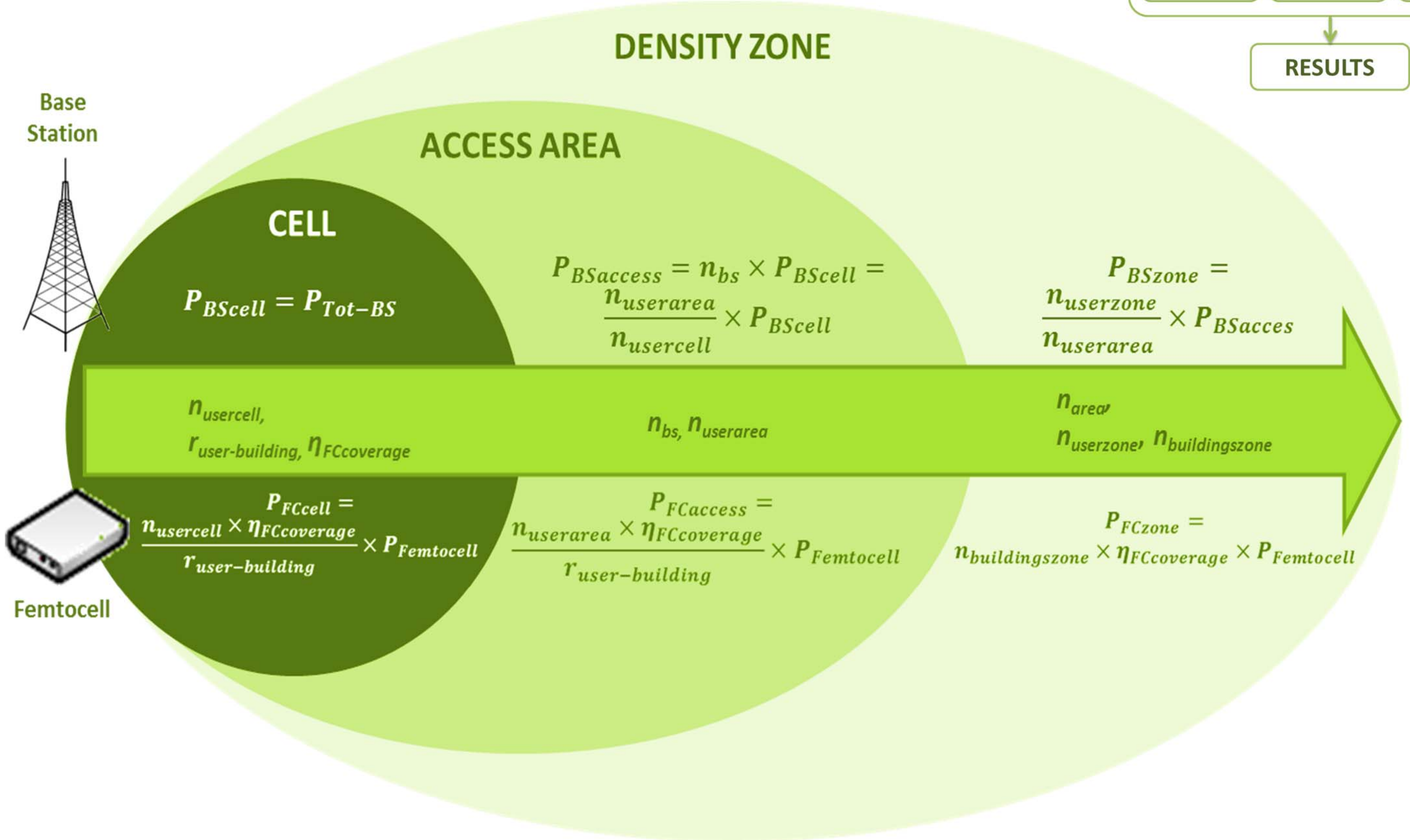
**Bandwidth: 20 MHz**

**Energy price: 0,14 €/KWh**

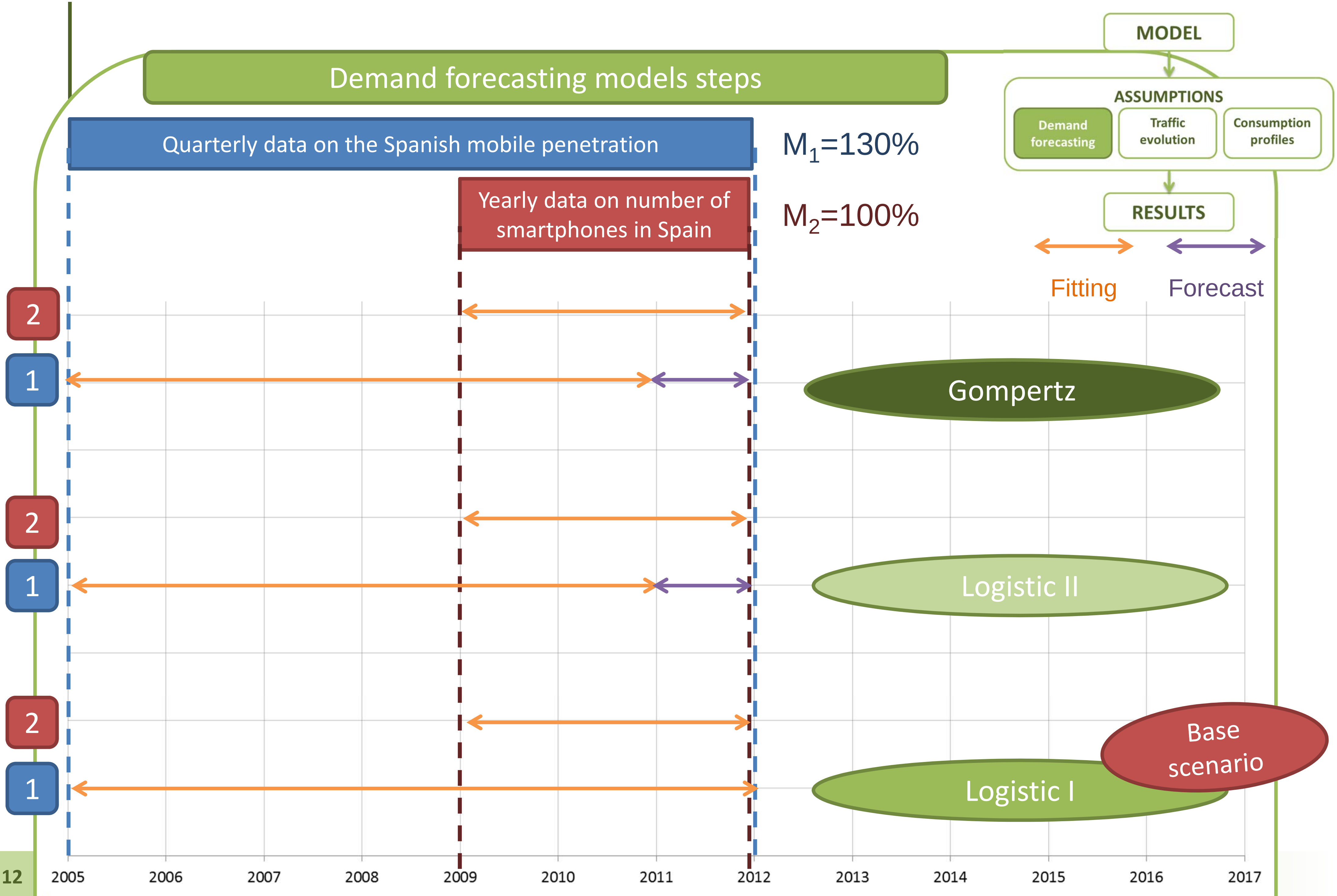
**Mobile/Wireless 4G network architecture.**
**Source: Feijóo and Gómez-Barroso 2010**

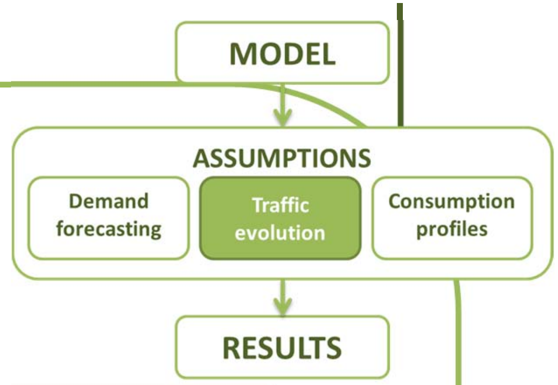



# 4G Access network architecture

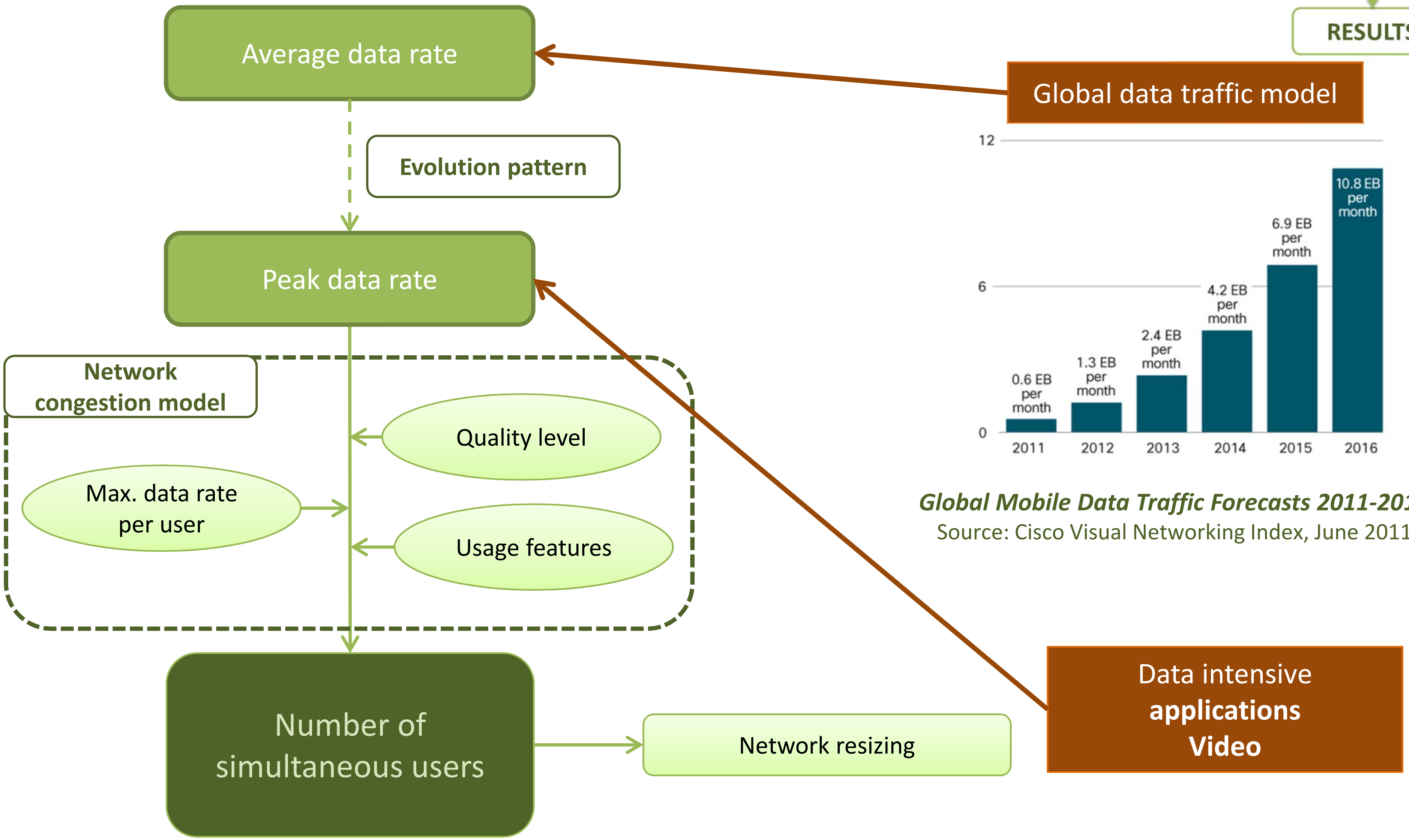


# Demand forecasting models steps



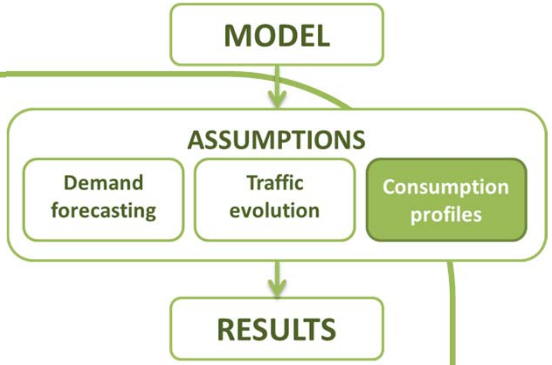



# Traffic evolution



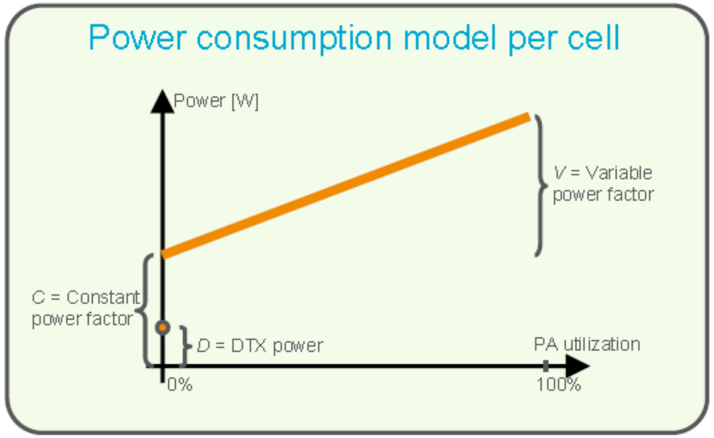

***Global Mobile Data Traffic Forecasts 2011-2016.***
Source: Cisco Visual Networking Index, June 2011;

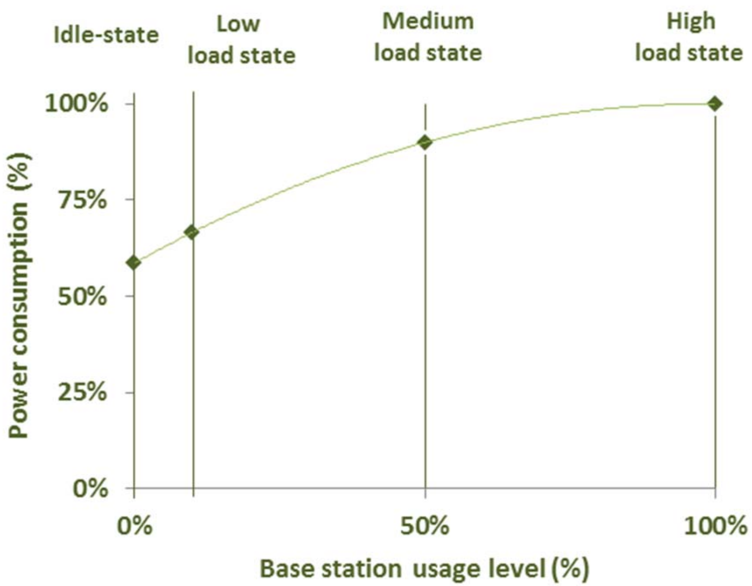
# Active device energy profiles



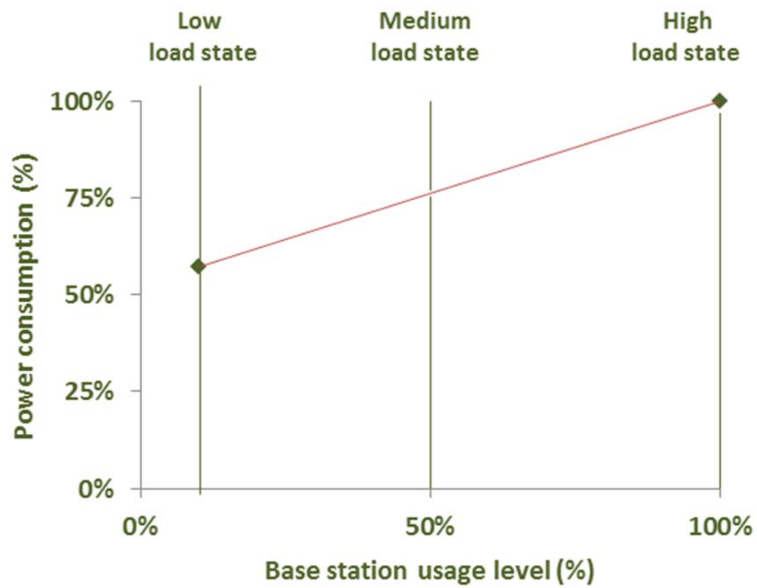

## *Reference idea*

**Source:**
Frenger, P., Moberg, P., Malmodin, J., et al. (2011). "Reducing Energy Consumption in LTE with Cell DTX".

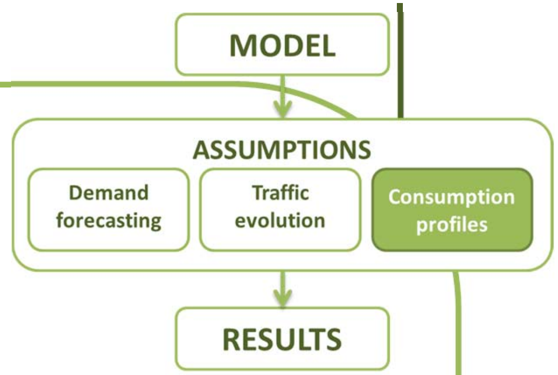



*Base Stations energy consumption model*

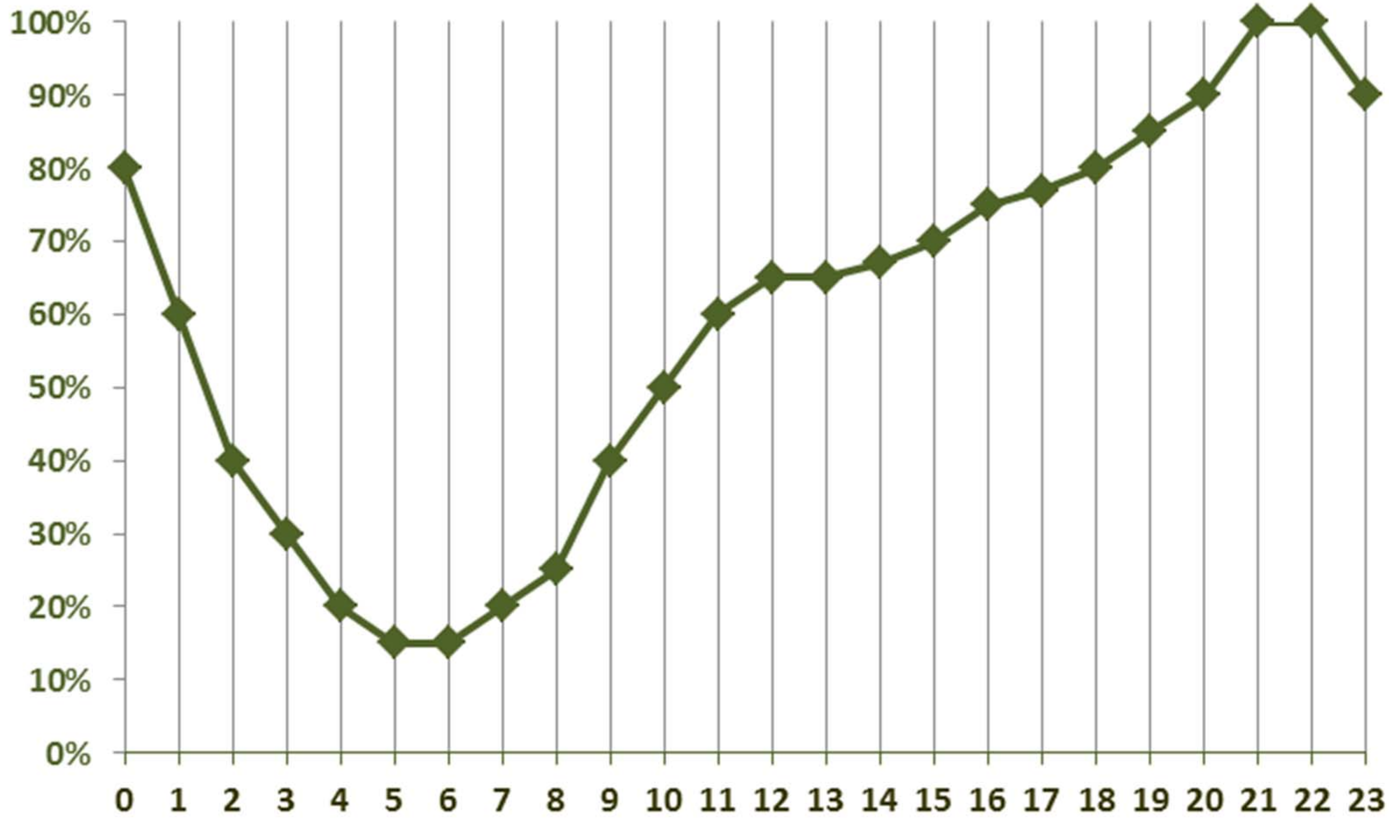



*Femtocell energy consumption model*



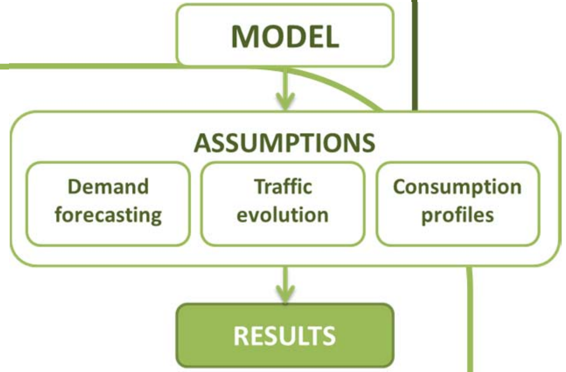

# Network daily usage

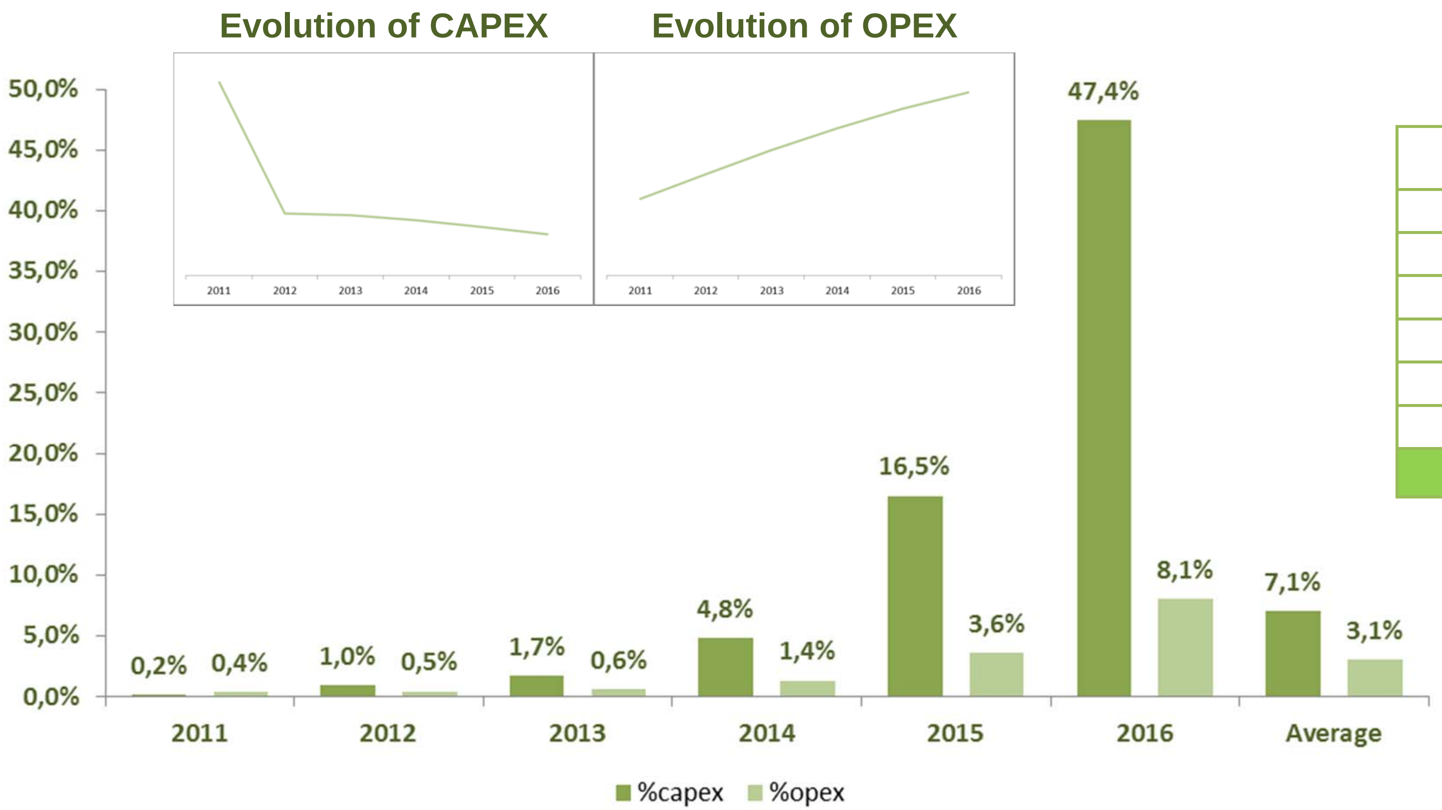
- Instead of assuming a 100% work cycle at all times for the devices an average daily profile of network usage is used




*Data traffic variation during a day*
*Source: Project EARTH*

# Results
# Baseline scenario evolution over time



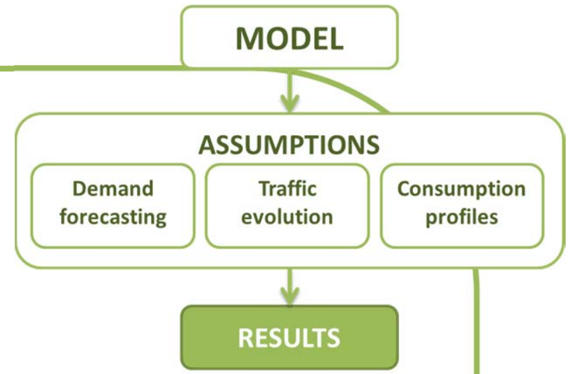



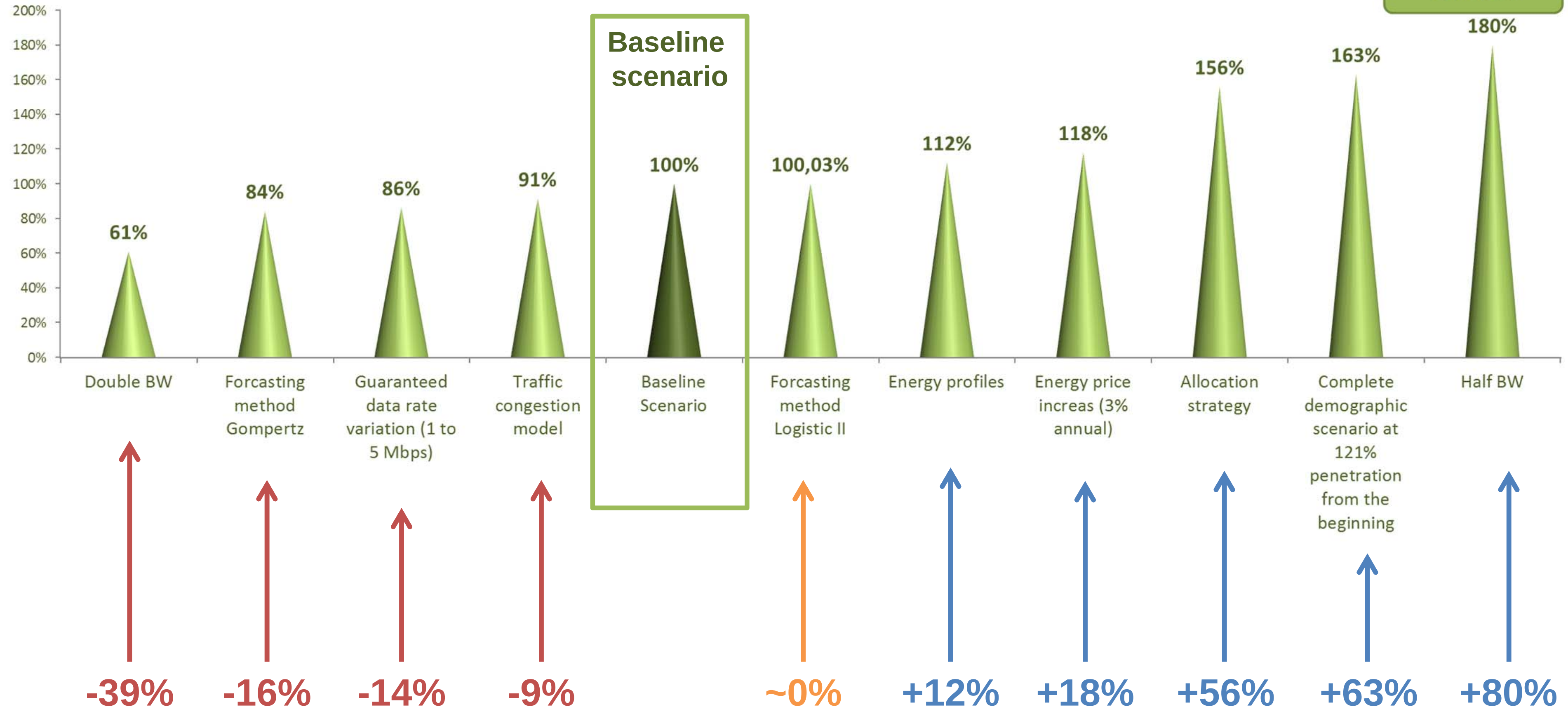

*Evolution of the cost of energy consumption (%) regarding network CAPEX and OPEX*

| Year | Consumption per year MW |
|---|---|
| 2011 | 41.795 |
| 2012 | 70.605 |
| 2013 | 145.935 |
| 2014 | 487.875 |
| 2015 | 1.091.663 |
| 2016 | 2.014.594 |
| **Total** | **3.852.467** |

| Year | Average consumption per subscriber per year (KW) |
|---|---|
| 2011 | 2,29 |
| 2012 | 2,85 |
| 2013 | 4,54 |
| 2014 | 12,44 |
| 2015 | 24,12 |
| 2016 | 40,29 |
| **Weighted average** | **18,37** |

# Results
# Variation of parameters scenarios




***Variation on the total cost of energy consumption (%) regarding the modification of the network design parameters described for the complete 2011-2016 period***

# Conclusions (I)

- This study has considered various parameters that impact on the cost/energy consumption of the access network.

  1. Users' **adoption** of the network (evolution of take-up as the network is deployed) and the **penetration** in terms of subscribers
  2. The yearly **traffic** evolution (scaling up of data traffic per user, both average and peak due to new applications and new users), quality of service and network congestion model.
  3. Daily **network usage pattern** and energy **consumption profiles** of network devices.

- Other network design parameters that impact on the cost/energy consumption such as: bandwidth, deployment strategy, and energy price.

## Conclusions (II)

- The most interesting results are:
    - The variation due to allocated bandwidth. If instead of 20 MHz only 10 MHz are available cost/energy would increase in **80%** while if the available BW is 40 MHz it decreases in **39%**. Therefore, spectrum allocated has a very important impact on energy / sustainability of networks.
    - Data traffic variations. If 1 Mbps is the data rate fixed for the 6 year period a **26% reduction** is achieved, but at the price of not meeting QoS levels through 2014-2016 period. If 5 Mbps is the data rate fixed for the 6 year period a **23% reduction** is achieved thanks to user packaging higher levels from the beginning in spite of the initial increase in network elements. This reflects the fact for the need of a correct design of the network from the beginning.
    - Energy consumption profiles of the network active devices. If current models are optimized (same technology than today's) it would mean a decrease of **12%** on the cost/energy consumption (10% due to femtocells and 2% due to base stations).

## What's next in the roadmap?

- Fixed networks model
- Energy prices evolution
  - This further step would allow for comparisons among energy consumption costs and deployment related expenditures
- Demographic evolution forecasting
  - The number of potential subscribers across the demographic scenario proposed could vary along the years. The update of this data or the study of the possible evolution would improve the accuracy of the model.

## Contact details

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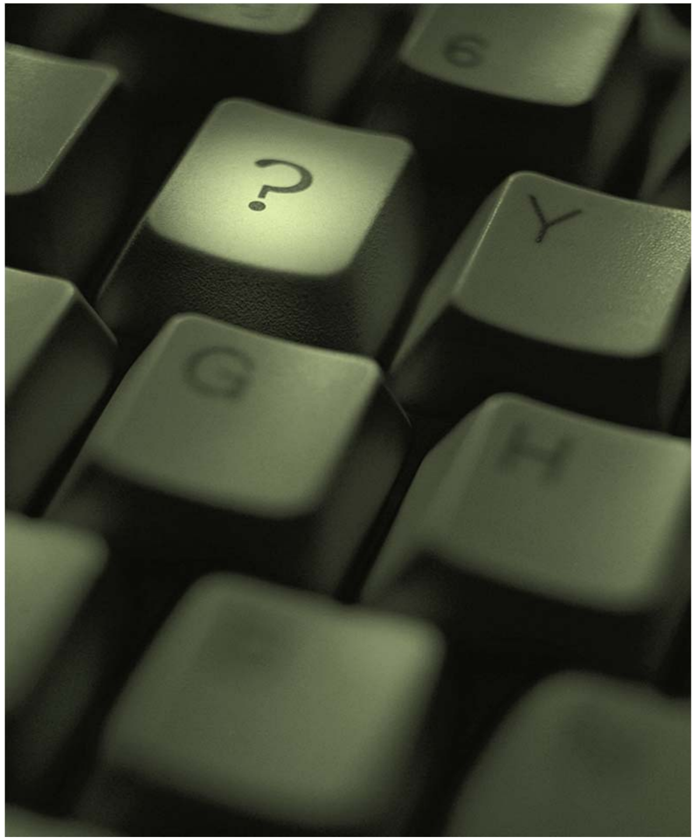
# Thank you for your attention!!

# Questions and suggestions



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