**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 developments

- The role of energy consumption seems mostly absent from the main analysis and the debate on NGN deployment.
Research questions

• Which design parameters affect the level of energy consumed in NGN? How?
• Does energy consumption impact fixed and mobile access networks differently? How to compare them?
• How does energy consumption affect NGANs capital and operational expenses?

Energy consumption framework

NGAN energy consumption baseline model

Choice of technologies, Network design & deployment, Active devices, Demographic framework, …

Prospective scenario

Demand forecasting using growth models according to actual data of the Spanish market
Traffic evolution and congestion model
Other parameters variations

RESULTS

Energy consumption cost for the 2011-2015 period
Energy consumed and cost per subscriber – Sensitivity analysis
Comparison with network related expenses
Choice of Access Technologies

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

### Mobile network architecture
- **Mobile/Wireless 4G network architecture**: Mobile network architecture for energy consumption calculations.
  - Source: Feijóo and Gómez-Barroso 2010
Reference idea


Active device energy profiles

Network daily usage

Data traffic variation during a day

Source: Project EARTH (2011)
• Main parameter to transform energy consumption units into operational expenditure → Price of the energy.
• The value used in the model is 0.14 €/KWh (reference level in the Spanish energy market in 2011).
• In general the forecasts of energy prices suggest an increase of 50% in 2030 compared to the levels in 2005. ("EU energy trends to 2030"[EC, 2009] & “Energy 2020. A strategy for competitive, sustainable and secure energy” [EC, 2010]).

**Network Design Parameters**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Fixed NGANs</th>
<th>Mobile NGANs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guaranteed QoS (Mbps)</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>Data traffic 2012 (%)</td>
<td>91%</td>
<td>9%</td>
</tr>
<tr>
<td>Target penetration (lines per 100 inhabitants)</td>
<td>80%</td>
<td>130%</td>
</tr>
<tr>
<td>Allocated Spectrum Bandwidth (MHz)</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Spectral Efficiency (bps/Hz)</td>
<td>-</td>
<td>15</td>
</tr>
</tbody>
</table>

15th International Telecommunication Society Biennial Conference

Energy and Economic Development

ECONOMICS AND FORECAST OF ENERGY CONSUMPTION IN NGN NETWORKS: THE CASE OF SPAIN
• Spain is used as a case study (applicable without major modifications to other similar 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”
From penetration, the market share fixes the maximum number of users subscribed to the operators’ network.

The operator can follow different deployment strategies (combinations for the number of users in the different zones to achieve its overall target).

- As deployment costs per user are inversely related with population density, the most rational strategy of the operator would be to start the deployment in those areas with higher population density. **Baseline Scenario**

- As a consequence of diverse types of regulatory conditions, some constraints could be set, i.e. increasing coverage to rural areas (low pop. density zones).
Calculation Process (2/2)
Total energy consumption per year

1. Energy consumption per hour per density zone for each device
2. Device energy profile
3. Network usage profile
4. Daily energy consumption per density zone for each device
5. Yearly energy consumption per density zone for each device
6. Total energy consumption per year for the complete scenario

Adoption forecasting

1. Fixed NGANs
2. Mobile NGANs

Spanish market figures of Mobile penetration
Spanish market figures of number of smartphones

Forecasted evolution of FTTH lines in the Spanish market
Forecasted evolution of mobile broadband (LTE) lines in the Spanish market

1st Stage
M = 80%

2nd Stage
M = 100%

1st Stage
M = 130%

2nd Stage
M = 80%

M = Market Saturation Value

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ECOSYSTEM AND FORECAST OF ENERGY CONSUMPTION IN NGN NETWORKS: THE CASE OF SPAIN

Traffic evolution

- Average data rate
- Peak data rate
- Number of simultaneous users
  - Network congestion model
  - Quality level
  - Usage features

Global data traffic model

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

Evolution of other parameters

- Fixed
  - Increase of Mbps per user from 30 to 100
  - Enhancement of energy efficiency in network active devices
- Mobile
  - Energy Price variation
  - 2% increase per year
  - Increase of Mbps per user from 1 to 5
  - Spectral efficiency increase to 20 bps/Hz
  - 40 MHz of allocated spectrum bandwidth
  - Enhancement of energy efficiency in network active devices

Evolution pattern

Network resizing

Data intensive applications
Video, Cloud Computing, ...
Results
General Results for FTTH-GPON

- FTTH penetration: 0,9%
- Number of subscribers (premises): 173,343
- Energy cost per subscriber: 8,80 €/year
- Number of inhabitants subscribed to FTTH: 466,008
- Energy cost per person: 3,34 €/year

\[ \Delta = \text{75,17\%} \]
\[ \Delta = \text{787\%} \]
\[ \Delta = \text{-25\%} \]
\[ \Delta = \text{5104\%} \]
\[ \Delta = \text{34,7\%} \]
\[ \text{X 51,33} \]
\[ \Delta = \text{-80\%} \]

Cost increase: X 50,13

2012 ➔ 2020

FTTH-GPON

Variation of the cost of energy consumed and other parameters in FTTH NGANs

Results
General Results for Mobile Broadband (LTE)

- Mobile broadband penetration: 38,13%
- Number of premises covered: 7,781,445
- Energy cost per premise: 3,54 €/year
- Number of mobile broadband subscribers: 24,816,197
- Energy cost per subscriber: 0,43 €/year

\[ \Delta = \text{63,86\%} \]
\[ \Delta = \text{74\%} \]
\[ \Delta = \text{913\%} \]
\[ \Delta = \text{92\%} \]
\[ \Delta = \text{27\%} \]

\[ \text{X 6,12} \]

Cost increase: X 6,18

2012 ➔ 2020

LTE

Variation of the cost of energy consumed and other parameters in 4G NGANs

Session 4: ICT and Economic Development
ECONOMICS AND FORECAST OF ENERGY CONSUMPTION IN NGN NETWORKS: THE CASE OF SPAIN

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Creating Platforms for All
Results
Comparisons over network expenditures - FTTH

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

<table>
<thead>
<tr>
<th>Year</th>
<th>CAPEX</th>
<th>OPEX</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>1.08%</td>
<td>2.00%</td>
<td>3.08%</td>
</tr>
<tr>
<td>2012</td>
<td>1.15%</td>
<td>2.00%</td>
<td>3.15%</td>
</tr>
<tr>
<td>2013</td>
<td>1.04%</td>
<td>2.00%</td>
<td>3.04%</td>
</tr>
<tr>
<td>2014</td>
<td>1.01%</td>
<td>2.00%</td>
<td>3.01%</td>
</tr>
<tr>
<td>2015</td>
<td>1.20%</td>
<td>2.00%</td>
<td>3.20%</td>
</tr>
<tr>
<td>2016</td>
<td>2.01%</td>
<td>2.00%</td>
<td>4.01%</td>
</tr>
<tr>
<td>2017</td>
<td>2.01%</td>
<td>2.00%</td>
<td>4.01%</td>
</tr>
<tr>
<td>2018</td>
<td>2.01%</td>
<td>2.00%</td>
<td>4.01%</td>
</tr>
<tr>
<td>2019</td>
<td>2.01%</td>
<td>2.00%</td>
<td>4.01%</td>
</tr>
<tr>
<td>2020</td>
<td>2.01%</td>
<td>2.00%</td>
<td>4.01%</td>
</tr>
</tbody>
</table>

Network costs
- CAPEX: 9.951
- OPEX: 13.114
- Total: 23.266

Results
Comparisons over network expenditures - LTE

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

<table>
<thead>
<tr>
<th>Year</th>
<th>CAPEX</th>
<th>OPEX</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>0.08%</td>
<td>0.95%</td>
<td>1.03%</td>
</tr>
<tr>
<td>2012</td>
<td>0.95%</td>
<td>0.95%</td>
<td>1.90%</td>
</tr>
<tr>
<td>2013</td>
<td>0.83%</td>
<td>0.95%</td>
<td>1.78%</td>
</tr>
<tr>
<td>2014</td>
<td>1.31%</td>
<td>0.95%</td>
<td>2.26%</td>
</tr>
<tr>
<td>2015</td>
<td>2.09%</td>
<td>0.95%</td>
<td>3.04%</td>
</tr>
<tr>
<td>2016</td>
<td>2.09%</td>
<td>0.95%</td>
<td>3.04%</td>
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<tr>
<td>2020</td>
<td>2.09%</td>
<td>0.95%</td>
<td>3.04%</td>
</tr>
</tbody>
</table>

Network costs
- CAPEX: 10.953
- OPEX: 27.032
- Total: 37.985
• Energy considerations have held a very limited role in the planning, management and regulation of NGNs, so far.

• If NGNs are to play a sustainable role in the future, then the energy consumption of NGNs—and their cost—must not be overlooked.

• At the same time, citizens are ever more conscious of their role in building a more sustainable society. For many of them, energy-saving aspects are becoming a factor to be considered in consumption decisions.
Conclusions (II)

- This paper has introduced a model for the assessment of the energy consumed by access networks in a practical setting. The baseline hints at both technological and policy enhancements to reduce the level of consumption in NGNs:
  - Obvious solution: improving the energy profiles of the devices used in the network rollout. This can be reached through a continuation of existing policies on energy efficient network devices.
  - The baseline also shows that other factors influencing energy consumption in the network have an even greater importance than active device consumption. In particular, the technological features of networks, such as the spectral efficiency and frequency bandwidth allocated to operators, strategic decisions such as QoS and the order of coverage for areas in the deployment.
  - Policy also has a considerable influence; some key parameters of networks design depend on regulatory decisions. Two examples have been considered in this paper: the case of frequency bandwidth allocated to mobile operators and the regulatory influence (for instance, license conditions) in the rollout strategy.

Conclusions (III)

- Results show that the energy used in fixed networks is higher than in mobile networks within the baseline described. However, if the cost of energy per subscriber per Mbps is considered, FTTH-GPON is considerably more efficient, and therefore, under this perspective, these technologies are more sustainable.

- Users lack this information and, in general, know little or nothing about the energy impact of their increasing usage of networks and devices, as well as the associated costs and effects on sustainability. In other words, they miss a key piece in making an informed decision.

- Against this background, the paper has attempted to place energy considerations in the forefront of the debate and, from the authors’ perspective, has shown that providing transparent information to consumers on their usage of ICT networks and devices is feasible and relevant.
Overview of the complete project

- NGAN
- Network maturity stage
- Deployment strategy
- Coverage target

- Technology adoption rate
- Active network devices energy performance
- Devices technological improvements
- Demand changes
- Subscriber traffic profile
- Traffic variations
- Traffic variations

This study has been developed under the European Investment Bank (EIB) STARBEI funding program. Usual disclaimer applies.
• Comparison of energy consumption of available technologies for NGANs deployments

• Variation of the design parameters:
  • Demand
  • Traffic
  • Usage during the day
  • Device energy consumption

• Temporal scenario

• Definition and combination of design parameters and prospective evolution of the baseline model proposed.

• Results would help us determine the impact of each factor on the related costs of energy consumption.