The Cost of Meeting Europe’s Future Network Needs

The cost of putting in place an infrastructure now, that will meet the Gigabit Society targets for 2025, 2035, 2045 and beyond

March 2017

Contents

About the FTTH Council Europe:
The FTTH Council Europe is an industry organisation with a mission to accelerate the availability of fibre-based, ultra-high-speed access networks to consumers and businesses. The Council promotes this technology because it will deliver a flow of new services that enhance the quality of life, contribute to a better environment and increase economic competitiveness. The FTTH Council Europe consists of more than 150 member companies. www.ftthcouncil.eu.

Contact:
Secretariat
FTTH Council Europe
Tel +43 664 208 36 27

Email:pm@ftthcouncil.eu

Foreword from the President

The current iteration of the FTTH Cost Model builds upon the existing work that has been done in 2012. The model is described in some detail in the chapters that follow but I would like to give the reason for this update. The Gigabit Society Communication issued by the European Commission on 14 September 2016 sets out a number of new targets other than those considered in the cost model of 2012. I should point out of course that the title and sub-title, which was quite deliberately chosen in 2012 of 'The cost of putting in place an infrastructure now, that will meet the Digital Agenda targets for 2020, 2030, 2040 and beyond' is all the more pertinent. Since the new targets of 100Mbps universally available and upgradeable, target of 1Gbps to socio-economic drivers and the general aim of Very High Capacity Connectivity can all be met using FTTH infrastructure in 2017, 2025 or 2050. To that extent there is no need to remodel how we get there. Nevertheless, there have been a number of things that happened since 2012 that do need to be considered today. In 2012, the EU was a union of 27 Member States, that number is now of 28 Member States with the accession of Croatia, a country of 1.5 million households that joined in 2013.

There has also been significant progress in the deployment of FTTH throughout Europe. The latest figure from iDATE for the FTTH Council Europe suggest that today, approximately 35% of households are passed with FTTH and that more than 10% are already enjoying the benefits of FTTH. Naturally, these figures mean that the cost of reaching the remaining households will be necessarily less by that amount- the exact way these developments are taken into account are detailed in the report. Over time as well, labour costs have risen throughout the EU, albeit with significant variations across EU Member States. The cost estimates are made in today's currency terms so factors such as inflation are taken into account.

Finally, some measures that already have been proposed by legislators, notably the Directive on Broadband Cost Reduction should facilitate the deployment of FTTH networks at lower cost. The FTTH Council and Comsof, who have modelled the actual costs, have noted the tardy implementation of the Cost Reduction measures and have adopted conservative assumptions about their impact – these lead to a reduction of about 12% in the overall costs for the remaining deployment. A conservative approach has been a guiding principle both in the original model and in this update. At a net €137bn to complete the deployment of FTTH to 100% of homes passed and 50% connected, the FTTH Council recognises that this represents an enormous challenge to operators and Member States to achieve the Gigabit Society goals as set out by the European Commission but this is a challenge which can and must be met for the sake of Europe's future. While I do not have a crystal ball, I will repeat an observation by my predecessor as President of the FTTH Council Europe and note that the World is not likely to end in 2025 and note that, as in 2012, the means to getting to the next target (for 2030 or 2035) will not require any change in infrastructure if FTTH has been deployed. While countries may join (or leave) the EU and while product costs may fluctuate, one additional advantage of choosing a future proof deployment is that the basic cost model will stand the test of time, as this model has.

The Council is openly sharing the detail of its cost model methodology in the hopes that other parties will do the same so that an exchange of views and opinions will lead to further refinements to the various cost models.

Executive Summary

The FTTH Council Europe has developed and amended its cost model that estimates the costs of deploying fibre networks to meet the Europe's connectivity needs, originally expressed in the Digital Agenda Targets for 2020 and now set out in the Gigabit Society Communication for 2025. The FTTH Council remains concerned about models which reveal very little about the data and methodologies used and in respect of certain cost models, the FTTH Council is concerned about the absolute level of the cost estimates. The results of some of these other estimates have been used to decry the Gigabit Society targets as being unrealistic or unattainable in some Member States or certain areas despite all evidence to the contrary. A further evolution since the original targets were identified is the emergence of a broad understanding of what the next generation of network capacity will require – 5G has the capacity to transform society and economies but the fixed network capacity requirements of these wireless networks are exceedingly high. Member States that fail to put this critical infrastructure in place risk falling behind within the European economy and risks weakening Europe's capacity to compete with global trading partners.

This report gives further details of the approach taken by the FTTH Council Europe to develop a cost model that provides a more detailed and transparent estimate of the total investment needed to build a next generation fibre network for Europe. It builds on the previous version of the model established in 2012 and it should be noted that this remains the only model on the market that is based on data from a series of actual deployments which have been made in different European countries.

One reason that the original 2012 model remains valid is that the model assumes the technology used will be Fibre to the home (FTTH) which is the only truly future proof technology that will continue to operate when there are increasing bandwidth, QoS, latency and jitter demands on the network without the need to upgrade the passive infrastructure. The Gigabit Society targets can be made just as easily as the Digital Agenda targets were and as the next iteration of targets will be a number of years from now. The key target set out in both the Gigabit Society document and the accompanying proposal for legislation to support that vision is the Very High Capacity (VHC). VHC is defined as being "an electronic communications network which either consists wholly of optical fibre elements at least up to the distribution point at the serving location or which is capable of delivering under usual peak-time conditions similar network performance in terms of available down- and uplink bandwidth, resilience, error-related parameters, and latency and its variation." An alternative means to set this target might be to set performance characteristics but this approach has the advantage of being both technologically neutral (since any network that can perform on a comparable level is included) and it is dynamic because the performance of FTTB will continually improve. In addition, it is clear that future wireless networks will need this level of connectivity if deployment is to be achieved.

The results of the cost model indicate that **€137 billion** would be required as the remaining cost to provide a complete coverage of FTTH across all the EU28 countries to meet the Gigabit Society targets. This includes 100% homes passed and 50% connected, it takes into account the FTTH infrastructure already deployed which currently stands at 36% with 11% of homes connected. This result also includes an estimated effect from cost saving opportunities linked to the measures proposed in the Directive on Broadband Cost Reduction (DIRECTIVE 2014/61/EU). These measures include the reuse of passive infrastructures and infrastructure sharing. The total savings amount to almost 20 billion of euros or an equivalent 12% reduction of the costs, which is still modest compared to some estimates of potential savings which can go as high as 40%. Throughout the model, conservative assumptions have been made in respect of the cost model so as not to underestimate the challenge to achieving these cost savings.

The FTTH Council would stress its belief that cost reduction measures are extremely important but emphasises the primary need to facilitate a competitive dynamic where it is feasible. Without such a dynamic to stimulate investment, cost reduction measures by themselves are likely to be largely ineffective.

The FTTH Council recognises that competition is unlikely to drive investment in less densely populated areas given the impact of lower density on costs in particular. Even with fully operational and appropriate sharing of passive infrastructures, selective use of public funds to stimulate fibre investments will be needed.

However, the FTTH Council believes that public finance should not be used in those areas where network competition either exists or could exist.

Conclusion

The Gigabit Society Targets for 2025 are obtainable with a future proof network deployment which will also be capable of delivering the target for 2035 and 2045 in terms of network requirements. The total cost of reaching the Gigabit Society targets for 2025 based on a FTTH network is €137bn. The FTTH Council cost model is the only cost model based on data from actual deployments.

Measures to reuse certain passive elements will lead to significant savings as part of this figure and must be implemented by Member States. However, without a continued emphasis on infrastructure based competition where such competition is feasible, the impact of cost-reduction measures are likely to be minimal.

Cost Model Overview

Project Approach

The FTTH Council engaged Comsof to model the cost of a FTTH deployment. Comsof has already modelled millions of households across all countries of Europe, using real geographical data, real network design rules and real material and labour costs.

Technical scenarios cover

- Point-to-Point (P2P) and Point-to-Multipoint (P2MP) with PON scenarios,
- Underground, overhead, wall mounted, … cable deployments
- Scenarios involving Microducts, Blown fiber, direct buried, pre-connectorised versus spliced cables etc.

It has also covered a wide variety of areas with

- very different mixes of Multi-Dwelling-Units (MDU) and Single-Dwelling-Units (SDU),
- urban versus rural areas,
- greenfield areas versus areas with significant volumes of reusable infrastructure such as poles and ducts.

In theory the model is capable of calculating the network designs and associated costs for all areas covering the EU28 member states if a minimal set of geographical input data (mainly streets and address points) would be available for all areas. But since this data was not available, the model starts from a set of real-life calculations on a selected set of representative areas (covering more than 350.000 homes across Europe), and then tries to extrapolate these results.

Figure1 below explains the approach taken for the FTTH Council cost model. There are 9 main steps in the model:

1. We select the smallest available set of geographical areas that cover the whole EU28 and for which reliable statistics about population density is available (this is NUTS 3 level as described below).
2. We introduce the concept of “populated density” to ensure the extrapolation model takes the right assumptions on density characteristics per area.
3. We derived the cost-density relation based on the set of representative areas across Europe and covering more than 350.000 homes passed.
4. We combine these data sets to derive a cost estimate per NUTS3 area.
5. We correct the cost estimation per area with a country specific labour rate correction factor
6. We apply the assumption that 50% of the households passed will actually be connected up to the home/ONT
7. This gives us the estimated cost for a full overbuild across EU28
8. We then extract the costs associated to already built areas to derive a cost for the areas not yet passed by a fibre (FTTH or FTTB) network.
9. Finally we apply the effect of cost reduction measurements to the cost per area to determine the final result.

EU28 Project Approach (2017)

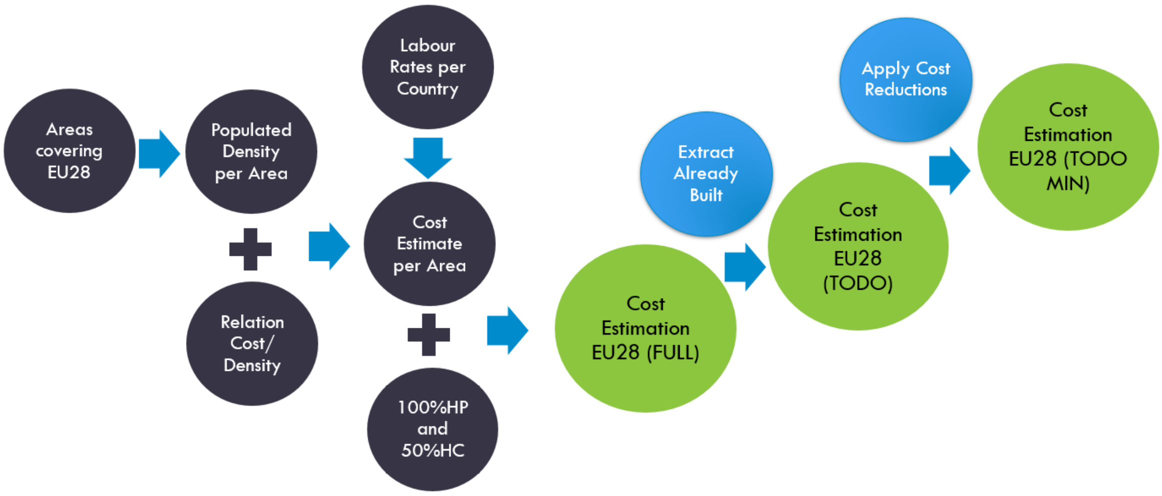


Figure 1. The Project Approach

Cost Model Scope

This cost model is developed to enable a more informed discussion on the deployment cost of FTTH networks in Europe. This cost model is used to calculate these deployment costs over the EU28 countries including the activation of 50% households by 2025.

The FTTH Council welcomes suggestions for possible improvements of the model, these are always welcome and ensure maximum benefit is realised from the output.

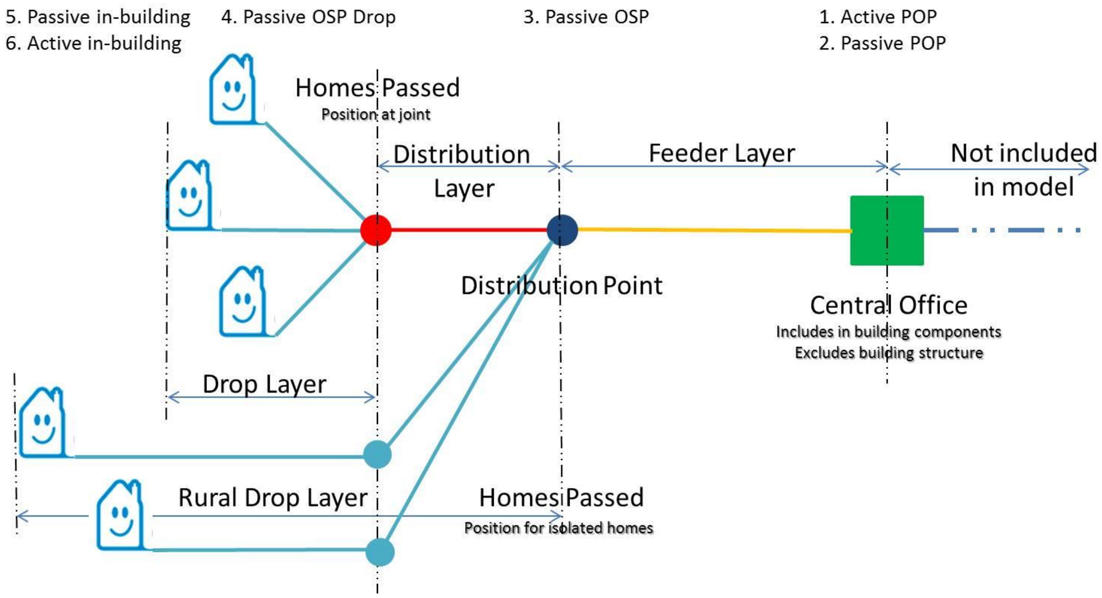


Figure 2 Network Design Building blocks

What is included in the current Cost Model?

The extent of the model is indicated in Figure 2 above. The model covers all components and the related civil and installation costs for the access network, running from the Central Office to individual homes.

Please note that depending on the level of isolation between homes, the 'homes passed' separation point from the 'homes connected' portion of the network can be significantly different in cost for different areas. Since we only assume a 50% take rate, the "homes passed" network for half of the isolated homes is considered to be at a point relatively far away from the home, as we will not build the infrastructure that is only needed for an assumed 50% of non-connected homes and thus not shared with the 50% assumed connected homes. This is treated in a statistical way across the model.

Allowance has been made for the mix of multi dwelling units (MDUs) and single family unit (SFU) builds. This is based on real data from the 15 different areas (containing in total 355k living units). Detailed information is provided in Appendix 1

For this release of the model, all calculations to identify the costs to pass and connect (activate) homes, assume the use of microduct and blown cable installation materials and techniques.

This methodology has been selected as the standard and most wide spread methodology used today. This is not however the lowest cost option. For example aerial installations have lower costs where an aerial network is practicable. On the other hand, for a 50% assumed take rate, it can avoid the deployment (and investment) into distribution fibers for the 50% non-connected homes. Moreover, when determining the cost per meter for civil work, some assumptions are made on the (future) adoption of efficient trenching methodologies like micro- and/or mini-trenching (up to 30% of trenches for full EU28 coverage are assumed to be realised with such technologies). One may argue about this assumption, but it is our belief that if 30% of cable lengths are not deployed with such cheaper trenching methods, then it is equally possible that those lengths of cables are deployed using aerial cables on poles, which will have a similar impact on overall costs.

The model initially calculates the cost for the whole areas, assuming that there is no existing build, and will afterwards eliminate the costs that are related to areas which are already built. The assumption used is that the existing build is deployed in the lowest cost areas first and to the highest costs areas last. This limits the cost reduction impact of the existing build on the overall cost but it appears to be the most realistic scenario in general even if there are known exceptions to the general case (e.g. Sweden). Cost savings will be available in the field portion but more importantly, if in-building costs can be reduced this would have a more material impact. The model assumes that cost reduction measures will be aligned with Directive of EU Commission (2014/61/EU). The estimates for cost reduction make the following specific assumptions; (i) 25% of Trenching cost (labour civil) replaced by cost to reuse ducts (ii) efficient coordination and sharing of civil work will lead to 10% of trenches being shared with other utilities (cost reduced by factor 2, i.e. costs are split evenly) and (iii) the re-use of in-building ready infrastructure results in 5% of in-building costs being eliminated. The overall impact of these three measures is a 12% reduction in modelled costs. This compares with a minimum 15% cost reduction in the studies cited by the Commission in its cost reduction impact assessment (COM(2013) 147 final) and a maximum saving of 40%.

The model includes the capability to develop results for both P2P and P2MP (GPON) design options. The headline figure provided is based on a P2MP solution.

When developing the model, existing practice on (civil) labour has been replicated where itinerant labour is used to deploy the infrastructure and this labour is usually cheaper than that of the local skilled resource so a weighted average of labour costs are used. However, for household connections a labour rate equal to that of the local labour cost is used given the likelihood that there may be customer interaction and linguistic skills at issue. This practice has been built into the labour costs within the model.

What is excluded from the Cost Model?

It is assumed that the Central Office equipment will be housed in existing Central Office buildings and therefore the capital cost for building central office structures is not included in the model. However, all necessary active equipment and their associated cabinets inside the Central Office have been included.

The model does not take into account discounted cash flow and unit price evolutions.

Currently all sample areas are calculated using common microduct techniques. Other (cheaper) deployments (e.g. aerial deployment) are not considered.

The model does not take future population growth or future urbanization and ruralisation into account between now and 2025.

No allowance has been allocated for Network design with software tools, Project Management or quality controls.

The model includes cheaper trenching in less dense areas (based on the assumption of less expensive re-instatement in less dense areas), but the trenching costs can be refined further. The model assumes that trenching only depends on density and labour cost index, but does not include, for example, the difference between hard and soft groundworks (these are very country dependant and will be reviewed when carrying out Country specific models.). For this reason, it is also not valid to split out the results of the model per country, as not all country specific effects have been brought into the model, which remains in essence a EU28 cost model.

Comparison with other cost models

A major strength of this model is the use of data linked to realistic deployable network topologies where designs have been implemented based on real GIS data to optimise the network design, reducing the number and length of products required and therefore reducing the build cost. Calculating these sample points results in a much more accurate bill of material that enables clear differentiation between deployment and activation costs (refer to figure 3 below) in order to evaluate multiple adoption scenarios. The model also takes into consideration specific refinements such as land use and country specific labour costs.

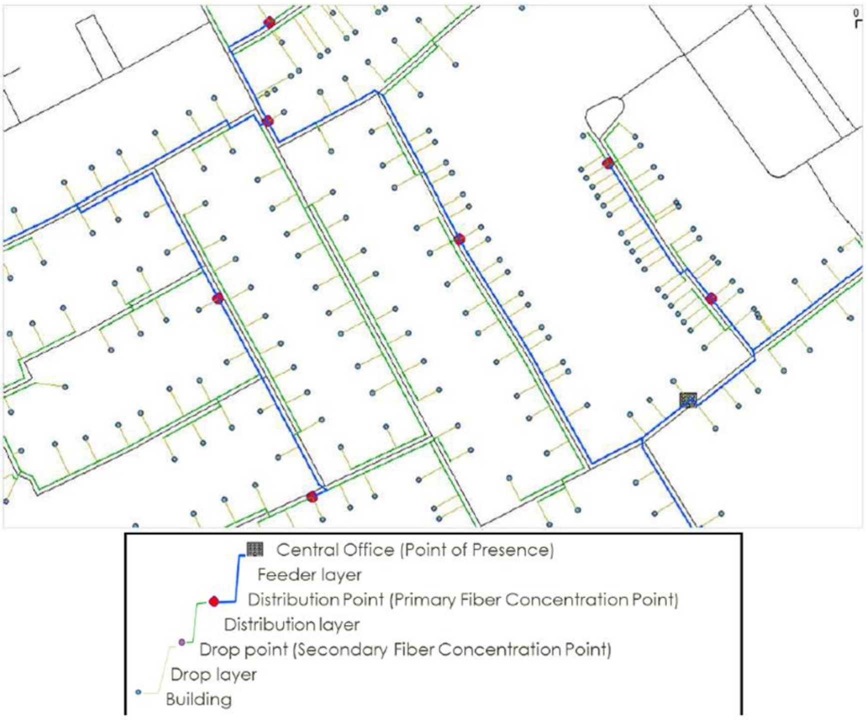


Figure 3 Example of an optimised network plan of a sample area

Cost Model Methodology

In the first stage of an FTTH network, the total cost of the project is needed in order to evaluate the business case. This cost is too often based on simple spread sheet calculations, assuming that estimation is possible and accurate by taking only a few geographical parameters into account. This leads to over and underestimations of the real cost to deploy a network which can often undermine the business case.

Another methodology, that calculates the cost based on real network elements and the build-plans to be used, is preferable and avoids this pitfall. A methodology that estimates costs in the classical way (i.e. drawing the plan by hand) for such a large area is not feasible at this stage given the scale and accuracy required. Therefore, automated FTTH design tools are needed which deliver accurate and optimized costs for large areas. These tools produce the build plan which include

- all the equipment that is necessary to deploy a fibre network
- the routes of all the fibres and the location of all the aggregation nodes
- the sum of the equipment used in the calculated network can be found in the *Bill of Material*
- The calculated cost of deploying the network and activating customers that wants to become connected.

The difference between a cost estimation based on a simple spread sheet and an optimal design tool can be substantial. More and more projects are now using automatic and optimal FTTH design tools to estimate the cost in the first stages of the project as a spread sheet analysis is not sufficiently accurate.

Automatic design tools need the input of Rules, Material and Geographical Information. The rules guide the automatic and optimal design tool to the desired network topology - using all the material that has been defined. The geographical information, in its simplest form, is the geographical location of customers. As the geographical information of the 28 European countries is not available at the required level of detail, an extrapolation model is proposed in order to give the best possible cost estimation to obtain the Gigabit Society targets.

Deployment costs and Activation costs have been identified as the primary outputs which map directly to the Gigabit Society targets and provide input to meet European and National Plans.

Deployment Costs

Deployment costs or 'homes passed [HP] cost' are the general costs, necessary to deploy the network or to 'pass' all the homes with fibre. A list of costs that are accounted as 'homes passed cost': public trenching, the central office building, the optical main distribution frame (OMDF), the feeding and distribution layer (cables, ducts, micro ducts) and the distribution point. Homes passed therefore amount to bringing fibre to a roadside connection point.

Deployment costs are strongly influenced by the population density, as shown in figure 4. Trenching is the most significant cost and therefore the area where there is the most potential for cost reduction opportunities. As noted already, the model assumes that 25% of trenching costs (labour civil) can be replaced by cost to reuse ducts and that efficient coordination and sharing of civil work will lead to 10% of trenches being shared with other utilities with costs split evenly between the parties. But it also for example considers the cost saving opportunities that can be realised in low-density areas by changing the design rules and cable deployment methods. Examples of the overall effect of such optimisations for rural areas have been presented during the rural-networks workshop at the FTTH conference in February 2017 and illustrate the big impact that this may have on costs, particularly in the least dense areas.

Activation Costs

Activation costs or 'homes activated (connected) cost' [HA] are those costs related to the activation of a home or a building. Examples include: customer premise equipment (CPE), drop point internal components, optical line termination (OLT), drop layer (trenching, cables, ducts, micro ducts)

The activation costs have not the same dependency on density as the deployment costs. The influence of population density on activation cost is far more subtle:

- Drop lengths vary (rural: long, urban: short)
- Drop trench costs vary (rural: cheap, urban: expensive)
- Drop section sharing (rural: almost no sharing, urban: more sharing). This is a function of density and number of MDU's.

When the density is extremely low, the cost per home activated increases strongly. This is related to the definition of HP and HA in low dense areas where it has been assumed that deployment of distribution cabling/trenches/ducts will not be executed, before the home is activated (with the exception of the last 5% where both HA and HP happen simultaneously).

In the current Cost Model “In-building cabling” is included in the HA cost but the re-use of in-building ready infrastructure is assumed to results in 5% of in-building costs being eliminated for new connections.

Cost/Density relationship

A major component of the proposed extrapolation model is the cost-density relationship. It assumes that the cost to roll-out an FTTH network over a certain area can be calculated based on the household density and the number of households. It is true that the cost of a fibre network depends on many geographical parameters, the most important one being the population density. Deploying a FTTH network requires a high amount of trenching. As trenching is expensive it can contribute 60% - 70% of the cost per home passed. For deployments based on alternative passive infrastructure such as aerial deployments, costs can be reduced significantly. Figure 4 shows the interaction between density and duct length. The figure represents two streets with different number of buildings (left= 4, right= 10) and thus a different population density. The two streets require the same amount of public trenching (the green horizontal line) but the cost is shared by more users on the right and therefore the cost per home is lower.

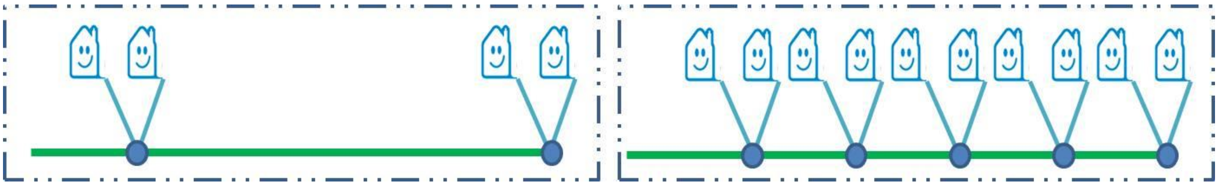


Figure 4: The relationship between population density and cost per home passed

It is important to note that not only population density influences the cost - but density is the simplest relation one can define.

Another geographical parameter that influences the cost is the amount of single dwelling units versus the amount of multi dwelling units in the area.

It is mathematically possible to find all the geographical parameters influencing the cost of a fibre network and to define a cost function containing all these parameters. However, such a model is not possible for the EU28 countries as all those parameters need to be exactly known in order to predict the cost. As will be discussed later, it is already challenging to obtain two simple geographical parameters: the area size and the population. Therefore the model breaks population into nine different categories based on population densities and uses the data from deployments in each category area as a cost proxy.

Trends

Figure 5 shows the 'cost per home' for the 36 sampled areas for varying household density. The total sum of living units (homes) for the new trend lines (adding up the original 355k sample points and the extra sample points).These sample points are then used to calculate a best-fitting curve. The result is of the form $f(x) = cx^b$or a power-curve.

The 'cost per home' is the following sum:

'Cost per home passed' +50%of 'Cost per home activated'.

This 'cost per home' curve is based on the assumption that:

- all EU28 homes must be passed

- Only half of the homes passed get activated (connected):a 50% adoption.

.

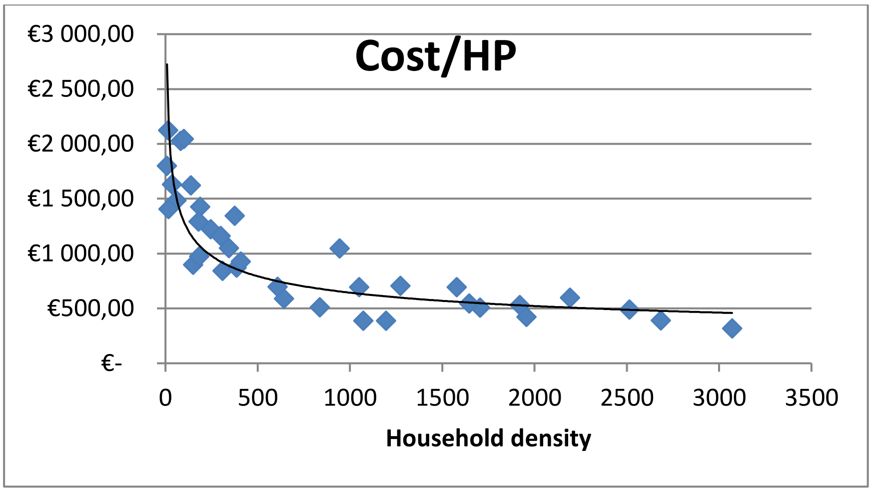
Note: the graphs in figure 5 must be interpreted with great caution and must in no way be used to determine the cost of a single FTTH project.

First of all: this graph does not specify which labour costs are used for the calculation of the sample points. As the pie-charts in figure 6 clearly indicate, labour costs (labour civil + labour install) can be up to 80% of the total cost of the network. Small variations in the labour cost can therefore have a major impact on the total cost.

Secondly, the sample points do have a decreasing 'trend' but do not exactly follow the trend line. The difference can be more than 30%. It is clear that household's density and cost per home have a decreasing trend, but there are other geographical elements that influence the cost.

If the area only consists of single dwelling units, the activation cost will be much higher compared to an area consisting out of large multi dwelling units. Therefore, the sample points not only vary in household density, but also vary in 'building style'. This information is shared in Appendix 1. The sample points have a varying building profile. It is not easy to find average building profiles for countries. This will be improving the accuracy of the modelling when completing country specific models.

As already stated, the model should not be used to predict the exact cost of a single FTTH project, or a single country. The more sample points used, the more geographical variations are taken into account and the more accurate the average function will be. The curve can be used to predict the accumulated cost of many FTTH projects and the larger the estimate, such as predicting the cost for EU28 countries the more accurate it will be.



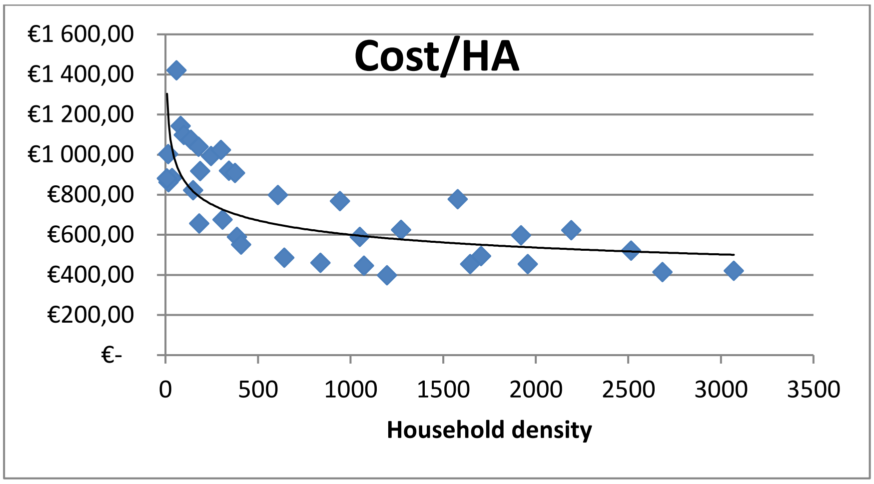


Figure 5: The cost per HP and HA for the 36 sample areas with a varying density

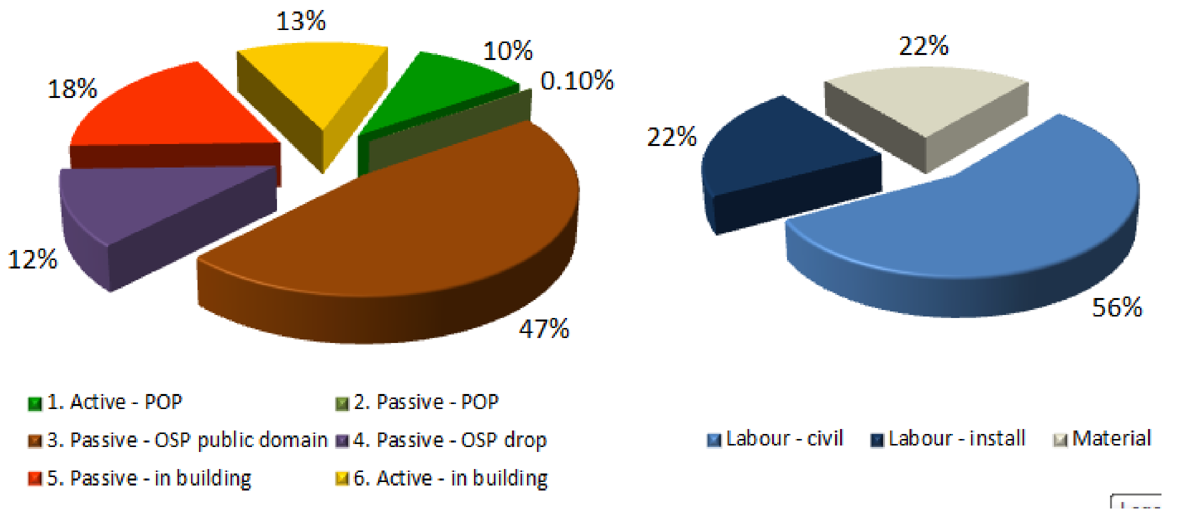


Figure 6: Example of the Home Connected costs (= cost per home passed + cost per home activated) for one of the sample areas – divided into the 6 cost categories of table 15 and for the same area divided into 3 categories labour civil, labour install and material cost.

Areas

The cost-density relation assumes that the cost to deploy a FTTH network in a certain area can be estimated based on the availability in a given area of the household density and the number of households. This report investigates the cost to deploy FTTH in Europe, or more specifically, the 28 countries that currently form the European Union (EU28 countries). The straightforward (but not correct) way of calculating the total cost of deploying fibre in Europe would be by using the trend line of figure 5. The population and population density of the European Union is known, the number of households and household density can be derived and therefore the total cost can be calculated.

This section will enhance this straightforward calculation to take a number of other factors into account.

Eurostat data

The data used in the following sections originates from Eurostat[3]. Eurostat is the statistical office of the European Union situated in Luxembourg. Its task is to provide the European Union with statistics at European level that enable comparisons between countries and regions

For each section, the name of the file that is used to perform the calculations will be mentioned. However, investigating the data provided by Eurostat, it became clear that the data are not completely error-free. Therefore, each dataset is also verified with other data sources in order to maximise the reliability of the input data.

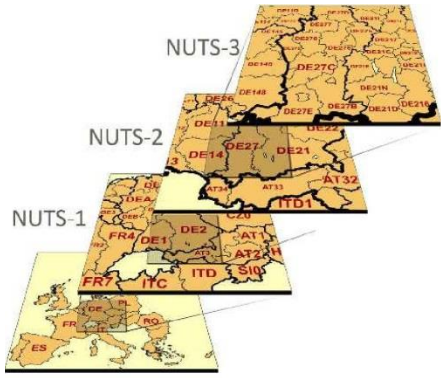


Figure 7 Hierarchical structure

[3]http://epp.eurostat.ec.europa.eu/portal/page/portal/about_eurostat/introduction

NUTS classification

It would be possible to use the general information of the EU28 countries to perform the calculations using the average values, however the more detail that is available the higher the reliability of the calculations. However, there is a trade-off between increasing the reliability and having statistics available for a certain level of detail. Eurostat defines the NUTS classification (Nomenclature of territorial units for statistics), a hierarchical system, see figure 7,for dividing up the economic territory of the EU[4].

The three NUTS levels for the 28 European Union member states regions are:

NUTS 1: major socio-economic regions [98 regions].

NUTS 2: basic regions for the application of regional policies [276 regions].

NUTS 3: small regions for specific diagnoses [1342 regions].

The NUTS 3 level is the deepest level for which reliable data is available.

As can be seen in figure 8, these 1342 regions are not homogeneous. The size of these regions varies strongly: in some countries, e.g. The Netherlands, Belgium and Germany, the NUTS 3 areas are small, whereas in Spain or Finland the areas are much bigger. The reliability of the calculations would greatly increase if the model did not use the data of NUTS 3 areas, but rather data on the level of villages. However, as no consistent data is available for this level of detail for the EU28 countries, NUTS 3 is the best alternative addressing all countries[5].

[4] http://ec.europa.eu/eurostat/web/nuts/overview

[5] http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Urban-rural_typology

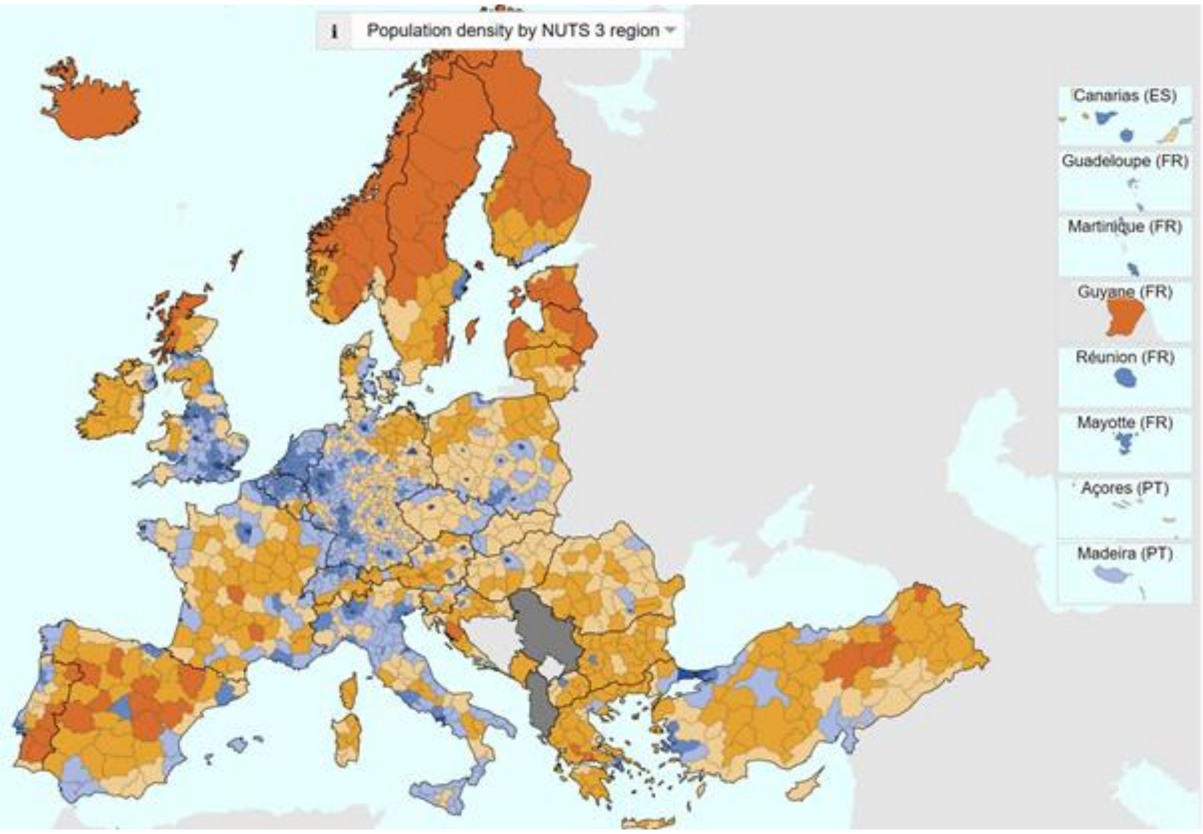


Figure 8: Map with the 1342 NUTS3 regions

Population, households and Area sizes

Population: Filename: [demo.r.pjanaggrd]; Extracted on: 12.01.16.

This file contains the population up to NUTS3 level. The most recent year of data is 2015, for some regions the most recent year is 2010.

Households: Downloaded file from: [lfst.Iihantych]; Extracted on 12.01.16.

This file contains the average number of persons per household per EU28 country. For EU28, the average is 2.4 persons per household. The most recent year of data is 2015. The trend line in figure 5 is not based on population density but uses household density. Using the data on the average number of persons per household, one can derive the number of households per NUTS 3 region from the population data.

Area sizes: Filename: [derno.r _d3area]; Extracted on 23.11.11

This file contains the total area size up to NUTS 3 level. This data can be used to calculate the household density, needed to apply the trend line, for each NUTS 3 region. However, this definition of household density would result in an overestimation of the cost therefore a new definition of household density is proposed and used in the model.

Redefining density

The problem with the current definition of household density (= number of households in NUTS 3 region / area size of NUTS 3 region) is visualized in figure 9. Of the two area sizes defined in the figure - 'populated area surface' and 'total area surface' - two different household densities can be calculated but which one is mathematically correct to be applied on the trend line? As the cost per home decreases for increasing household density, it is obvious that selecting the right density figure is of critical importance for extracting reliable estimates.

Figure 10 simplifies the problem by comparing two virtual regions $Area_{left}$ and $Area_{right}$. Table 11 summarizes the characteristics of the two areas, assuming that each green box has the following characteristics: number of households = X, area surface = Ykm^2. As already stated before, the largest cost to deploy a FTTH network, is related to trenching.

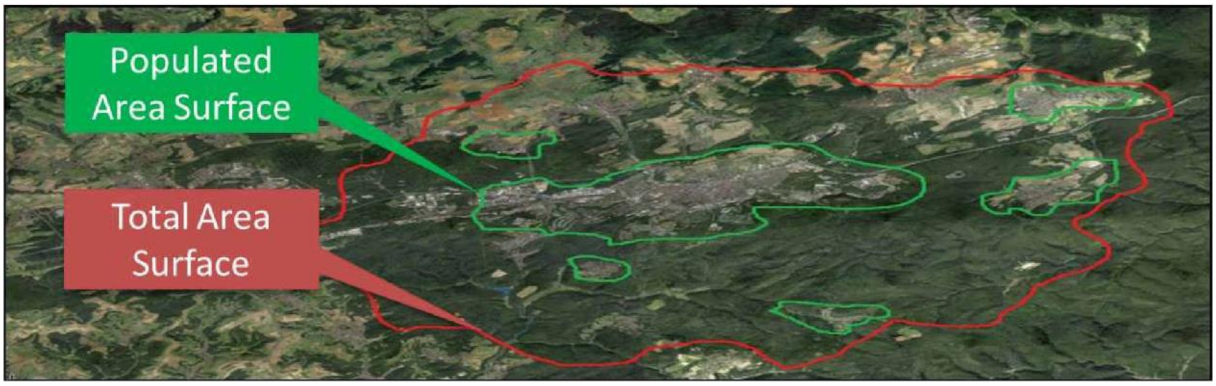


Figure 9: The difference in 'populated area surface' (inner green polygons) and 'total area surface (outer red polygon).

Figure 10: Simplification of the populated area problem, area statistics summarized in table 11.

For the two areas, this amount is roughly the same, as one will only trench in the populated areas. If the amount of households *(X)* would be the amount that one central office could serve, then the cost to deploy a network is the same for the two areas, i.e. 6x the cost of a green box. If *X* is smaller, the difference in cost between the two areas is the amount of ducts and cables needed in the feeder layer. This extra cost is in general rather small compared to the total cost in most cases. As the average number of households in a NUTS 3 region is more than 161.000,multiple central offices are needed in each NUTS 3 region which implies that *X* in many cases will be large enough to justify the approach chosen. This clearly shows that the approximation of density based on the populated area surface (in green) is the best density parameter to consider for our extrapolation model.

Characteristic	$Area_{left}$		$Area_{right}$
Number of households	$6X$		$6X$
Area surface (red)	$6Y$		$12Y$
Area surface (green)	$6Y$		$6Y$
Household density (red)	$\frac{X}{Y}$	$>$	$\frac{X}{2Y}$
Household density (green)	$\frac{X}{Y}$	$\approx$	$\frac{X}{Y}$

Table 11: Two household densities can be calculated: (red) and (green).

Land Use overview

The redefinition of household density will only be more exact if data are available from which the populated area surface can be derived. This data can be extracted from the LUCAS project.

The Land use/cover area frame survey (LUCAS) project is initially developed to deliver, on a yearly basis, European crop estimates for the European Commission. With time, the survey has become essential in providing policymakers and statisticians alike with increasing amounts of data on different forms of land use in Europe and proved to be a useful tool in the area of environmental monitoring[6].

The LUCAS project contains two datasets: 'land use' and 'land cover'. The 'land use' dataset is used to derive 'populated area surface' from 'area surface'. The land use data divides each NUTS 2 area surface size in the following 6 different land uses:

1. Agriculture
2. Forestry
3. Hunting and Fishing
4. Heavy Environmental Impact
5. Services and Residential
6. No Visible Use

To calculate the 'populated area surface', it is possible to only include the land use 'Services and Residential'. This land use however is too small; people live in the other categories as well. For example, a lot of farmers will live in the land use 'Agriculture', but it is clear that taking into account this land use for all regions would also add all the agricultural fields - which is not desired.

Therefore, the following definition of populated area surface is applied:

Populated area surface = 'Heavy Environmental Impact' + 'Services and Residential'.

This choice is verified on some regions, using satellite pictures. It showed that 'Heavy Environmental Impact' can be related to both industry and large living blocks (MDU's). This land use is included completely in the populated area surface in order to be on the safe side concerning the reduction of 'total area surface' to the 'populated area surface'.

The land use data categorizes only NUTS 2 levels, while the more detailed data of NUTS 3 level are needed. Straightforward application of this land use percentage of NUTS 2 on each NUTS 3 level within the NUTS 2 region results in incorrect population densities. Therefore a 'rule based' correction is designed. Please refer to Appendix 2.

The Figure below visualizes the percentage of the EU28 population living in a NUTS3 region of a certain household density. From the graph, it becomes clear that most of the NUTS3 regions have a density between 300-600hh/km².

[6]http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/LUCAS_%E2%80%94_a_multi-purpose_land_use_survey

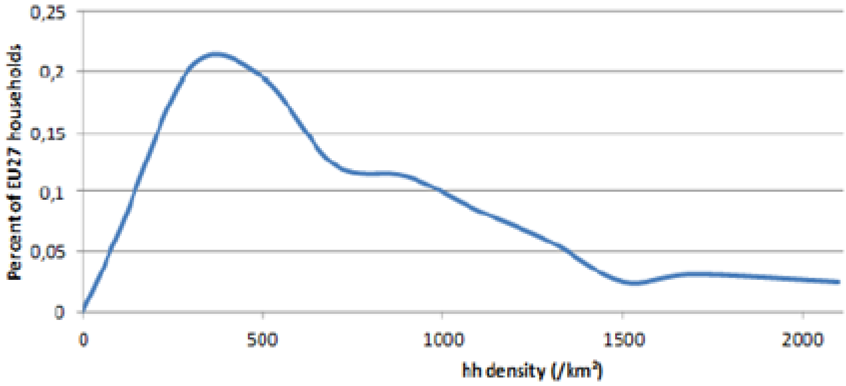


Figure 13: The percentage of EU28 population living in a region with a certain household density.

Local labour costs and assumptions for applying in the Cost Model

Labour costs: Filename: [lc_ncost_r2]; Extracted on 12.01.16.

As stated earlier, up to 80% of the home activated cost stems from labour costs. It is well known that the labour cost is not equal for all EU28 countries. Large differences do occur, so for each country its local labour cost shall be applied. The data from Eurostat on this heading contains the labour cost at country level of the year 2012. For each country, the data are normalized upon the EU28 average of €22.25/hour, which is in itself an increased value by 2,2% as opposed to the average labour cost that was used in 2012 (with Eurostat numbers then based on 2008).

Because the reference calculations that are used for the extrapolation were not updated separately between 2012 and 2016, it was decided that for the new calculations, we normalize the labour rates per country against the numbers from 2012 (based on 2008). As such we incorporate an average rise of labour costs over the 4 years.

Historically the cost of hardware decreases over time and as volumes increase. However, due to lack of reliable numbers these effects have not been included in the model.

Countries with a high labour cost index often have a strong competition of labourers from countries with a lower labour cost. Applying the normalized labour cost index (used for the ‘labour install’ category) to the 'labour civil' category would not take labour movement into account and would result in an overestimation of the labour civil costs. To take this competition into account, the 'labour civil' category is slightly adapted. The resulting labour cost indexes - 'labour civil' and 'labour install' –as used in the calculations are visualized in figure 14.

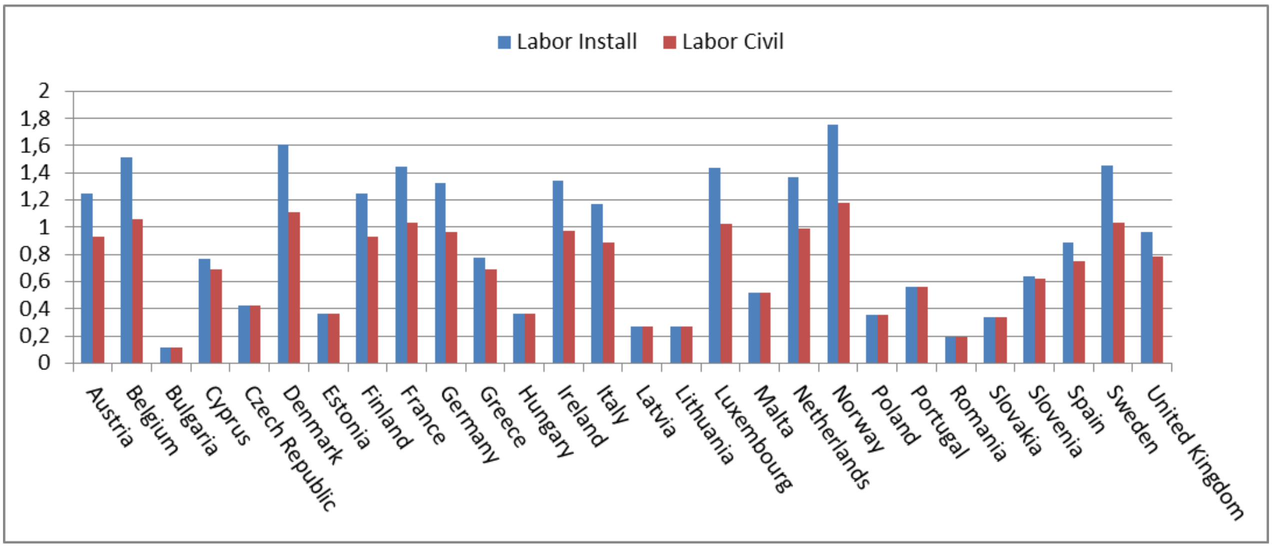


Figure 14: The Labour Cost Index for 'labour civil' and 'labour install'.

Applying these corrections for the various national labour costs results in 28 different trend lines (not shown in figure 5, but used to calculate the total cost for the EU 28 countries). One line for each country and each to be applied for the NUTS 3 regions in this country.

Geographical information

A further essential input for the automatic and optimal FTTH design tool is geographical information of the regions. Geographical information consists of customer information and street information. For this study15 different areas were used as an input to calculate the cost-density relation. After an area is processed by a design tool, the topology and associated bill of material is known and this results in one sample point for the cost-density relation. Each area is processed twice, covering two different FTTH network topologies. The difference between the two simulations is due to different changes of the network topology: varying capacity of the Central Office, varying granularity of cables, etc.

Each of 15 areas is an existing area somewhere in Europe. The sample points are thus based on real geographical data and represent real sample points.

Table 15 contains some geographical information of the sample areas that are used to create the cost-density relation. The areas vary in population density from low to high density. In total 355.000 living units (homes) are simulated.

Area size *(km^2)*	Households	Density *(hh/km^2)*
20.6	45056	2191
20.8	32824	1578
117.0	125360	1072
92.5	31785	344
79.3	14483	182

Table 15: Geographical information about the sample areas used for the cost-density relation.

This data set does capture the trend of the cost-density relation well and as noted already, for a large population will be relatively accurate. However in order to strengthen the statistical reliability of the trend line, additional points were added in 2 iterations:

- First, 21 additional sample points were added to validate the cost/density trend line shown in figure 5.
- In a Second stage, more than extra 230 reference areas were added, covering in total more than 2,3 million buildings.

Sample results

The result of each sample area is an optimized network plan, the associated bill of material and accurate cost estimation. An example of an automatic network plan is shown in figure 3.

The three layers of the fibre network are automatically calculated: the drop layer (connecting buildings to the drop point), the distribution layer (connecting drop points to the distribution point) and the feeder layer (connecting distribution points to the central office). More than 45 components are included in this network.

The prices of these 45 network components determine the total cost of the network. Each network component is defined by three costs: “labour civil”, “labour install” and “material cost”. All the network components are categorized against six cost categories. Each network component is also categorized as either a “deployment” or “activation” cost.

An example of this breakdown is shown in table 16.

UNIT COSTS		labour civil		labour install	material	total
ctive POP						
Active Equipment in the POP						
	OLT Card - PON	€	-	€	€	€
	OLT Card - P2P	€	-	€	€	€
	^OLT Shelf	€	-	€	€	€
assive POP						
Passive Equipment in the POP						
	ODF			€	€	€
assive OSP	ublic domain					
Civil works						
	buried - area type High 1					
	buried - area type High 2					
	buried - area type High 3					
	buried - area type Medium 1					
	buried - area type Medium 2					
	buried - area type Medium 3					
	buried - area type Low 1					
	buried - area type Low 2					
	buried - area type Low 3					
Ducts						
	cost per m					
Micro-ducts						
	bundle 24x4/6mm					
	bundle 5x10/14mm					
Fibre Cable - Distribution						
	2F BUNDLE					
	4F BUNDLE					
	12F BUNDLE					
	24F CABLE					
	48F CABLE					
	96F CABLE					
Fibre Cable - Feeding						
	12F BUNDLE					
	24F BUNDLE					
	48F BUNDLE					
	72F BUNDLE					
	24F CABLE					
	48F CABLE					
	96F CABLE					
	192F CABLE					
	384F CABLE					
Customer Premises Drop Box						
Street Cabinet						
	Housing					
	Internal components (mini ODF,					
Manhole						

Splitters			
	1:4 splitter	€	€
	1:8 splitter	€	€
	1:32 splitter	€	€
Splicing			
	Fusion Splice (1F)	€	€
	Closure (96F)	€	€
	F)	€	€
4. Passive OSP Drop			
drop connection			
	duct on private domain	€	€
	trench private domain - area type High 1		
	trench private domain - area type High 2		
	trench private domain - area type High 3		
	trench private domain - area type Medium 1		
	trench private domain - area type Medium 2		
	trench private domain - area type Medium 3		
	trench private domain - area type Low 1		
	trench private domain - area type Low 2		
	trench private domain - area type Low 3		
Fibre Cable - Drop			
	2F BUNDLE	€	€
	4F BUNDLE	€	€
	12F BUNDLE	€	€
	24F CABLE	€	€
	48F CABLE	€	€
		€	€
5. Passive – in building			
Entry in Building			
	per building	€	€
Basement Equipment			
	MDU 2-3	€	€
	MDU 4+	€	€
	1:8 splitter	€	€
In house cabling			
	SDU	€	€
	MDU 2-3	€	€
		€	€
6. Active – customer premise			
CPE			
	per home P2P	€	€
	per home PON	€	€

Table 16: An example selection of network components.

Tolerance and confirmation / Summary of testing results.

The straightforward use of the trend line of the previous chapter on EU28 level would result in an overestimation of the total cost to deploy fibre in Europe for various reasons. The approach is improved considering the following aspects:

- The average number of people per household is country dependent. As this number strongly influences the household density of each country, it has been taken into account.
- The trend line is constructed based on calculations on sample areas of large scale so that they relate well to the NUTS 3 regions. The trend line may not be used to extrapolate on country-level, instead NUTS 3 regions need to be considered.
- The household density of a NUTS 3 level, calculated by dividing the number of households by the total surface size of the region, is too low to use as basis for extrapolation. It would include the surface of unpopulated areas which does not influence the cost of a FTTH network. Using the concept of populated area, a corrected household density is derived which is a much better measure for extrapolation as the unpopulated areas are excluded from the statistics.
- The labour cost index influences costs (and thus also the trend line) to be considered for a specific country. For some countries this means an increase, for others it is a decrease in total cost as compared to the results derived when using the same average cost values for all countries in Europe. Since densities are different in different countries, this correction has an impact on overall costs at EU28 level as well.

For each of the 1342 NUTS 3 regions, the deployment and activation cost has been calculated. In summary, this means that for each NUTS 3 region, the corresponding country-specific trend line is selected, its corrected household density is derived from land use statistics, and this populated density is used as x-value on the trend line to calculate the corresponding cost per home (y-value). Multiplying this number with the number of households in the region, results in the total cost to deploy a FTTH network in that specific region.

Connecting homes that are in remote areas

The extrapolation model is based on the categorisation of EU28 in NUTS3 areas. It is well known that, due to the remote location of the homes, rural connections can be more expensive. In order to ‘guesstimate’ the impact of remote homes on the total cost, in a simulation each of the 1342 NUTS3 area is divided into two areas, one where 95% of its population lives, and one where 5% of its population lives in remote homes.

The cost of the “95%-part” areas is calculated using the trendlines, as discussed before. The cost of the remaining “5%-part” area is estimated at €0/home passed and €7000/home activated. For all the areas (both the “95%-part” and the farmers “5%-part”) an adoption of 50% is assumed.

Cost Model – The results

This document has described how the relation between population density and cost per home is derived to estimate the cost to deploy fibre in a given region. The origin of the data used to go from the 1342 NUTS3 regions to EU 28 is documented as well as the adaptations that have been made to the data. By combining the results for each region an estimated cost to deploy the FTTH network (Homes Passed) can be derived as well as an estimated cost needed to activate (a percentage of) the homes within the region (Homes Activated).

The Gigabit Society targets refer to two targets (i) 100% of European households should be able to subscribe to a bandwidth of 100Mbps which can be upgraded to 1Gbps and (ii) all socio economic drivers being able to have access to 1Gbps by 2025. Of all the homes that are passed, half of them will subscribe to the fibre network and receive a bandwidth of at least 1Gbps. This level of adoption is high compared to the current adoption rates of FTTH.

Ultimately 3 different results are derived from the model:

1. **Cost to complete overbuild in EU28: €210 billion**
    a. This is an update from the result of the cost study from 2012 which reported a number of €202 billion to cover EU27
    b. The update includes the update of input data such as population data, labour rates, .. as well as the inclusion of Croatia.
2. **Cost to build where an FTTH network is not yet available in EU28 today: €156 billion**
    a. This is derived by extracting the areas for an amount of households that is equal to the already existing builds per country.
    b. The iDATE data[7] produced for the FTTH Council has been used for this purpose.
    c. The most dense NUTS 3 areas have been eliminated until the amount of eliminated households equals the estimated amount of already covered households. The last NUTS 3 area would be only partially stripped.
3. **Cost to build where an FTTH network is not yet available in EU28 today and considering cost reductions: €137 billion**
    a. As already described in this report the civil activity can amount to 70% or more of the overall deployment costs. By opening up existing infrastructure, significant savings are possible. However there are costs associated with using existing infrastructures which could lower expected benefits, including planning, ROW, H&S, Quality and inspection checks.
    b. Cost savings will be available in the field portion but also for in-building costs. The model assumes that cost reduction measures will be aligned with the Directive of the EU Commission (2014/61/EU). The estimates for cost reduction make the following specific assumptions;
        i. 25% of Trenching cost (labour civil) replaced by cost to reuse ducts
        ii. efficient coordination and sharing of civil work will lead to 10% of trenches being shared with other utilities (cost reduced by factor 2, i.e. costs are split evenly)
        iii. the re-use of in-building ready infrastructure results in 5% of in-building costs being eliminated.
    c. The overall impact of these three measures is a 12% reduction in modelled costs. This compares with a minimum 15% cost reduction in the studies cited by the Commission in its cost reduction impact assessment (COM(2013) 147 final) and a maximum saving of 40%.
    d. To enable maximum benefit from use of infrastructure sharing there will need to be some regulatory, Standards and legal changes to enable the opening of non-telecom infrastructures and telecom infrastructure owned by non SMP operators for access combined with the establishment of reasonable charges for the use of these infrastructures.

[7] http://www.ftthcouncil.eu/resources/key-publications

Note that in all above scenarios all European households have the possibility to take a fibre connection, meaning that they have the possibility to subscribe to at least 100Mbps and at the same time, the possibility to upgrade to 1Gbps subsequently (as also an objective under the Gigabit Society Communication.

Appendix 1 - Sample Points – SFU/MDU info

This document describes information about the building profile of the 8 sample areas, delivered by Comsof.

Terminology:

- SFU = single family unit (a single living unit inside a building)
- MDU = multi dwelling unit (multiple living units inside a building)

General information

The eight sample points delivered by Comsof are based on real cities; this means that the building profile originates from real data. The geographical location of the cities varies, but all of them are European cities/villages (from UK to Greece). As the geographical location varies, the sample points are subject to local building profiles.

A more advanced improvement of the extrapolation model would be to create trend lines per country based on sample points with a building profile matched to the country.

Summary information

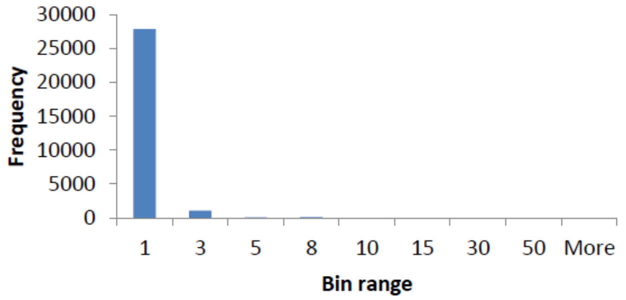
The table to the right summarizes the average number of living unit per building (average), the maximum number of living units per building (max) and the sum of the living units for each sample

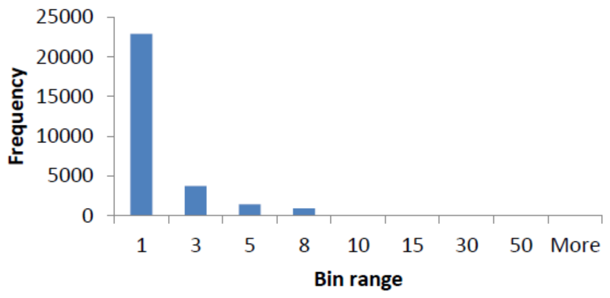
Sample	average	max	sum
H1.1	1.1	56	32824
H2.1	3.0	171	65175
H3.1	1.0	11	31785
H3.2	2.5	47	12178
H2.2	3.3	162	125360
M2.1	1.7	56	14483
H1.2	1.5	22	45056
H3.3	1.6	24	6813

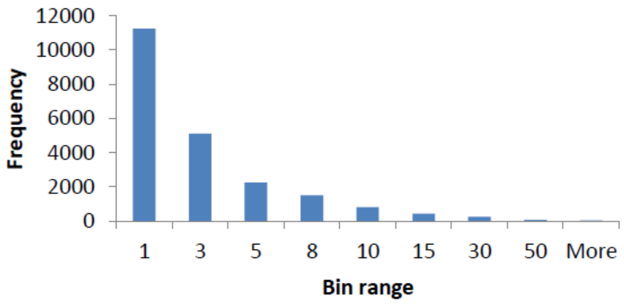
Histogram information

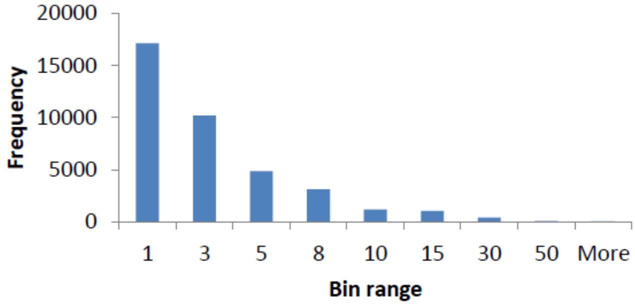
In the figures below, the building profile information is visualized in a histogram for each sample point.

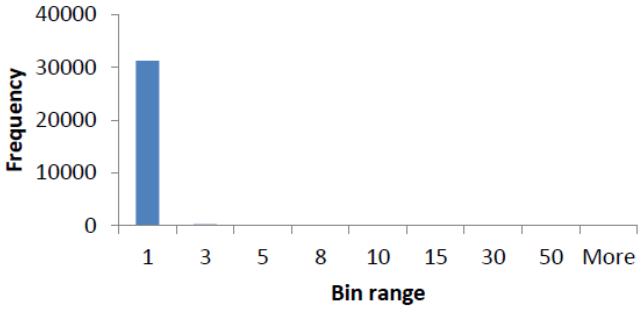
Note: Frequency represents No. of homes in the following graphs.

Histogram of building profile	Notes
	H1.1 This building profile is very low – there is a high number of SFU. This results in a very low average living units/building.

<table>
<tr><td>
</td><td>H1.2

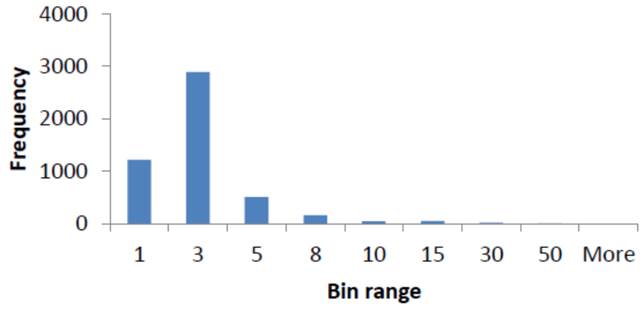
A building profile with a lot of SFU and very low amount of MDU. This results in a low average living units/building.</td></tr>
<tr><td>
</td><td>H2.1

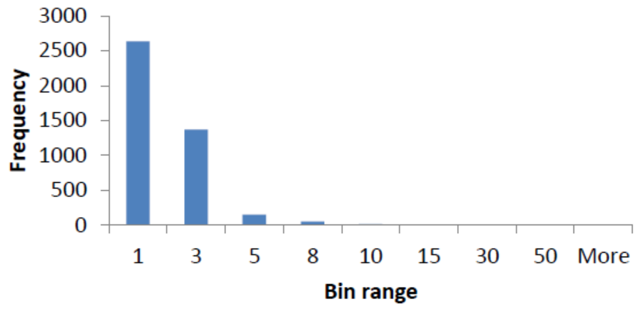
This building profile consists of a lot MDU of great size. There are buildings up to 171 living units – although not visible in the histogram due to the scale of the frequency axis. This results in a high average living units/building.</td></tr>
<tr><td>
</td><td>H2.2

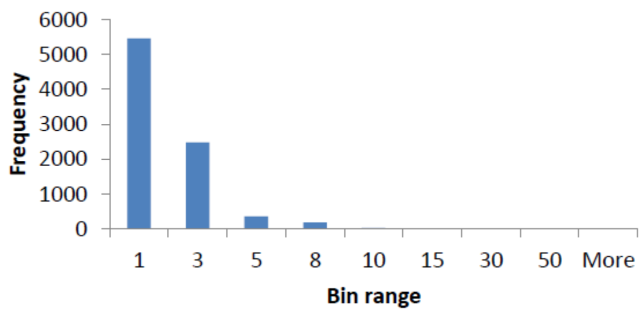
This building profile consists of a lot MDU of great size. There are buildings up to 162 living units – although not visible in the histogram due to the scale of the frequency axis. This results in a very high average living units/building.</td></tr>
<tr><td>
</td><td>H3.1

This building profile is extremely low. It seems as if no MDU are present, but this is due to the scale of the frequency-axis.

This results in a very low average living unit/building.</td></tr>
</table>

<table>
<tr>
<td>
</td>
<td>H3.2

A building profile with a lot of MDU of size 2 and 3. This results in a medium average living units/building.</td>
</tr>
<tr>
<td>
</td>
<td>H3.3

A building profile with a lot of SFU and low MDU's. This results in a low average living units/building.</td>
</tr>
<tr>
<td>
</td>
<td>M2.1

A building profile with a lot of SFU and low MDU's. This results in a low average living unit/building.</td>
</tr>
</table>

Appendix 2 - Correction to the land use data

Suppose a NUTS 2 region consists of two NUTS 3 regions $Area_{left}$ and $Area_{right}$ From table A4.1, one derives that at NUTS 2 level two third of the region is populated.

Region	**Populated** Area Surface	**Unpopulated** Area Surface
$Area_{left}$	*6X*	0
$Area_{right}$	*6X*	*6X*
NUTS 2	*12X*	*6X*

Table A4.1: Explanation of rule based applying land use information of NUTS 2 regions to its NUTS 3 regions

Applying this figure to its NUTS 3 regions, would result in two incorrect populated area surfaces: the calculated populated area surface would be *4X* for $Area_{left}$ and *9X for* $Area_{right}$. That is why the following 'rule based' formula is chosen to adapt the area size of the NUTS 3 regions.

Definitions:

'tot. hh. dens.' = household density based on total area surface
'pop %'= percentage of area that is populated

Formula:

IF

('tot. hh.dens.'>800 AND (total area size (NUTS 3) / total area size (NUTS 2)) <10%) THEN'pop %' NUTS 3 = 100%

ELSE

IF ('tot. hh.dens.'>300 AND (total area size (NUTS 3) / total area size (NUTS 2)) <10%) THEN 'pop %' NUTS 3 = ('pop %' NUTS 2 + 100%)/2

ELSE

'pop %'NUTS 3 = 'pop %'NUTS 2

With the above described rules, the populated area size of a NUTS 3 region which is very dense but is only a small part of the total NUTS 2 region (<10%) will be the same as its total area surface. As such this rule avoids corrections in the dense city centres inside a NUTS 2 region, tempering the effect of the area surface reduction.

This rule based formula captures for example NUTS 2 = Ile de France containing eight NUTS 3 regions of which one is the centre of Paris (extremely dense). The area surface size of the centre of Paris will not be corrected (first IF-statement) - otherwise, its household density would be extremely high and this does not correspond to the real situation. However, the other seven NUTS 3 regions do contain a lot of forests and they need to be corrected. If their household density is still high (800 >*density* > 300) and the size is still only a relative small portion of the NUTS 2 region, their populated area size will only be corrected by an amount that is half of the correction of the total NUTS 2 region (second IF-statement). However, if the NUTS 3 regions are a large part of theNUTS 2 region or less densely populated, the populated area correction of the NUTS 2 region will be fully applied to the NUTS 3 region (third statement).

This 'rule-based' approach ensures that the correction of area size towards populated area size is not (fully) applied in the most densely populated parts of the NUTS 2 region. The rule is based on the land use, as defined by the LUCAS project, but not directly applied but by ensuring that the household densities are now more linked to those defined by the green polygons. Note again that this rule based approach plays on the safe side as it will result in a situation where in general (on a NUTS 2 level), the overall 'unpopulated' area of the NUTS 2 region will be smaller than the statistic derived from the LUCAS data.