# Efficient transition from old to new infrastructure: the case of optical fibre local loop

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October 3, 2011

**Abstract**

In Europe, telecommunication networks are shifting from the old generation copper network to the next generation one, and the optimal policy of regulating this transition is widely discussed. This article proposes a policy that would ensure minimal deployment costs and at the same time intensify competition. The recommended policy is based on a regulated infrastructure monopoly with cost-based access price. The building of sole infrastructure maximises scale effects while the service-based competition puts downward pressure on the retail prices. Investment incentives are supported by two measures: granting monopoly rights, which eliminates potential competition between parallel fibre networks, and switching off the copper network, which eliminates competition between copper and fibre networks. The averaged national access price removes the digital divide between areas with different population density. A redistribution fund may need to be established in order to compensate infrastructure operators in unprofitable thinly populated areas. This policy recommendation is generic and can be applied to different countries. It is supported by a cost model based on French data. The model estimates the cost of access fibre infrastructure as a function of density for two main scenarios: our proposed policy versus the market structure currently observed in France. It evaluates the impact of our proposed policy in terms of total savings thanks to better usage of scale effect and lower investment risk.

**Key words:** next generation networks, telecommunications, regulation.

**JEL-code:** L51, L96

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# 1 Introduction

Telecommunication operators worldwide are currently deploying their next generation access networks. A crucial role of industry regulators is to determine a regulation pattern that will ensure quick transition from the old copper network to an optical fibre one. Determined at the early stage, such regulation pattern will provide dynamic consistency and policy commitment in future; also, it will allow to avoid future errors. Regulators, industry participants and economic theorists are actively discussing industry organisation that would promote the quickest spread of fibre technology to the benefit of final users. However, as of today, there is no consensus on how fibre should be regulated, and a wide array of policies is used by regulators in Europe and worldwide.

Concerning the scope and the strategy of fibre regulation, telecommunications regulators face the following questions:

1. Should the fibre deployment be regulated?
2. Should the regulation principles be uniform on the whole national territory, or, with national territory being heterogeneous, should it depend on each particular zone's characteristics?
3. To which extent should the regulation strategy depend on the historically formed market structure of broadband; should the rules be the same for the fixed telecommunications incumbent and new entrants?
4. What kind of measures should be taken:
    a. imposing obligation of access (access to civil engineering allows an entrant to build a fibre network using the existing ducts; passive unbundled access – "black fibre" – does not include active electronic equipment; active or virtual unbundled access includes active electronic equipment);
    b. regulating access price (even though regulators often agree on its cost orientation, the exact scope of costs may differ);
    c. subsidizing deployment in uneconomical areas;
    d. other remedies.

A multiplicity of answers to these questions was proposed both in theoretical articles and in policy recommendations. Below we cite some of literature dealing with these questions and discuss their conclusions and proposed solutions.

Nitsche and Wiethaus (2009) construct a model of competition between and incumbent and an entrant. They compare four regulatory regimes:

- "LRIC" (long run incremental cost), where the deployment cost is compensated through access price only if NGN is successful (which happens with a certain probability);
- "FDC" (fully distributed cost), where the deployment cost is compensated through access price even if NGN is not successful (for example, through access price to the copper);
- Risk-sharing, where operators jointly develop a network and use it without access payment;
- Regulatory holiday, where no obligations are imposed.

Consumer surplus is determined by two factors: investment levels and competition degree. The risk sharing happens to be surplus maximising; it both incites investment and increases competition. FDC is the second best solution: even though competition may be lower than in LRIC, the level of investment is higher. Because of risk, LRIC induces low investment, and therefore appears to be less efficient. Regulatory holiday is the worst solution: even though it provides the best investment incentives, the consumer surplus is extracted by the monopoly.

There is a disadvantage of risk sharing solution that is not accounted for: a new entrant cannot use the infrastructure previously constructed by operators. So, it has a clear disadvantage of limited competition which is not taken into account in the model since no new operators are modelled. Moreover, the established oligopoly will lead to a high probability of tacit collusion.

Lebourge (2010) claims that infrastructure competition is the optimal market structure for fibre deployment. He explains that such competition will lead to strong innovation, high service penetration and coverage. We claim that the effect of innovation and new technology is insignificant. First, the scope for innovation is very low in fibre local loop. One needs to distinguish between active and passive network elements: if the former are indeed subject to strong technological progress, the latter mainly consist of fibre cable costs and labour costs that do not decrease. Second, there is a mechanism which ensures that operators indeed use the most efficient technology. They organise a call for tender to choose the constructing firm that is ready to build the network with the lowest cost and best quality.

Often authors do not give precise answer on how the fibre network should be regulated, referring to different conditions on each individual territory. For example, Atkinson (2008) claims that the optimal market structure on each market will depend on specific circumstances on each market such as density, availability and cost of existing infrastructure, etc. A similar conclusion was made by Soria and Hernández-Gil (2010), who claim that a market analysis should be performed on each sub-national territory separately with the objective of determining the optimal policy on this particular territory.

Another question discussed in the economic literature is how the access price both to copper and to fibre local loop should be determined. It will impact investment decisions and competition intensity. A low fibre access price tends to attract more service-based competition but risks to undermine investments in fibre. A low copper access price may hinder the migration to fibre, but may incite the incumbent to invest in next generation network.

The European Telecommunications Network Operators' Association (ETNO) and the European Competitive Telecommunications Associations (ECTA), two eminent trade associations in telecoms, have proposed contradicting measures. While ETNO recommended the same pricing method for both the fibre and copper network, ECTA indicated that access price to copper should be cut substantially to create enough incentive for incumbents to invest in fibre.[1]

Bourreau, Cambini and Dogan (2011) model competition between two operators: an incumbent and a new entrant, both of them may deploy next generation network. They find that if fibre access is not regulated, the optimal copper access price should be determined as a compromise between three contradicting effects: the investment incentives of alternative operator increase with copper access price, the investment incentives of the incumbent decrease with copper access price, and the consumers' incentives to migrate to fibre increase with the copper access price.

[1] ETNO's position is based on a study by Plum Consulting available at http://www.etno.eu/Default.aspx?tabid=2381; ECTA's proposal is based on the WIK's study available at http://www.ectaportal.com/en/REPORTS/WIK-Studies/WIK-Study-Apr-2011/.

They also consider an alternative regulation policy where the access to next generation network is regulated as well. In this case migration takes place at a wholesale level, that is why consumers' choice is irrelevant. They find that in equilibria where the NGN coverage of incumbent is greater, the entrant needs to make a choice between leasing access to OGN and NGN. To encourage him/her to switch to NGN, a low OGN access price should imply a low NGN access price. In equilibrium where the entrant's NGN coverage is larger, there is, on the contrary, a reverse relationship between two access prices: a low copper price combined with a high fibre price to give the new entrant more competitive advantage and to incentivise next generation network investment by both incumbent and new entrant.

Gavosto, Ponte and Scaglioni (2007) apply a real option model to explain the investment decision in next generation networks to capture uncertainty. They find that, contrarily to wide spread opinion, access price regulation negatively affects investments in NGN only in the initial period; in the long run, according to the real option model, investments are not affected.

Brito et al. (2008) study whether a two-part tariff access to a next generation network may solve the problem of lack of commitment. They conclude that it is possible only under certain circumstances and if fixed fee is not too high.

In this article we argue that the optimal policy is the one that guarantees infrastructure monopoly on fibre local loop in each zone and imposes access obligation with regulated price. The access price should be geographically averaged and a redistribution mechanism should be established to fund investment in low density areas. Another important component of the proposed policy is switching off the copper network at the moment the fibre network becomes operational in the given area. Such regulatory policy will both promote the fibre construction and respect consumers' interests.

We will proceed as follows. In section 2 we explain why the proposed policy is superior to alternative policies. In section 3, we describe the model and present calculation results that support our policy recommendations. In section 4 we discuss how the proposed policy may be implemented. Section 5 concludes.

## 2 Optimal policy discussion

In this section we propose a regulatory policy for fibre local loop which can be applied in different national contexts.

The first characteristic of proposed policy is authorising only one fibre local loop network in each zone of the national territory. Indeed, it allows to benefit from the full scale effect in the situation of natural monopoly. As will be shown below in section 3, the investment cost significantly increases with duplication.

For example, on a mobile network the scale effect is not as great as on an electricity network. While in the first one the infrastructure competition is promoted in the Member States, in the second one the infrastructure sharing is introduced.[2] Similarly, the fixed network, including fibre, is traditionally divided in two parts: core network and access network that is the subject of the current article. It is recognized that the core network may be replicated because scale effects are not as high as in the access infrastructure.

As will be shown later, infrastructure competition leads to cost increase and, at the end, to the retail price increase. Moreover, infrastructure will be developed only in high density areas, so that city dwellers could benefit from low prices. The non-dense zone, on the contrary, represents a natural monopoly. Without regulation, the inhabitants of this zone will suffer from lack of competition and high price.

Another disadvantage of infrastructure competition is unequal competitive position of operators. A problem is faced by the potential investor who is not the incumbent: he has a lower expected demand than the incumbent which may be insufficient to justify the high deployment cost, in which case only the incumbent deploys. Hence, the competition is tilted.

In some countries, there is also a risk that the civil works' capacity would not be sufficient for two or three fibre infrastructures, which will create infrastructure bottlenecks. Hence, there may also be an additional cost of deploying several parallel fibre local loops. In the case when the existing civil works

[2] Lebourge (2010) compares fibre network to mobile network to prove that the absence of access regulation is more efficient in both industries. Still, cost characteristics differ significantly between these two types of technologies, with fibre network being closer to natural monopoly.

do not have sufficient capacity to containing all the fibre lines, additional investment in civil works will be needed.

We suggest that, to ensure competition, an access obligation should be imposed on the monopolist, and the access price should be regulated and cost-based. Today, the fibre network cost information is available to the regulator, so that the cost level may be efficiently estimated.

It is also essential to keep the fibre investment on a high level. First, it is achieved by establishing a sufficient level of return on capital. Second, it is achieved by protecting future revenues. The deploying operator is granted fibre monopoly. Moreover, we propose to switch off the copper simultaneously with fibre activation, to avoid competition between two technologies and ensure stable demand.[3]

The chosen technology should simplify infrastructure access. There exist two general types of fibre network structure: the PON technology which consists in deploying in certain parts of horizontal network the only fibre that groups multiple subscribers and the point-to-point technology that consists in deploying at least one fibre per subscriber within the local loop. The point-to-point technology is more costly one, but it is more advantageous in prospect. First, it is better able to accommodate future demand for a higher speed access since there is no capacity sharing on the local loop level. Second, and very important in our context, it makes it simpler to unbundle.

PON technology allows for virtual unbundling, but this type of unbundling leaves less freedom to service providers and leads to less innovation. That is why we recommend using a point-to-point technology: even though it is more expensive, the loss in cost is compensated by an increased level of service-based competition and, correspondingly, consumer welfare. Such kind of competition will lead not only to lower prices but also to a diversity of offers. Offers may differ depending on the bundle of services included: phone, internet, a number of television posts. For example, a black fibre access is imposed on operators in Netherland, Sweden, New Zealand, etc. An obligation of virtual unbundling exists in UK, Austria and Australia.

[3] The copper switch-off is discussed in the new consultation of European Commission: "Questionnaire for the public consultation on costing methodologies for key wholesale access prices in electronic communications" 03 October 2011

We propose to fix a uniform national access price to the fibre and to establish a mechanism of fund redistribution from uneconomic zones to economic ones. It will allow to avoid the digital divide and to develop service-based competition everywhere. Heterogeneous prices would lead to low access and correspondingly retail price in dense areas but high access and retail price in and no service competition in non-dense areas.

Infrastructure competition stimulates digital divide: in dense areas competition indeed leads to a positive market outcome. However, on non-dense areas, duplication becomes unprofitable and consumers suffer from higher price and lower service level.

## 3 Model

In order to justify our policy recommendations, we construct a cost model of fibre local loop: it allows to estimate the cost of each element of the local loop network as well as the total cost, and to check how the result changes in particular with the number of operators, technology and WACC. It also allows to simulate numerically the wholesale access geographically averaged price in France, and to estimate the retail price increase following transfer from copper to fibre.

The data and assumptions we use include cost of different network elements, network configuration parameters of equipment capacity and cable length and, for each of 36,000 municipalities, geographic and demographic data such as number of buildings and households, road length, etc. Details can be found in Annex A. Data.

The cost of network includes the following categories:

1. capital costs of a passive fibre network,
2. operating costs including maintenance cost and access payment for civil engineering of France Telecom,
3. a part of common costs allocated to unbundled access service.

Ducts are included not in capital costs but in operating costs, since the existing civil engineering is used.

A detailed description of the model structure can be found in Annex B. Detailed model description.

We use the model to estimate parameters of market equilibrium for two main scenarios: our proposed regulatory policy and market configuration currently observed in France. We compare these scenarios with respect to average cost level as a main comparison criterion, together with cost allocation per zone, access price and retail price.

### 3.1 Regulated monopoly with wholesale access

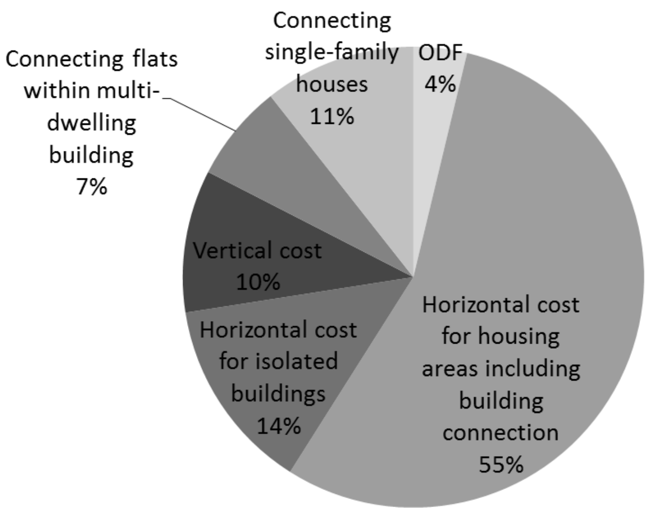
In this section, we estimate fibre local loop costs and corresponding prices that would be established if our proposed policy of regulated monopoly was implemented in France. Using the model described above, we calculate monthly cost per line as a function of density.

We choose such network configuration that would stimulate the increased service-based competition. It explains the usage of the point-to-point technology and a big size of ODF. The ODF capacity is equal to 20,000 lines in Paris and 10,000 lines outside Paris.[4] This high ODF capacity allows for a viable competition on the core network level: it becomes profitable for operators to connect to an ODF where there is a sufficient number of potential customers.

First, let us consider the obtained cost structure. The fixed costs constitute about 71% of the total costs. Figure below shows the share of each component in these fixed costs. Horizontal cost has the greatest weight which is especially significant in non-dense areas. These costs are not subject to technical progress and mainly consist of labour force and cable price.

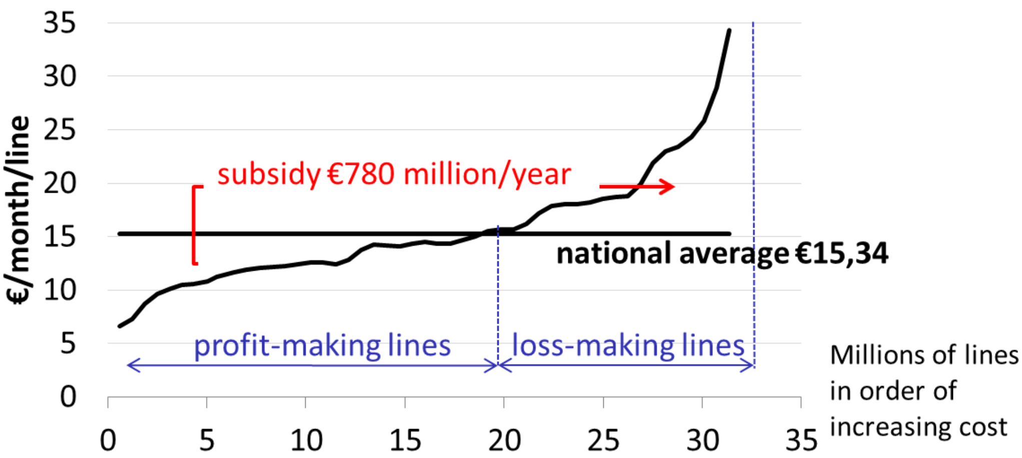
[4] The number of 10,000 was used in a study by ARCEP (French telecommunications regulator). Etude portant sur la mutualisation de la partie terminale des reseaux en fibre optique. Octobre 2008

**Figure 1. Fixed cost structure in regulated monopoly, %**




The total cost was divided by 32 million of lines to obtain the national average. Then, all the lines were classified according to the density of the area they belong to. Each community of 36,000 municipalities was rated among one of 50 density categories. For each density interval, the absolute value of monthly cost is given, including CAPEX and OPEX. In Figure 2 communities are ordered according to their density, from more dense to less dense.

**Figure 2. Cost as a function of density, €/line/month**




The average cost is €15.34 per month per line. We propose to fix this single level of access price to fibre on the whole national territory. The over-profit in dense areas will need to be redistributed to less dense areas through a funding mechanism so that to exactly compensate operator in each area for the costs incurred.

This scheme of subsidizing uneconomic areas is already used in French copper network. In fibre network, the subsidy will be equal to €782 million per year. 60% of economic lines will subsidise 40% of uneconomic lines.

To estimate the average retail price, we assume that the absolute value of difference between access price and retail price is the same for fibre and copper technologies. This difference includes essentially commercial cost, as well as cost of active equipment and profit margin, and there is no reason to assume that this difference will be higher in fibre than in copper. The value added tax is of 19.6%. Today in France, the access price to copper local loop is at €9 per line per month. The currently observed average subscription price in France is €32 per line per month including tax.

When passing from copper to fibre, the retail monthly connection price will rise from €32 to €39 or approximately 20%. Even though this calculation was made only for France, the retail price increase will not be excessive in other European countries as well. The internet connection price in France is already rather low compared to average European level, so the gap between copper and fibre does not tend to be greater.

### 3.2 Unregulated competition

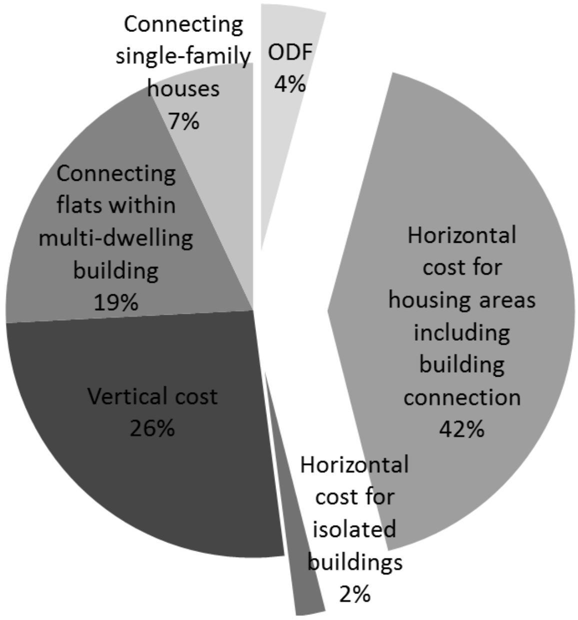
In this section we consider the case where fibre deployment is not regulated. As observed in France, it leads to well-developed infrastructure competition in dense areas and no competition in non-dense areas. Indeed, in highly profitable dense areas several competing operators will develop their fibre networks in parallel. [5] In these areas the competition is infrastructure-based and not service-based; that is why when calculating the corresponding network cost we choose the PON technology instead of the more costly point-to-point technology; this technology would be used by a rational operator. In non-dense areas, on the contrary, only one network will be deployed since duplication would be unprofitable. But given that the monopoly is not protected by regulation, the investor will need to be compensated for the risk by a higher WACC, that is why in non-dense areas the cost of competition will be higher than in regulated monopoly. The technology used in non-dense areas is

[5] In France, dense areas as defined by ARCEP (French telecommunications regulator) include 148 of 36,000 municipalities and slightly more than 20% of fixed lines.

point-to-point: obligation of unbundling makes it rational to use point-to-point architecture to economize on expensive active equipment.

First, let us consider more in details how the cost is calculated in dense areas. Since several networks are constructed, a part of infrastructure needs to be duplicated: ODF buildings, ODF and horizontal cost (study, supply and laying) including connecting buildings. These three categories of costs constituted 42% of fixed cost and 30% of total cost in monopoly in dense areas (see Figure 3). The remaining infrastructure elements are mutualised among operators. The vertical cost and cost of connecting flats within building increase by 15-30% because of the need to deploy several fibre lines.

**Figure 3. Fixed cost structure in dense areas in monopoly**




There is a factor that partially compensates for the cost increase following the duplication. It is the technological factor: PON technology is less expensive than the point-to-point one. Horizontal cost (study, supply and laying) excluding connecting buildings is higher by 20% in point-to-point.

When several parallel networks are active, the variable costs increase as well: a larger infrastructure requires more operating costs, and the cable maintenance cost is multiplied by the number of operators in dense areas. The common cost increases as well with other cost categories.

The cost that remains stable is the duct access payment. We suppose that the total price paid by all the operators for the access to France Telecom civil works is such that it strictly compensates its cost. For example, each of two competing operators has to pay twice less than a monopoly operator. That is why the total price paid by all the operators does not change with their number.

Now, let us consider cost calculation in non-dense areas, where only one fibre network is built. Most likely this network will be built by the incumbent who already owns copper infrastructure, and so will be in a better position to construct a next generation network. In France ARCEP has obliged operators to construct a network of point to point type in non-dense areas. [6]

Since costs are not duplicated and the point-to-point technology is used, the investment to be made is the same as in the regulated monopoly. However, since there is no obligation to remove copper, the investor faces a higher risk than in the case of regulation. In more expensive non-dense areas, if the investor does not arrive to attract sufficient demand for fibre, the capital expenses are not compensated. Where justified, the European Commission recommends including a risk premium when setting access prices to the unbundled fibre loop.[7] That is why in the base model we suppose that in non-dense areas WACC in the non-regulated scenario is higher than WACC in the regulated scenario. Hence, we take WACC=10.40% for the first case and WACC=15.40% for the second case to calculate the capital cost.

The total investment needed to build a nationwide network significantly increases with the number of operators: by 13% for 3 operators, which is equivalent to a social welfare loss of €4.8 milliard.

**Table 1. Total investment as a function of number of operators, € million**

| | Regulated monopoly | Competition (nb of operators) 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Total investment | 36 666 | 39 268 | 41 479 | 43 690 | 45 901 |
| Increase compared to monopoly | 100% | 107% | 113% | 119% | 125% |

The cost in competition is higher than the cost in monopoly because of two effects: infrastructure duplication in dense areas and a higher WACC in non-dense areas. If we suppose that the access price is cost-oriented, this price in competition is strictly higher than the price in monopoly. Moreover, access price grows higher as the number of alternative infrastructures increases.

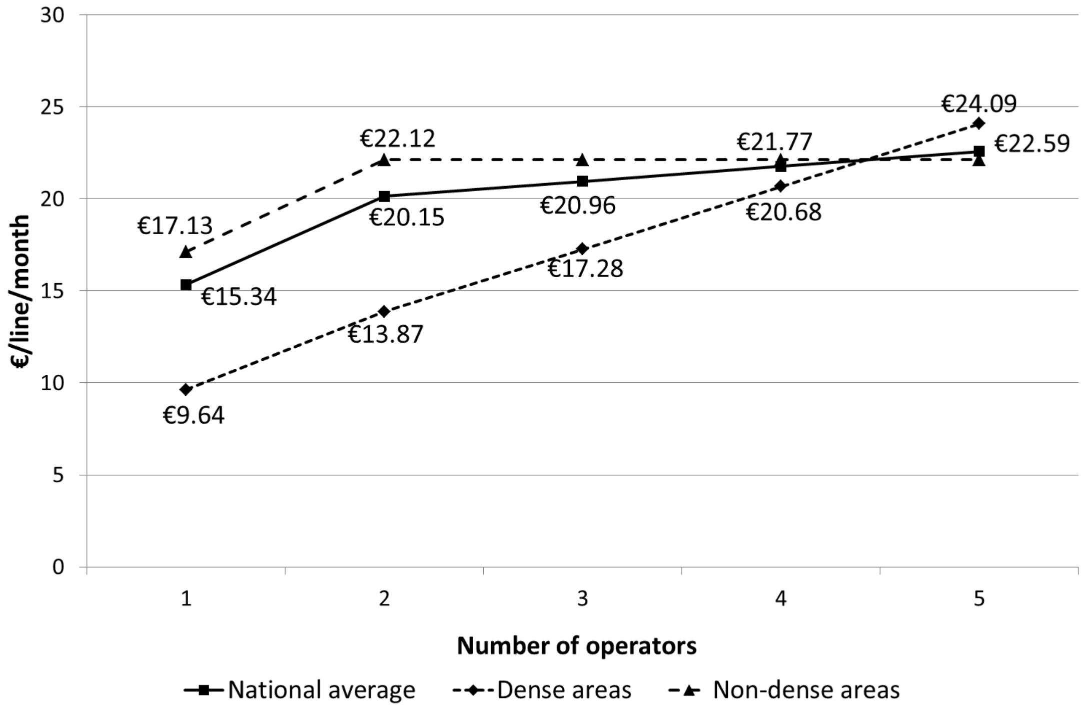
Figure 4 traces average cost as the number of competitors increases. The increase in cost in dense areas is explained by duplication. The average cost of a line situated in non-dense areas is 77% higher than the cost of a line in a dense area in monopoly, and 59% in duopoly. This gap is lower in duopoly since the total cost in dense areas is higher because of duplication.

[6] ARCEP (Electronic Communications and Postal Regulatory Authority) Decision No. 2010-1312 of 14 December 2010 specifying the terms and conditions for accessing ultra-fast broadband optical fibre electronic communications lines on the whole territory except very high-density areas

[7] European Commission. Commission recommendation of 20 September 2010 on regulated access to Next Generation Access Networks (Text with EEA relevance) (2010/572/EU)

The plain line summarizes the two dotted lines and demonstrates how the average national access price changes as the number of competitors increases. This cost increases by 31% for 2 competitors and by 37% for 3 competitors compared to monopoly.

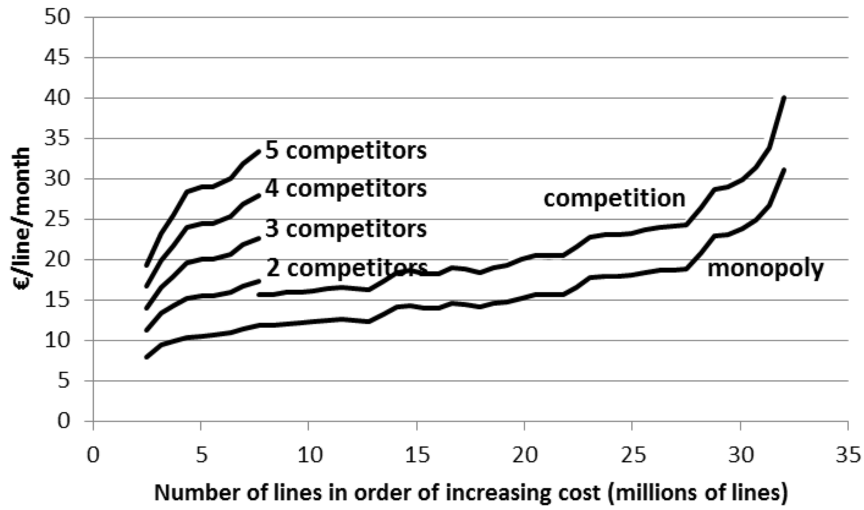
**Figure 4 : Average cost depending on number of operators, €/line/month**




The effect of duplication on national price significantly depends on the size of high density areas. In countries with high average density the duplication will take place on a great surface, and its negative effect will be particularly significant.

Figure below demonstrates how the cost function changes with the number of competitors. Because of duplication, the cost of construction may become higher in dense areas than in non-dense areas. It will lead to absurd local disruptions in retail price. When 5 competitors are building their networks in parallel, the average cost of one line in dense areas is even higher than the average cost of one line in non-dense areas: €24.09 vs. €22.59.

**Figure 5. Cost as a function of density range, depending on the number of competing operators**




## 3.3 Sensitivity analysis

In this section we check the robustness of our results by varying the most significant assumptions.

### 3.3.1 Point-to-point vs. PON cost

There is no consensus on how more expensive the point-to-point network is compared to a PON network. Several studies suggest that the costs are almost the same, while others claim that point-to-point CAPEX is 40% higher than that of PON (see Annex

Annex A. Data for more details). We study how this assumption changes our results.

In the base model we have assumed that only one cost category increases in point-to-point: horizontal cost for apartment/office buildings excluding connecting buildings. It represents the greatest extra-cost when several fibre cables are installed instead of only one.

We have considered alternative scenarios, assuming that the horizontal cost excluding connecting buildings increases by 0%, 10%, 20% (as in the base case), 30% and 40%.

**Table 2. Sensitivity of average access cost with respect to extra cost of point to point horizontal network, €/line/month**

| | Additional horizontal cost in point-to-point | | | | |
|---|---|---|---|---|---|
| Nb operators | 0% | 10% | 20% | 30% | 40% |
| 1 | 14.32 | 14.83 | **15.34** | 15.85 | 16.36 |
| 2 | 18.82 | 19.49 | **20.15** | 20.82 | 21.48 |
| 3 | 19.63 | 20.30 | **20.96** | 21.63 | 22.29 |
| 4 | 20.44 | 21.11 | **21.77** | 22.44 | 23.10 |
| 5 | 21.26 | 21.92 | **22.59** | 23.25 | 23.92 |

The average access cost increases/decreases by less than €1.02 compared to the base case. The total welfare gain thanks to implementing the proposed policy compared to the current French market structure (3 operators) varies between €2,039 million and €2,277 million per year, or at maximum by 12%.

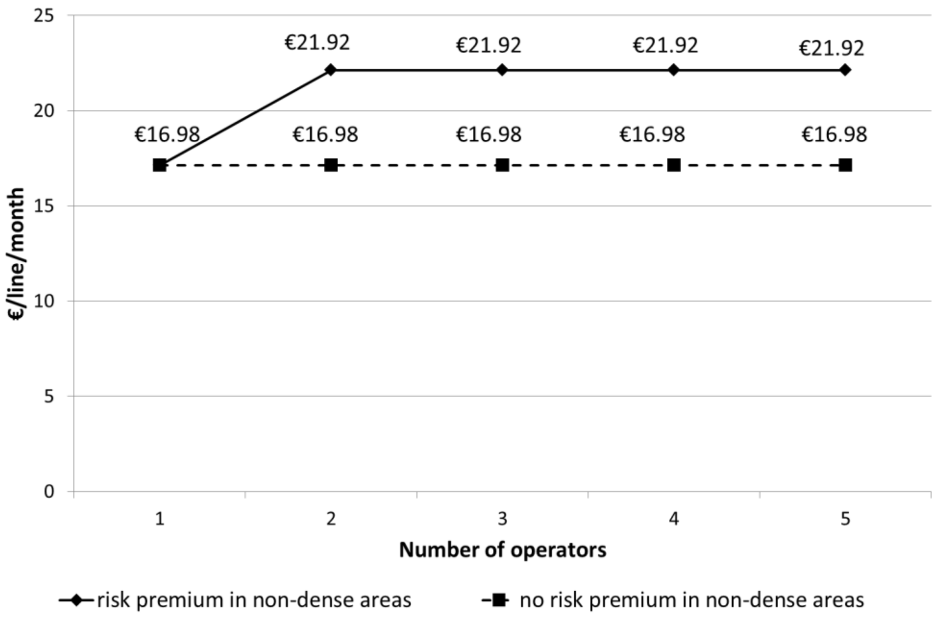
When there is no additional cost of point-to-point, the total investment in monopoly is equal to €33.4 milliard versus €36.6 milliard in the base model. The cost both in monopoly and in competition slightly decrease, the gap between monopoly and competition increases.

### 3.3.2 Risk premium

A risk premium is added to WACC in non-dense areas with potential competition. In the base model it is 5% level recommended by ARCEP 5%. In this section we estimate costs with alternative risk premium values.

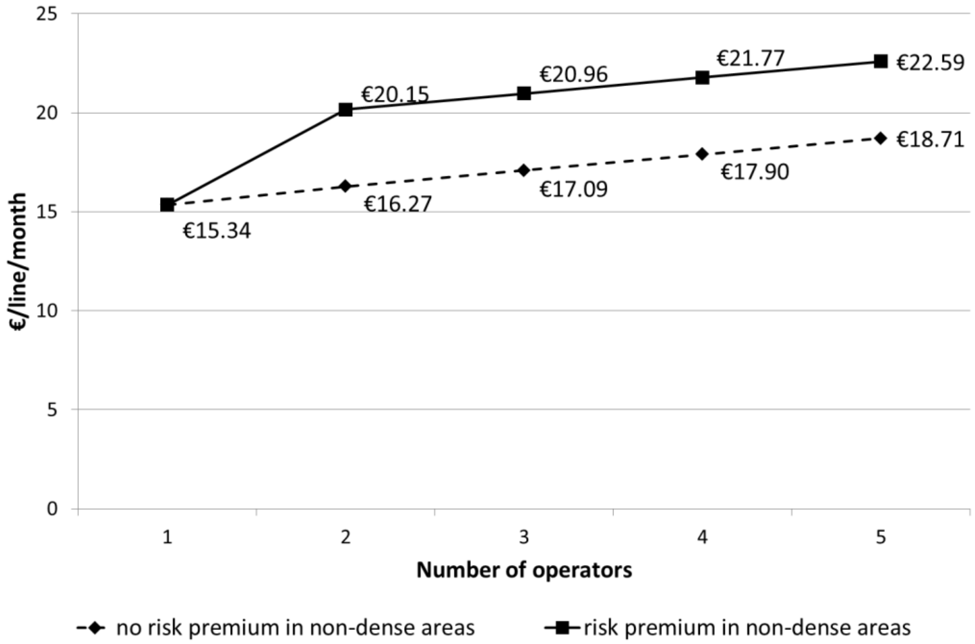
If no risk premium is granted to operators in non-dense areas, it significantly changes the access price in non-dense areas. In fact, the price becomes the same irrespective of number of operators: see **Figure 6**. The plain line corresponds to the benchmark scenario where the gap is significant between monopoly cost and duopoly cost in non-dense areas. The dotted line corresponds to the alternative scenario where the same WACC is taken for both monopoly and oligopoly.

**Figure 6 : Average cost in non-dense areas depending on the number of operators, €/line/month**



As a result, the national average price in competition is only insignificantly higher compared to monopoly: see Figure 7.

**Figure 7 : Average cost depending on the number of operators, €/line/month**




Another alternative scenario that we consider lies between our base case scenario and the extreme case of no risk premium. It includes a risk premium of 2.6% which gives a WACC of 13%. The results for all three scenarios are presented in **Table 3**.

**Table 3. Sensitivity of average access cost with respect to risk premium, €/line/month**

| | Risk premium | | |
|---|---|---|---|
| Nb operators | 0.0% | 2.6% | **5.0%** |
| 1 | 15.34 | 15.34 | **15.34** |
| 2 | 16.27 | 18.25 | **20.15** |
| 3 | 17.09 | 19.06 | **20.96** |
| 4 | 17.90 | 19.87 | **21.77** |
| 5 | 18.71 | 20.69 | **22.59** |

A higher WACC increases the average access cost in competition.

# 4 Discussion of implementing the proposed policy

There exist different ways to implement the regulation principles that we propose. It depends on specific country and zone characteristics. Regulators should think of optimal contract design in each particular case.

For a small country with homogenous tele-density characteristics it seems optimal to give the national license to a sole operator. In order to promote efficiency, this operator should be chosen based on a call for tender. The criteria of choice should include technical characteristics, construction speed and the price operator is going to charge for the unbundled access. To be able to reply to the call for tender, alternative operators should be given access to the incumbent's civil engineering. Then, a cost-oriented access to ducts and trenches should be regulated. The winner will be obliged to grant access to retail operators on the announced price level. In the case the infrastructure operator is also a service provider the wholesale division should be structurally separated from the retail division. Since the new network must cover all consumers and the access price is averaged, the operator will automatically subsidize uneconomic areas.

If, on the other hand, the national territory is large and contains zones with different density and geographical characteristics, it may be appropriate to divide the territory into administrative units and to appoint the infrastructure operator in each zone. These operators may be similar or different. The wholesale prices proposed by operators in each zone will be lower in less dense areas. As one of the objectives of the regulators is to avoid digital divide, the regulated price will be uniformed, the national price calculated as an average of each zone's prices weighted by number of potential users. Then, the question arises on how to redistribute the higher margin obtained in densely populated areas to the less populated areas. The solution is to create a common fund. This fund will be the price gap between the revenue from dense areas and the revenue that they would have obtained basing on the lower announced price. The over-profit from these areas will be transferred to infrastructure constructors in less populated areas where the average national price does not cover the cost. A similar scheme is used in the road industry in France.

Another possible design is to establish shared investment mechanism. In this case, several operators may co-invest in one network.

We have eliminated competition between copper and fibre since the old technology is switched off. But another potential source of competition is the coaxial cable technology which has a great market share and almost nationwide coverage in such countries as Belgium and Netherlands. Technical structure of cable network does not allow for unbundling that is why there is no access regulation. Even if the copper is switched off, cable will continue to represent a competitive risk for fibre. The regulator may need to set a higher fibre WACC to account for competitive risk and to maintain investment incentives in fibre. The competing cable network may also have positive effects by pushing fibre operators to raise efficiency of their active equipment.

The policy will need to be supplemented with protection of low-income customers: those customers who use only telephone service should be subsidized, so that the price they pay does not increase with transmission to fibre.

## 5 Conclusion

We have proposed a policy of fibre network regulation that should be adopted at the early stage of transition from old generation to new generation technology. It consists in appointing only one fibre network operator in each zone, and granting access to this network on a cost-based, nationally averaged price. The copper access needs to be deactivated once fibre is built. If necessary, a national fund needs to be created to redistribute over-profit from economic areas to uneconomic areas.

We have compared our proposed policy to the market structure that is being established in France. We find that the current policy adopted by ARCEP will lead to the access price of €17.26 per line per month in dense areas versus €9.63 per line per month for our proposed policy. The total gain in costs is for the national territory is equal to €179 million per month, or 27% saving.

As was shown in section 4, our general recommendations can be implemented in practice in different ways. National-level studies need to be conducted with the objective of determining the best way to implement the policy in each national context.

# 6 References:


1. Atkinson, Robert. Market Structure for Ultrabroadband. *Communications and strategies.* Special issue, November 2008

2. Basque, Denis, Laurent Benzoni and Anh Tuc Nguyen. From copper to fibre: an optimal regulatory policy. *The Journal of Regulation,* June 2011

3. Bourreau, Marc, Carlo Cambini and Pinar Dogan. Access Pricing, Competition, and Incentives to Migrate From “Old” to “New” Technology. *HKS Working Paper No. RWP11-029*

4. Brito, Duarte and Pereira, Pedro and Vareda, João. Can two-part tariffs promote efficient investment on next generation networks? *International Journal of Industrial Organization,* vol. 28, #3, pp.323-333, 2010

5. Gavosto, Andrea, Guido Ponte and Carla Scaglioni. Investment in Next Generation Networks and the Role of Regulation: A Real Option Approach. *SSRN eLibrary.* 2007

6. Lebourges, Marc. Competition via Investment and Efficient Model for FTTH Rollout. *Communications & Strategies* n°78, 2nd quarter 2010

7. Nitsche, Rainer and Lars Wiethaus. Access Regulation and Investment in Next Generation Networks: A Ranking of Regulatory Regimes. *ESMT Working paper* No. 09–003. 2009

8. Soria, Bruno and Félix Hernández-Gil. Do NGAN Economics Allow for Network Competition? *Communications and strategies.* No. 78 - New business models for Next Generation Access 2nd Quarter 2010

# 7 Annex

## Annex A. Data

We describe the data used in the model on fibre local loop parameters in France and its sources.

### Network data

The following data on future network configuration is available:

- total number of lines – 32 million lines (Source : Notice explicative de l'outil de simulation de la tarification du génie civil de boucle locale en conduite de France Télécom - May 2010)
- number of meters of sewage used by the network

### Geographic data

The geographic data was collected by Geocible, a firm specialised in geomarketing. For each municipality, the following data was available:

- Number of households in each municipality,
- Number of one-off houses,
- Number of apartment/office buildings,
- The surface of housing areas,
- Number of kilometres of routes inside housing areas,
- Number of kilometres of routes outside housing areas, leading to isolated buildings.

### Cost data

<u>Investment costs of different network elements</u> were provided by Bouygues Telecom, a French telecommunications operator:

- Cost of ODF building and of different ODF components;
- Elements of horizontal cost for apartment/office buildings: subduct, cable, splicing, welding, reflectometry tests;
- Elements of horizontal cost for isolated buildings: poles and cables;
- Element of vertical cost;
- Cost of connecting flats/offices within building and of one-off houses.

Cable maintenance cost is estimated as 3% of CAPEX.

According to ARCEP's decision 05-0834, common costs are equal to 5.78% of other costs. This decision concerns the costs of a copper network, but parameters may serve to approximate the fibre network costs.

The data on WACC value and assets lifetime, which are necessary to calculate depreciation, are based on ARCEP's recommendations. ARCEP's decision 05-0834 fixes a lifetime of 25 years for local loop assets.

The base WACC is equal to 10.4% as recommended by ARCEP in its decision 2010-001 for the fixed telecommunications activities of France Telecom.

ARCEP in its decision n° 2009-1106 recommends to allow for a risk premium in non-dense areas where potential entry is possible. Recommended by ARCEP WACC level is 15%.[1] A German study published on the Bundesnetzagentur website (German telecommunications regulator) proposes to use a risk premium of 2.59%.[2] We take a 5% risk premium corresponding to WACC=15.4%.

Duplication. We consider that multifibre is 30% more expensive than monofibre. This assumption is based on the cost data of the existing operators published in Annex 2 of « l'Offre de référence SFR d'accès aux immeubles FTTH V 1.0 – 18/02/2010 » and Annex 1- Prix of « Offre d'accès à la partie terminale des lignes de communication électroniques à très haut débit en fibre optique de France Télécom ».

Additional technology cost. There is no consensus on the cost of point-to-point technology compared to PON. Several studies mention that these costs are close.[3] Others claim that the additional investment is in in the range of 10-25%. For example, according to WIK[4], P2P FTTH architecture requires less than 10% additional investment than the PON architecture; the result is based on

[1] ARCEP. Décision se prononçant sur une demande de règlement de différend opposant les sociétés Bouygues Telecom et France Télécom. Décision n° 2010-1232 en date du 16 novembre 2010

[2] Richard Stehle. Wissenschaftliches Gutachten zur Ermittlung des kalkulatorischen Zinssatzes, der den spezifischen Risiken des Breitbandausbaus Rechnung trägt. 24 Nov. 2010

[3] See for example Allied Telesis. FTTx Solutions for Service Providers. 2009 and Metro Ethernet Forum "FTTH - Understanding which market scenarios are best served by active Ethernet point-to-point (EP2P) and which are best served by point-to-multipoint PON architectures" and IDATE Digiworld summit. FTTx economics: conditions for profitability.

[4] WIK-Consult. Study for the European Competitive Telecommunication Association (ECTA). The Economics of Next Generation Access - Final Report. September 10, 2008

modelling for a hypothetical European country. Kulkarni, El-Sayed, Gagen and Polonsky (2008)[5] find that in a dense urban area PON provides a CAPEX saving of about 20% compared to P2P (P2P was 25% more expensive than PON). A the same time, the OPEX modelling results show a saving of 55-60% for GPON compared to P2P, mainly due to civil works rental but also to additional expense on maintenance. According to a study by Analysis Maison, in the UK CAPEX in PON is 18% higher than in point-to-point.[6] Some authors claim that the cost gap is significant. From the data published by Axione (2010)[7], it can be deduced that additional CAPEX of deploying point-to-point network is of 40%.

In our base case, we take an average estimate of 20% of additional cost applied to the horizontal cost since it mostly this cost that increases in point-to-point architecture.

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[5] Samrat Kulkarni, Mohamed El-Sayed, Paul Gagen, Beth Polonsky « FTTH network economics: Key parameters impacting technology decisions » Telecommunications Network Strategy and Planning Symposium, 2008. Networks 2008. The 13th International, pp. 1-27, 2008

[6] Analysis Maison. Final report for the Broadband Stakeholder Group. The costs of deploying fibre-based next-generation broadband infrastructure. 8 September 2008

[7] Axione. Etude comparée de la mise en œuvre des architectures PON et point-à-point. 1 April 2010

## Annex B. Detailed model description

First, we explain how the network cost is calculated for PON technology and without duplication. Then, how this cost is calculated for point-to-point technology. Finally, we explain how the same cost is calculated with duplication.

### Calculating costs for PON technology

The costs were calculated for each of 36,000 municipalities in France, and then the sum was taken to calculate the total cost.

The cost groups are considered in the following order:

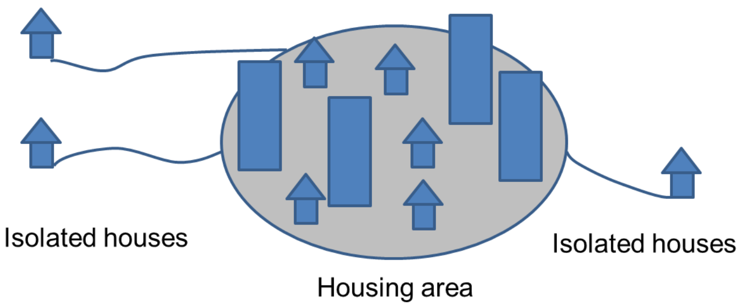
- CAPEX: annualized costs of deployment;
- OPEX: operating costs;
- the part of common network costs allocated to local loop unbundling service.

CAPEX

Hereby we explain how each cost category of CAPEX was calculated.

The territory of each community is divided between housing area – highly populated area, for example, a town centre – and isolated houses – those that are detached from housing area.

**Figure 8. Buildings classification according to their location**

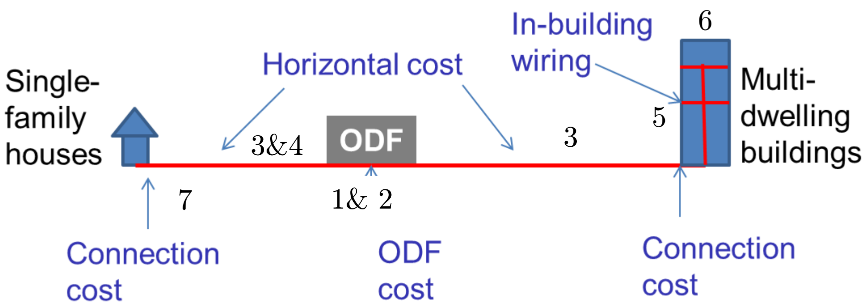



According to their characteristics, two types of buildings are considered:

- apartment/office building (multi-dwelling units) with several floors which host multiple households or firms and are necessarily situated in housing areas,
- one-off buildings.

The following scheme shows where each cost driver is situated in the network

**Figure 9. Cost drivers' position in the network**




| # | Cost category | Calculation |
|---|---|---|
| | | ODF |
| 1 | ODF accommodation cost | To calculate the total surface of buildings that are needed for ODF, we multiply the total number of lines by surface needed per line (2 m² per 1,000 lines in PON). The cost includes buying and preparation of the building. The unit price is equal to €7,500/m$^2$ in Paris and €5,500/m$^2$ in other municipalities. The unit cost of equipping is €2,570/m$^2$. |
| 2 | ODF equipment cost | ODF splitter: a splitter allows to join together 8 lines. So, the number of couplers that are needed is calculated as the total number of fibre lines divided by 8. The unit cost of a coupler including buying and installing is equal to €120.<br>Optical rack:<br>• Splicing: one drawer may contain 144 fibre lines (2 drawers per transport cable). The cost per drawer is €1,491.<br>• Splitters: each splitter may contain 64 fibre lines. The cost per drawer is €1,748.<br>• pigtails (a cable fitted with a connector at one end and bare fibre at the other. The non-connectorised end ('the pigtail') is intended to be permanently attached to a component or terminal.)<br>Bays. For each municipality, the number of ODFs needed to connect subscribers is calculated taking 10,000 subscribers per ODF outside Paris and 20,000 subscribers in Paris. Fibre lines are grouped in cables containing 288 fibre lines in PON. Based on this number of fibre lines arriving to each ODF, it is possible to deduce the number of fibre cables arriving to each ODF. For each cable, a bay should be installed. The unit price of a bay is €1,723.<br>Cost of connecting in ODF. For each transport cable identified above, a connection cost is added. This cost is €3,628/cable. |
| | | Horizontal cost |
| 3 | Horizontal cost (study, supply and laying) for housing areas including cost of connecting buildings (civil engineering) | This cost includes multiple cost items :<br>• For transport network (near ODF)<br>o Cost of laying of subduct €6/m/line<br>o Cost of cable and of their laying €8/m/line<br>o Costs of big splicing box (used to connect cables |

| | | |
|---|---|---|
| | | between themselves): €2,600/box<br>▪ The number of boxes is calculated as the product of number of ODFs and the number of transport cables in ODF<br>o Cost of small splicing box €29.7/box<br>▪ There is one small splicing box per 12 fibre lines<br>o Cost of welding €2,016 per 288 fibre lines<br>o Cost of reflectometry tests on fibre, €16.7/fibre<br>• For distribution network (near buildings)<br>o Cost of laying of sub-duct €6/m/line<br>o Cost of cables and their laying €3/m/line<br>o Cost of splicing box: €399/box<br>o Cost of welding €21 per 48 fibre lines.<br>• For the network connecting buildings<br>o Cost of laying distribution cables (12 fibre) at €3/m/line<br><br>The cost of connecting is equal to €1,500 per multi-dwelling building and €520 per single-family house (labour force for building civil engineering). |
| 4 | Horizontal cost (study, supply and laying) for isolated buildings | Outside the housing areas, fibre is installed on poles. It is supposed that operators install its own poles which cost €9.08 per meter of cable including installation (decomposed in €3.50 for cables and €5.58 for poles). |
| In-building wiring and connection | | |
| 5 | Vertical cost | The vertical cost concerns only multi-dwelling units and includes two elements.<br>1. Cost of deploying at the building entry<br>For each municipality, the number of multi-dwelling buildings is multiplied by the average distance between the entry to the building and the in-building box estimated at 20 m per building. This distance is multiplied by unit cost of supplying and pulling the fibre cable (12 fibre) 2.8 €/m.<br>2. Vertical cost proper<br>The cost corresponds to the cost of deploying fibre in rise pipe of a building. It is supposed that all firms are situated in multi-dwelling buildings. For each French municipality, the total number of firms and households in multi-dwelling buildings is calculated. The cost of deploying in rise pipe was calculated based on<br>The cost function of rise pipe per subscriber is calculated based on data supplied by Bouygues Telecom on municipalities of Roubaix, |

| | | |
|---|---|---|
| | | Villeurbanne and Paris.<br>The cost function allows to calculate the vertical cost for each municipality depending on the number of subscribers per building. |
| 6 | Cost of connecting flats/offices within building | The cost of connecting a flat in multi-dwelling building is €200 (half of this cost is already included in vertical cost). |
| 7 | Cost of connecting clients in single-family houses | The cost of connecting a single-family house is €200. |

The depreciation method is such that payment is stable over the years. Capital cost is calculated with WACC=10.40%.

OPEX

| Cost category | | Calculation |
|---|---|---|
| Cable maintenance | | 3% of CAPEX. This proportion holds for copper and in practice may become even lower for fibre since the latter is less sensible to bad weather |
| Civil engineering rental | Ducts rental | To deploy underground fibre lines and connect multi-flat buildings, the ducts of France Telecom are used. The corresponding rental price is calculated as the number of lines that are not served by sewage, multiplied by the rental price per line, which decreases with density |
| | Sewage rental | In Paris, Neuilly and Levallois, sewage is used to pose fibre. The corresponding rental payment is calculated as the total number of meters of sewage used multiplied by price per meter |

Common costs

The cost is equal to 5.78% of all the other costs (annuity, cable maintenance and civil engineering rental).

### Calculating costs in monopoly (point-to-point technology)

The total cost is divided by the total number of lines to get the average cost of premises connected.

The technology used is point-to-point.

CAPEX

| # | Cost category | Calculation |
|---|---|---|
| | ODF | |
| 1 | ODF accomodation cost | Same as in PON |

| | | |
|---|---|---|
| 2 | ODF equipment cost | Same as in PON |
| | Horizontal cost | |
| 3 | Horizontal cost (study, supply and laying) for housing areas including cost of connecting buildings | Includes two subcategories:<br>• connection cost is the same as in PON technology<br>• remaining costs are constituted mainly of cable costs and need to be increased by 20% in point-to-point technology because of a greater cable capacity |
| 4 | Horizontal cost (study, supply and laying) for isolated buildings | Includes two subcategories:<br>• pole price is the same as in PON<br>• cable price is increased by 20% because of a greater cable capacity |
| | In-building wiring and connection | |
| 5 | Vertical cost | Same as in PON |
| 6 | Cost of connecting flats/offices within multi-dwelling building | Same as in PON |
| 7 | Cost of connecting clients in single-family houses | Same as in PON |

Capital cost is calculated with WACC=10.40%.

OPEX

| Cost category | | Calculation |
|---|---|---|
| Cable maintenance | | Same as in PON |
| Civil engineering rental | Ducts rental | Same as in PON |
| | Sewage rental | Same as in PON |

Common costs

The cost is the same as in PON.

### Calculating cost in competition (PON technology in dense areas and point-to-point technology in non-dense areas)

We suppose that several providers are operating in dense areas. That is why certain infrastructure elements are duplicated and the corresponding costs must be multiplied by competitors' number. We suppose that the infrastructure is doubled in all the dense areas, so that there is competition for every customer. The technology used in non-dense areas is point-to-point, the same as in the monopoly model, in order to allow for a simpler unbundled access. The technology used in non-dense areas is GPON since there is no need for unbundled access.

To calculate the average, the total cost, CAPEX plus OPEX, is divided by the total number of lines.

<u>CAPEX</u>

| # | Cost category | Calculation |
|---|---|---|
| | | ODF |
| 1 | ODF accommodation cost | The cost is equal to<br>- the monopoly cost multiplied by the number of operators in dense areas<br>- the monopoly cost in non-dense areas |
| 2 | ODF equipment cost | The cost is equal to<br>- the monopoly cost multiplied by the number of operators in dense areas;<br>- the monopoly cost in non-dense areas |
| | | Horizontal cost |
| 3 | Horizontal cost (study, supply and laying) for housing area including cost of connecting buildings | This cost is divided into two subcategories – connection cost and the rest – which are treated differently.<br>The cost is equal to<br>- the monopoly cost multiplied by the number of operators and corrected for technology (PON 20% less expensive than Pt to Pt) in dense areas;<br>- the monopoly cost in non-dense areas. |
| 4 | Horizontal cost (study, supply and laying) for isolated buildings | The cost is the same as in monopoly |
| | | In-building wiring and connection |
| 5 | Vertical cost | The monopoly cost is increased by 30% to account for multifibre |
| 6 | Cost of connecting flats/offices within multi-dwelling building | The monopoly cost is increased by 15% to account for multifibre |
| 7 | Cost of connecting clients in single-family houses | The cost is the same as in monopoly |

In dense areas, the following costs increase proportionally to the number of operators:

- ODF accommodation cost,
- ODF equipment cost,
- horizontal cost.

Costs that increase compared to the sole network because of the need to deploy multi-fibre in dense areas:

- cost of vertical network,
- connecting flats within building.

Costs that become lower thanks to using PON instead of point-to-point technology in dense areas:

- horizontal cost (study, supply and laying) for housing area excluding cost of connecting buildings
- horizontal cost (study, supply and laying) for isolated buildings – cable costs only

The capital cost is calculated with WACC=10.40% in dense areas and WACC=15.40% in non-dense areas.

OPEX

| Cost category | | Calculation |
|---|---|---|
| Cable maintenance | | The cost is equal to<br>- the monopoly cost multiplied by the number of operators in dense areas;<br>- the monopoly cost in non-dense areas |
| Civil engineering rental | Ducts rental | The cost is the same as in monopoly |
| | Sewage rental | The cost is multiplied by the number of operators |

Common costs

These costs are the same as in monopoly.

## Annex C. Detailed results tables for the base case

### Table 4. Cost variation in dense areas, €/line/month

| | | Cumulated number of lines, mln | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Nb operators | Average cost | 1.87 | 2.49 | 3.18 | 3.74 | 4.32 | 5.02 | 5.51 | 6.38 | 6.98 |
| 1 | **9.64** | 6.61 | 9.26 | 9.57 | 10.24 | 10.54 | 10.51 | 10.79 | 11.16 | 11.80 |
| 2 | **13.87** | 9.60 | 13.11 | 13.66 | 14.83 | 15.71 | 15.30 | 15.78 | 16.25 | 17.32 |
| 3 | **17.28** | 11.78 | 16.25 | 17.07 | 18.92 | 20.41 | 19.62 | 20.41 | 20.96 | 22.66 |
| 4 | **20.68** | 13.95 | 19.40 | 20.47 | 23.01 | 25.11 | 23.94 | 25.05 | 25.66 | 28.01 |
| 5 | **24.09** | 16.13 | 22.54 | 23.88 | 27.10 | 29.81 | 28.25 | 29.68 | 30.36 | 33.35 |

### Table 5. Cost variation in non-dense areas, €/line/month

| | | Cumulated number of lines, mln | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nb operators | Average cost | 7.67 | 8.32 | 8.96 | 9.59 | 10.20 | 10.87 | 11.51 | 12.16 | 12.80 | 13.44 | 14.07 | 14.72 | 15.36 |
| 1 | **17.13** | 11.91 | 12.00 | 12.22 | 12.20 | 12.39 | 12.60 | 12.64 | 12.26 | 12.41 | 14.11 | 14.21 | 14.42 | 13.72 |
| 2-5 | **22.12** | 15.68 | 15.77 | 16.06 | 16.02 | 16.31 | 16.59 | 16.65 | 16.12 | 16.34 | 18.37 | 18.51 | 18.80 | 17.84 |
| | | 16.00 | 16.64 | 17.28 | 17.92 | 18.56 | 19.19 | 19.84 | 20.48 | 21.11 | 21.76 | 22.39 | 23.04 | 23.68 |
| | | 14.32 | 14.83 | 14.02 | 14.34 | 14.75 | 14.80 | 15.79 | 15.62 | 15.69 | 15.72 | 17.54 | 17.95 | 18.02 |
| | | 18.65 | 19.38 | 18.26 | 18.69 | 19.25 | 19.36 | 20.69 | 20.45 | 20.54 | 20.59 | 22.50 | 23.06 | 23.16 |
| | | 24.32 | 24.96 | 25.59 | 26.24 | 26.88 | 27.52 | 28.16 | 28.80 | 29.44 | 30.08 | 30.72 | 31.36 | 32.00 |
| | | 18.02 | 18.14 | 18.64 | 18.69 | 18.78 | 18.91 | 22.75 | 23.08 | 23.08 | 24.49 | 25.34 | 28.01 | 34.30 |
| | | 23.16 | 23.32 | 23.99 | 24.06 | 24.20 | 24.36 | 28.54 | 28.99 | 28.96 | 30.91 | 32.06 | 35.71 | 44.30 |

### Table 6. Annual cost of fibre network, € million/year

| | Regulated | Competition (nb of operators) | | | |
|---|---|---|---|---|---|
| | monopoly | 2 | 3 | 4 | 5 |
| Annual depreciation+capital cost | 4164 | 5867 | 6118 | 6369 | 6620 |
| Cable maintenance | 232 | 273 | 314 | 355 | 396 |
| Civil engineering rental | 1173 | 1176 | 1178 | 1181 | 1183 |
| Common cost | 322 | 423 | 440 | 457 | 474 |
| **Total cost** | **5891** | **7738** | **8050** | **8361** | **8673** |