The Cost of Meeting Europe’s Network Needs

The cost of putting in place an infrastructure now, that will meet the Digital Agenda targets for 2020, 2030, 2040 and beyond

July 2012

Fibre to the Home Council Europe

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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.

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Executive Summary

The FTTH Council Europe has seen a number of attempts to model the costs of building networks to meet the Digital Agenda Targets for 2020. Concerns have been expressed by the FTTH Council about the methodologies used, insofar as these were available, and also as regards the absolute level of the cost estimates. The results of these other estimates have been used to decry the Digital Agenda Europe (DAE) 2020 targets as being unrealistic or unattainable in some quarters regardless of the clear need for high speed access, a need which continues to evolve.

This report details on 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 should be noted that this is the only model that is based on data from a series of actual deployments which have been made in different European countries.

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 continued failure in Europe to specify an upload speed is in stark contrast to other parts of the World, Japan for instance set only one target in 2004 which was for a universal 30Mbps target which was upload only. A FTTH network can meet such targets for today but also as they evolve beyond 2020. The model is based on a completely new build and assumes no passive network reuse. Subsequent modelling seeks to estimate the savings that might be achieved through targeted reuse of passive infrastructures.

The results of the model indicate that €**202 billion** would be required to provide a complete overlay of the EU27 countries to meet the DAE targets. This includes 100% homes passed and 50% connected (with 50% of the most remote 5% both passed and connected).

The FTTH Council has commissioned another study which shows that FTTH networks enjoy a close to 50% uplift in ARPU over time[1.] These results are consistent across markets and indicate that where there is a competitive and regulatory dynamic which supports investment, operators can invest. However, the FTTH Council is concerned that the current balance being struck between access remedies is undermining that market dynamic and believes it should be reviewed in order to place a greater emphasis on network investment and network competition where that is sustainable.

Cost reduction measures can further support the business case and lower entry barriers if a competitive dynamic exists. The FTTH Council finds that there are potential savings that could be made by applying various developed alternative passive infrastructure installation methods combined with the targeted reuse of passive infrastructures and that these savings amount to 10's billions. While the FTTH Council has not estimated the cost of putting such measures in place, it is clear from the sums involved that there are very large savings available to Member States who put such measures in place. 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.

[1] Ref Diffraction Analysis Study

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. Many observers have questioned the effectiveness of the CEF funding of the order of €7bn in the context of a total network cost which is far in excess of the FTTH Council's.

However, the FTTH Council believes that the CEF funds should not be used in those areas where network competition either exists or could exist. Instead the CEF should be targeted in the 'grey' areas where only one network exists. If we consider that the 'white' areas will be covered with other technologies in the period to 2020 and target what might be considered to be 35% of households that are grey, a more concrete context for the CEF can be established.

The model shows that if we consider the use of CEF to deploy in this 'grey' area, the cost would be **€73billion.** Other work[2] by the Council which looks at financing, financial instruments and co-investment suggests that such a scaling of finance is possible to cover these areas. However, it requires a step-change in co-ordination and structure compared to the established financing mechanisms in transport and energy since the CEF funding will need to be combined with local government and private investment to develop investments not currently scheduled in most instances.

The model output identifies the cost of deploying a full overlay build and does not take into account any additional upsides which in themselves have the potential for further 10's billions of cost savings such as:

- Taking into consideration existing NGA networks.
- Utilisation of existing techniques that will reduce the cost of deployment
- Sharing of existing infrastructure (not only telecoms but also other utilities)

Conclusion

The DAE Targets for 2020 are obtainable with a future proof network deployment which will also be capable of delivering the DAE 2030 and DAE 2040 network requirements. The total cost of reaching the digital agenda targets for 2020 based on a completely new build FTTH network is €202bn. The FTTH Council cost model is the only cost model based on data from actual deployments.

Measures to reuse certain passive elements can lead to significant savings on this figure. Without a reemphasis on infrastructure based competition where such competition is feasible, the impact of cost-reduction measures are likely to be minimal.

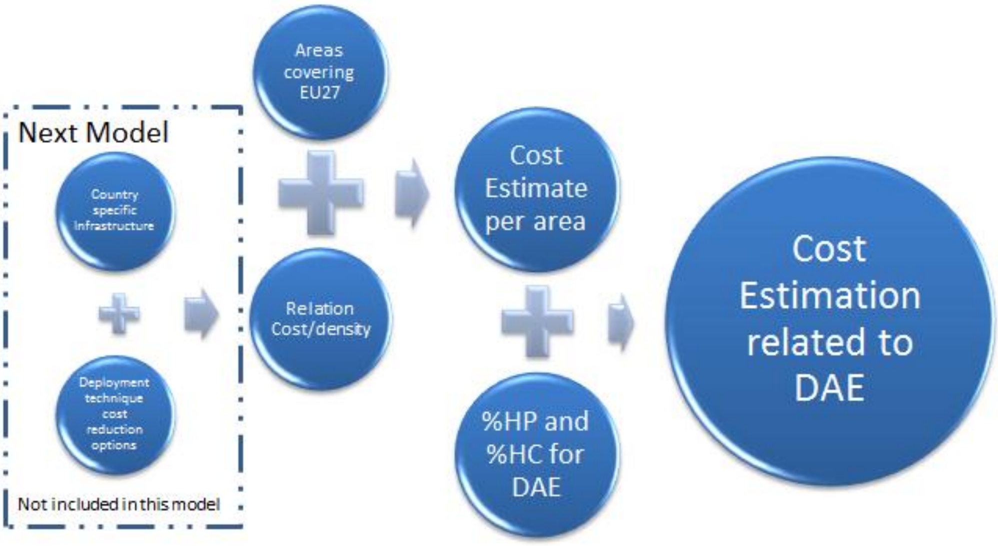
Looking beyond the competitive areas where public funding may be needed, the next 35% of households would cost approximately €73bn. When the CEF funding is set against this figure, with financial instruments and co-investment from local government and private sector, this targeted areas can also be served.

[2] Ventura Partners study

Cost Model Overview

Project Approach

The FTTH Council engaged firms to model the cost of FTTH deployment that had already modelled three quarter of a million households using real data and under a variety of scenarios but it is unrealistic to calculate the actual cost to deploy FTTH in the 27 European Union members based on such data. There was therefore a need for an extrapolation model which could use the data generated based on actual data and scale it up to a European level. Figure1 below explains the approach taken by the FTTH Council. Two inputs are identified for this model: the cost-density relation and the areas covering the EU27. The result of these inputs is cost estimation for each of the areas. Together with the assumed subscriptions rates to obtain the DAE targets, the total cost to reach these targets has been established. The effect of country



specific infrastructure and the effects of deployment technique cost reduction options are not included in the current Cost Model. The next edition of this white paper will contain country specific calculations for Germany and the cost reduction results for alternative technologies

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 EU27 countries including the activation of households to reach the DAE targets by 2020.

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

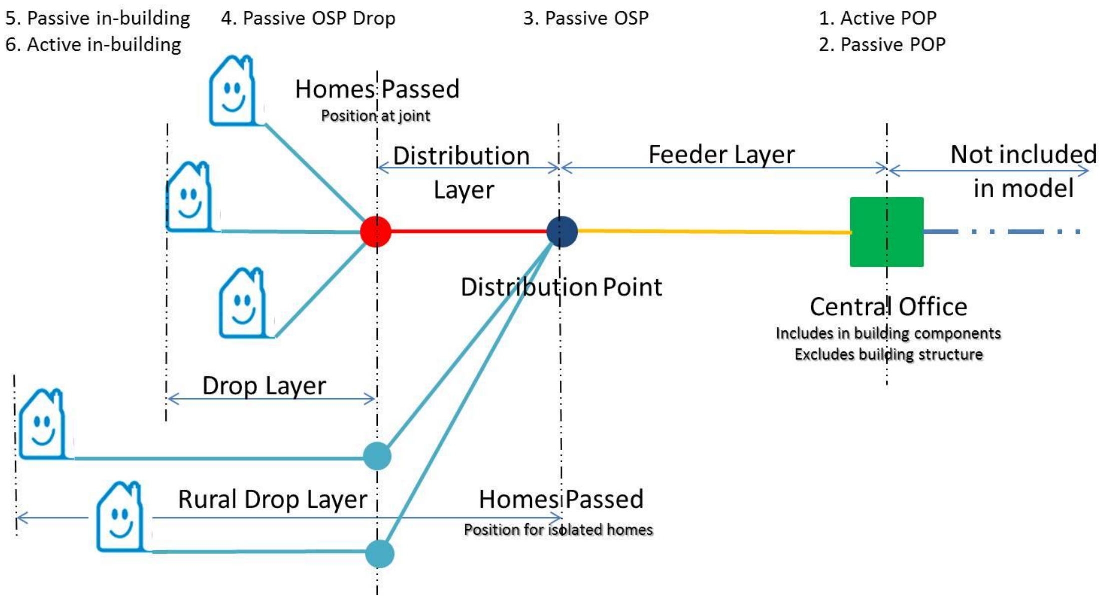


Figure 2 Network Design Building blocks

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 level of isolation between homes, the 'homes passed' separation point from the 'homes connected' portion of the network sometimes will move beyond the distribution point, closer to the isolated homes. A distribution point between several homes can be shared as, even if some of them are isolated. Therefore in some situations the homes passed border will differ from that shown in figure 2.

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. These alternative approaches will be introduced in future editions of the model which examine specific Member States.

The model assumes that there is no existing build so provides a complete overlay. The fact that existing passive networks are not reused has the main advantage that the 'field' network can be better optimised to suit today's population distributions. However, 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 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. 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.

Existing infrastructure (for example ducts and poles) that could be re-used for FTTH deployments are not considered.

Regions that are already enabled with Fibre to the Home have not been identified and are therefore not excluded but over laid in the overall results.

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

The model does not take future population growth or future urbanization and ruralisation into account between now and 2020.

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 ground works (these are very country dependant and will be reviewed when carrying out Country specific models.).

Comparison with other cost models

A major strength of this model is the use of data provided from actual deployed 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.

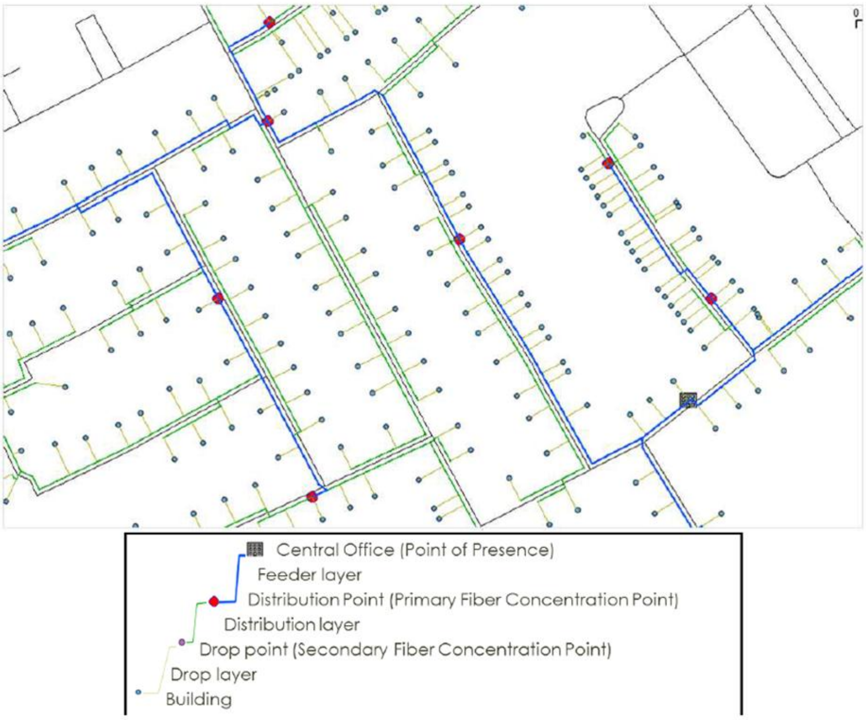


Figure 3 Example of an optimised network plan of a sample area

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 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 27 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 DAE targets.

Deployment costs and Activation costs have been identified as the primary outputs which map directly to the DAE 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,), 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.

Activation Costs

Activation costs or 'homes activated (connected) cost'[HA] are those 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.

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.

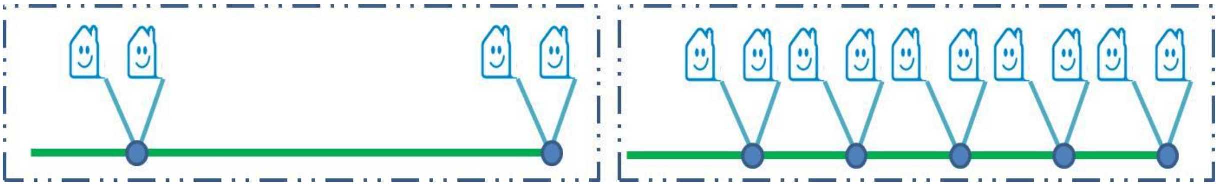


Figure 4: The relationship between population density and cost per home passed

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 EU27 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 EU27 homes must be passed in order to meet the DAE target
- Only half of the homes passed get activated (connected): a 50% adoption.

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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.

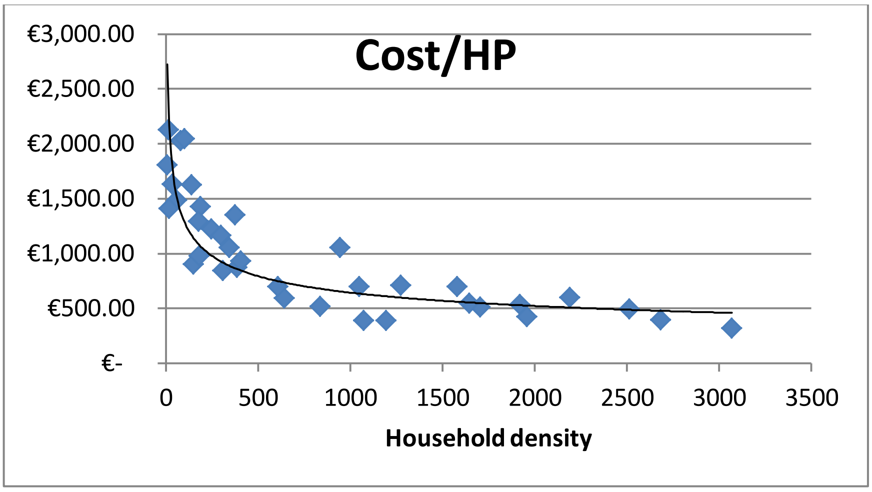
First of all: this graph does not specify which labour costs are used for the calculation of the sample points. As the pie-charts in figure 6 clearly indicate, labour costs (labour civil + labour install) can be up to 80% of the total cost of the network. Small variations in the labour cost can therefore 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. 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 EU27 countries the more accurate it will be.



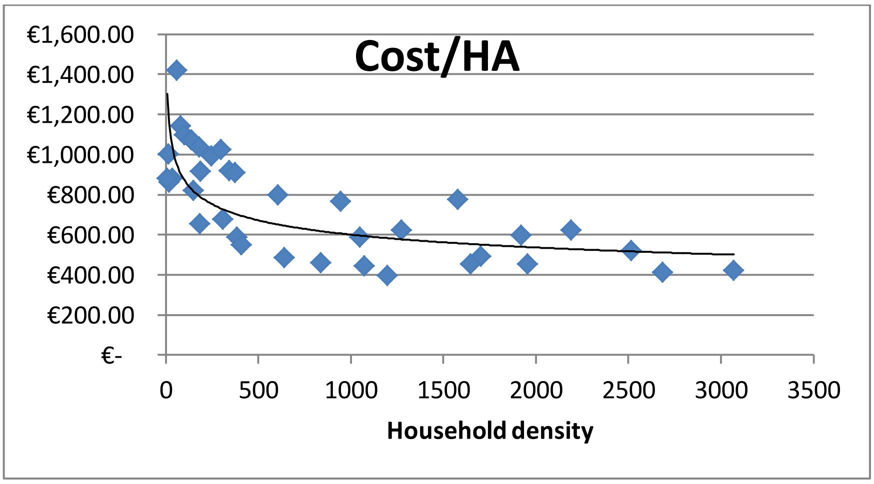


Figure 5: The cost per HP and HA for the 36 sample areas with a varying density

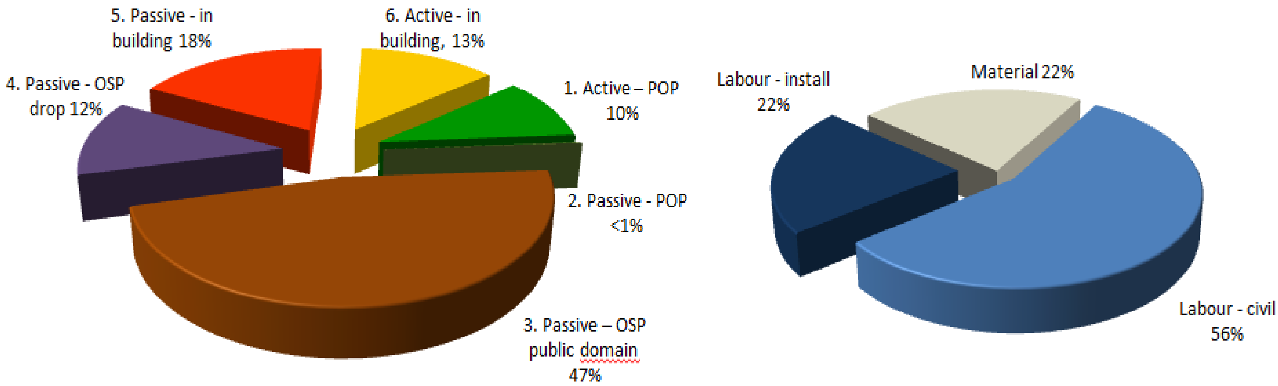


Figure 6: Example of the Home Connected costs (= cost per home passed + cost per home activated) for one of the sample areas – divided into the 6 cost categories of table 15 and for the same area divided into 3 categories labour civil, labour install and material cost.

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 areas of the household density and the number of households. This report investigates the cost to deploy FTTH in Europe, or more specifically, the 27 countries that form the European Union (EU27 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

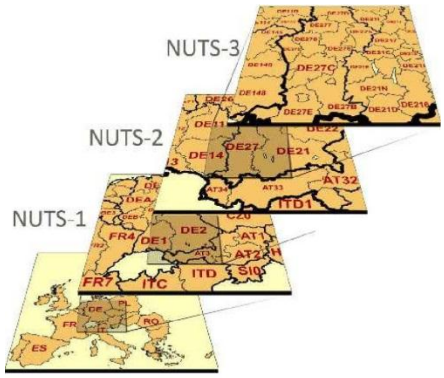


Figure 7 Hierarchical structure

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.

[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 EU27 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 27 European Union member states regions are:

NUTS 1: major socio-economic regions [97 regions].

NUTS 2: basic regions for the application of regional policies [271 regions].

NUTS 3: small regions for specific diagnoses [1303 regions].

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

As can be seen in figure 8, these 1303 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 EU27 countries, NUTS 3 is the best alternative addressing all countries[5].

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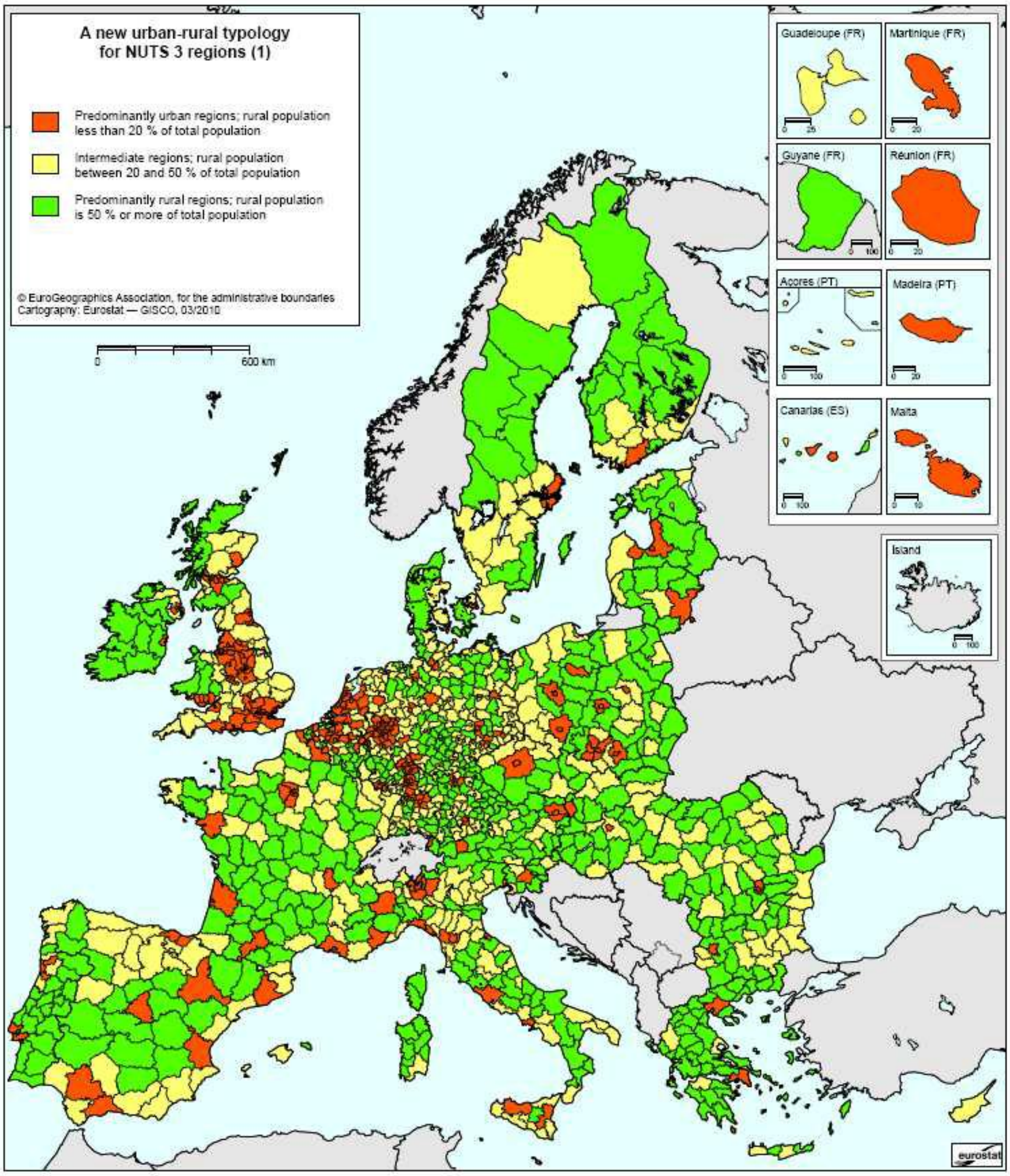
[4] http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction

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



(1) This typology is based on a definition of urban and rural 1 km^2 grid cells. Urban grid cells fulfil two conditions: 1) a population density of at least 300 inhabitants per km^2 and 2) a minimum population of 5 000 inhabitants in contiguous cells above the density threshold. The other cells are considered rural. Thresholds for the typology: 50% and 20% of the regional population in rural grid cells.

For Madeira, Açores and the French outermost regions, the population grid is not available. As a result, this typology uses the OECD classification for these regions.

Figure 8: Map with the 1303 NUTS3 regions

Population, households and Area sizes

Population: Filename: [demo.r.pjanaggrd]; Extracted on: 23.11.11.

This file contains the population up to NUTS3 level. The most recent year of data is 2010, for some regions the most recent year is 2009.

Households: Downloaded file from: [lfst.lihantych]; Extracted on 23.11.11

This file contains the average number of persons per household per EU27 country. For EU27, the average is 2.4 persons per household. The most recent year of data is 2010, for some regions the most recent year is 2009. 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.

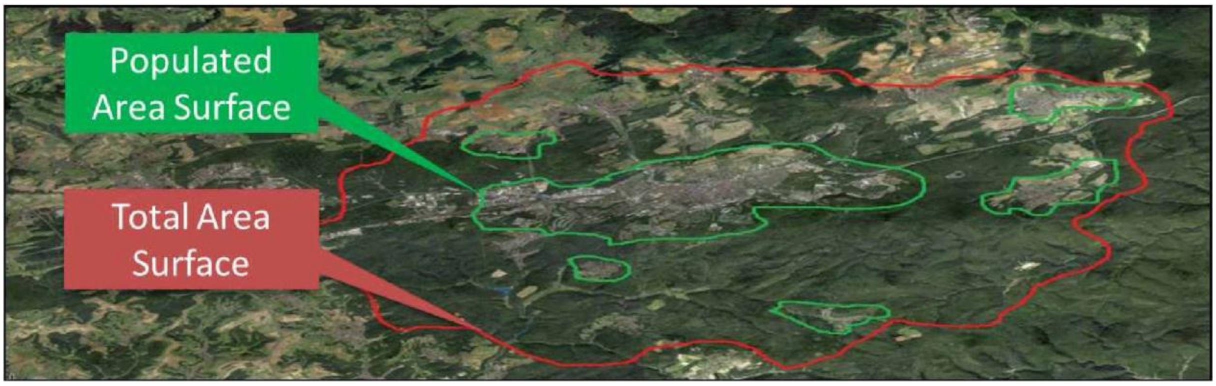


Figure 9: The difference in 'populated area surface' (inner green polygons) and 'total area surface (outer red polygon).

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].

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

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.

Local labour costs and assumptions for applying in the Cost Model

Labour costs: Filename: [lc_n08cost_r2]; Extracted on 24.11.11

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 EU27 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 2008. For each country, the data are normalized upon the EU27 average of €21.78/hour. 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 13.

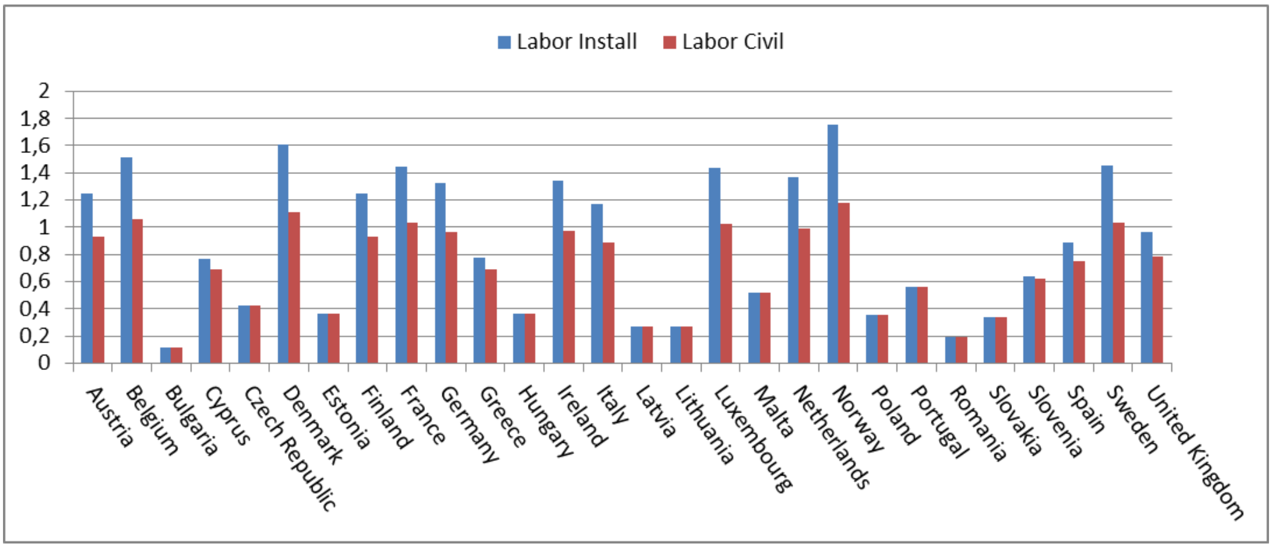


Figure 13: The Labour Cost Index for 'labour civil' and 'labour install'.

Applying these corrections for the various national labour costs results in 27 different trend lines (not shown in figure 5, but used to calculate the total cost for the EU 27 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 study 15 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 14 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 *(km²)*	Households	Density *(hh/km²)*
20.6	45056	2191
20.8	32824	1578
117.0	125360	1072
92.5	31785	344
79.3	14483	182

Table 14: 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, an additional 21 points have been added to validate the cost/density trend line shown in figure 5.

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 15.

UNIT COSTS

	labour civil	labour install	material	total
1. Active POP				
Active Equipment in the POP				
OLT Card - PON	€ -	€	€	€
OLT Card - P2P	€ -	€	€	€
Shelf	€ -	€	€	€
2. Passive POP				
Passive Equipment in the POP				
		€	€	€
3. Passive OSP				
blic 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 15: 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 EU27 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 EU27 level as well.

For each of the 1303 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 EU27 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 1303 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, according to the DAE targets. This results in a total cost of €202 billion for the EU 27 countries. In the next Edition of the White Paper more results will be shown on (country specific) rural. connections.

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 1303 NUTS 3 regions to EU 27 is shown and how the data are adapted to the needs of this study. By combining the results for each region an estimated cost to deploy the FTTH network can be derived and an estimated cost needed to activate (a percentage of) the homes within the region.

The DAE targets can be obtained with different levels of adoption, where a higher adoption will lead to lower investment costs. In figure 16 three cases are shown. In this cost model 50% Adoption is chosen as the Key scenario.

Using the 50% adoption level, all regions would receive the full coverage FTTH network needed to fulfil the first DAE target [100% of European households should be able to subscribe to a bandwidth of 30Mbps]. Of all the homes that are passed, half of them will subscribe to the fibre network and receive a bandwidth of at least 100Mbps, to fulfil the other DAE target [100% of European households should be able to subscribe to a bandwidth of 30Mbps]. This level of adoption is high compared to the current adoption to FTTH, however is needed to fulfil obtain the DAE targets.

The total cost of investment is €202 billion.

Note that in this scenario all European households have the possibility to take a fibre connection, meaning that they have the possibility to subscribe to at least 100Mbps.

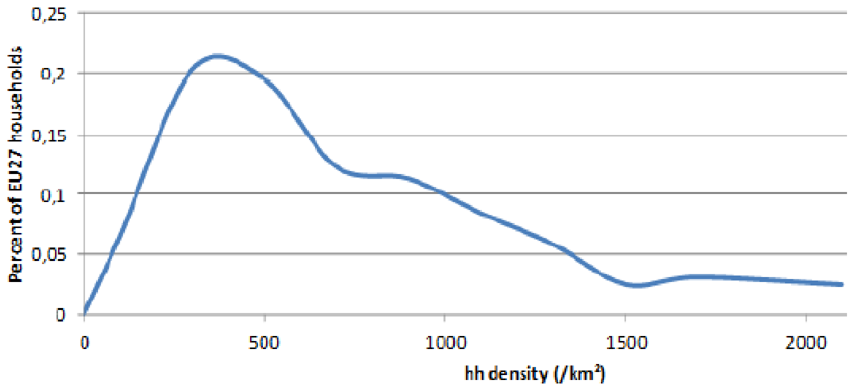


Figure 16: The percentage of EU27 population living in a region with a certain household density.

Figure 16 visualizes the percentage of the EU27 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.

EU27

The total investment cost to reach both DAE targets for all EU 27 countries is estimated to be **€202 billion**.

EU27 Grey Zones

The total investment cost to meet the DAE targets for the Grey zones of the 27 EU countries is calculated to be in the region of **€73billion**.

This is based on an assumed 35% of the population that are within the areas applicable to CEF funding (although this could increase further by including the white areas)

Potential upsides to model

There are a number of upsides to the model which will further reduce the deployment costs. These have not been included in this first edition of the Cost Model White Paper but will be in future editions.

Hardware cost reductions over time

Historically the cost of hardware decreases over time and as volumes increase. These effects have not been included in the model.

Take into consideration builds already complete or in progress

The model assumes a 100% overlay and does not take into consideration where builds that meet the DAE target specification are in place or are in the process of being implemented.

Use of alternative installation techniques and infrastructures

Significant savings could be made by the use of alternative installation technologies not considered in this model.

Sharing of infrastructure including that of other utilities

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.

Regulatory and Standards issues related to infrastructure sharing and cost cutting solutions

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.

On-going work and next steps

Developing Country specific models – initially focusing on Germany and the UK.

1.1. To include more detailed local estimates (will also feed back into overall EU27 model improving accuracy)
1.2. To incorporate alternative build methods that are appropriate for each region, for example direct buried drop cabling or aerial drops.

To consider an element of infrastructure sharing.Review the estimation for the most isolated communities and households that make up the last 5-20%.and depending on circumstances correcting the area sizes with land use, it would be better to use statistics on NUTS 3 level, but this is currently impossible as the statistics are only available on NUTS 2 level.

Appendix 1 - Sample Points – SFU/MDU info

This document describes information about the building profile of the8 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

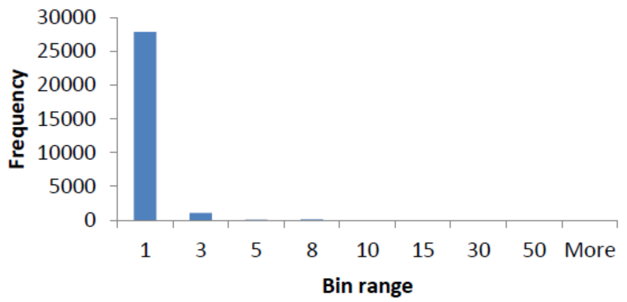
The table to the right summarizes the average number of living unit per building (average), the maximum number of living units per building (max) and the sum of the living units for each sample

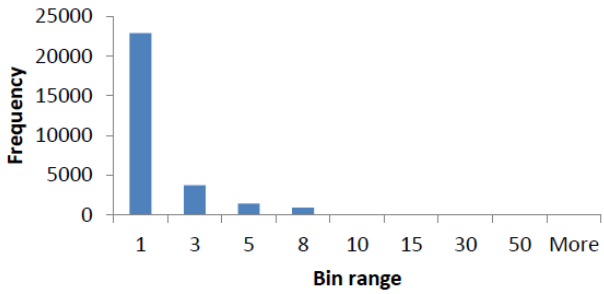
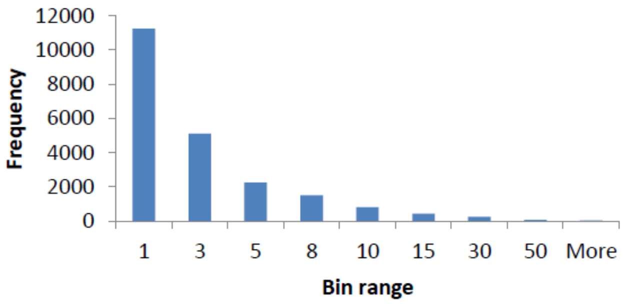
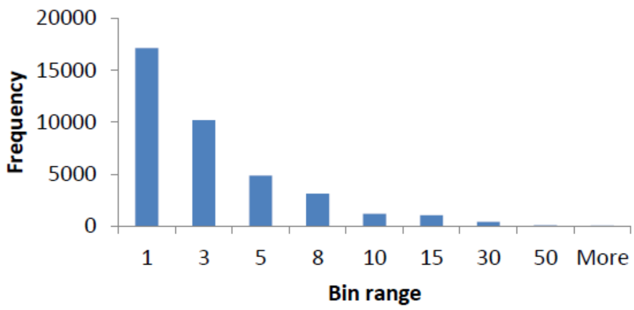
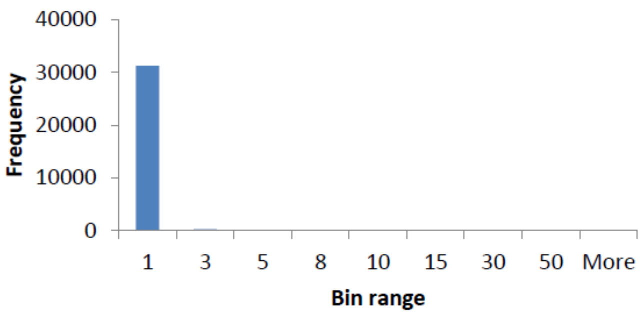
Sample	average	max	sum
H1.1	1.1	56	32824
H2.1	3.0	171	65175
H3.1	1.0	11	31785
H3.2	2.5	47	12178
H2.2	3.3	162	125360
M2.1	1.7	56	14483
H1.2	1.5	22	45056
H3.3	1.6	24	6813

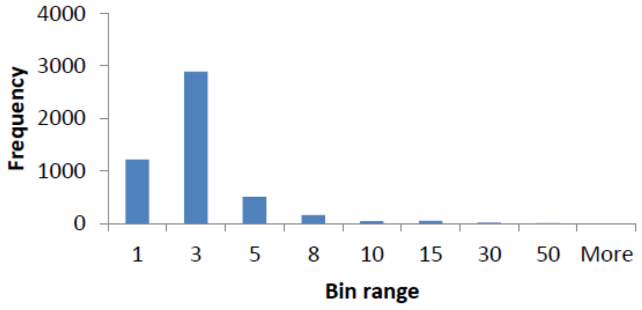
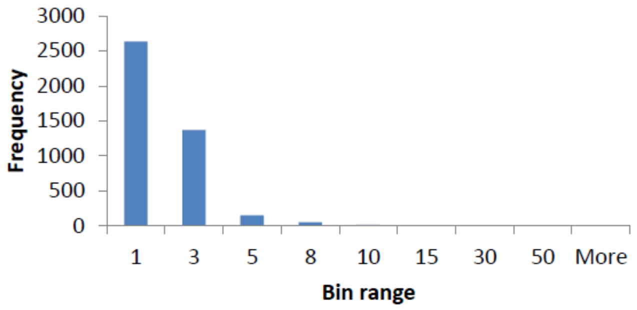
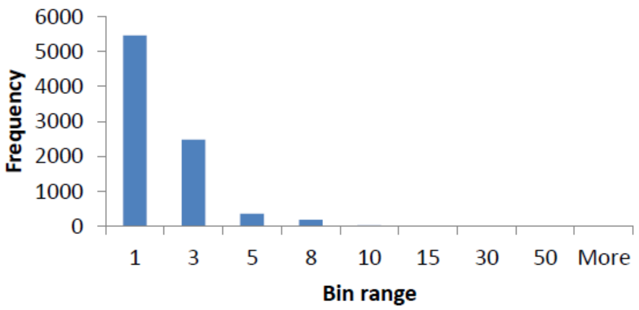
Histogram information

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.

	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.
	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.
	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.
	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.

	H3.2 A building profile with a lot of MDU of size 2 and 3. This results in a medium average living units/building.
	H3.3 A building profile with a lot of SFU and low MDU's. This results in a low average living units/building.
	M2.1 A building profile with a lot of SFU and low MDU's. This results in a low average living unit/building.

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.

<u>Definitions</u>:

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

<u>Formula:</u>

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 the NUTS 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.

Appendix 3 – Cost Model Project Team

This work would not have been possible without the support from the project team (*in alphabetical order)*:

Dick van den Dool	**Draka**
Albert Grooten	**Grooten FTTH Consultancy**
Luc De Heyn	**Comsof**
Chris Holden	**Corning**
Raf Meersman	**Comsof**
Sebastian Orlowski	**Atesio**
Tony Shortall	**Telage**
Hartwig Tauber	**FTTH Council Europe**
Roland Wessäly	**Atesio**

The Council would also like to thank many other members of the FTTH Council and outsdide partities who have provided real life data and feedback.