# The evolution of fixed access networks in Belgium: the road to Fibre to the Home, an economic assessment.

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## Abstract

An optical fibre based access network offers of all available technologies by far the highest speed and can support an unlimited set of services. Its capacity outperforms that of the other fixed networks, but the costs associated with the rollout of an all-optical access network still remain challenging. This paper evaluates the feasibility of an optical access network covering the Belgian market. Several rollout scenarios have been evaluated and the most interesting results are presented.

## Introduction

Optical fibres are now omnipresent in Wide Area Networks (WANs) and Metropolitan Area Networks (MANs), providing a backbone with enormous bandwidth capacity. Most broadband access networks, however, still rely on either twisted pair (Digital Subscriber Line or DSL) or coaxial cable (Hybrid Fibre Coax or HFC networks), thus having much smaller bandwidths. At the end of 2005, in Belgium, there was a market share of 65% for DSL (mainly deployed by the former telephone monopolist Belgacom), and 35% for cable (main operator is Telenet, only operating in Dutch-speaking Belgium) (see Figure 1). Optical access networks, on the other hand, can offer bandwidths that are much higher than the old technologies and can therefore support an enormous variety of services simultaneously: video on demand, two-way videoconferencing, interactive gaming and IP telephony, to name a few.

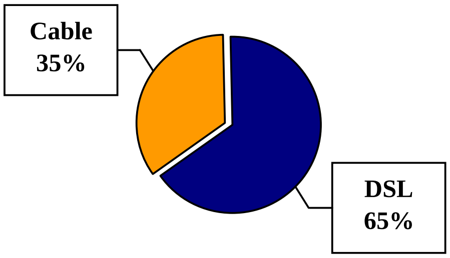


**Figure 1: Broadband in Belgium [1]**

Currently, telecommunication companies are adapting their networks for triple play, the combination of Internet, TV and telephone services distributed over the same network. This network convergence leads to a substantial increase in bandwidth demand. At the moment, the existing access networks are not capable to sustain this increase and consequently remain the bottleneck. This is often referred to as the 'last mile' problem.

Using optical fibre in the access seems to be the logical next step. One can distinguish between several implementations, differing in the extent to which the optical fibre is deployed: with Fibre To The Home (FTTH) or Fibre To The Building (FTTB), the fibre reaches the user's house or building; Fibre To The Curb (FTTC) brings the fibre to a service node near the user. Several other FTTx acronyms exist to designate often-similar implementations. Combinations of optical access networks with traditional copper or cable networks or wireless networks make up intermediate solutions. There is no universal solution for the access, rather several more or less suitable options depending on the situation.

Traditionally, an optical fibre access network was not realistic due to the very high installation and equipment costs. However, cost erosion of the end equipment and new rollout techniques can make FTTx a feasible option in certain cases. FTTH and FTTB still require enormous investments, whereas FTTC seems to be a more economical solution.

In this paper, we will evaluate several rollout scenarios for FTTx in Belgium. Two different approaches are considered to deal with this problem. Firstly, there is the *evolutionary* approach. This gradually addresses the problem by updating the technological standards and slowly introducing more fibre in the access network. The other solution, the *revolutionary* approach, consists of building a new FTTH network. An all-optical network completely replaces the existing DSL or HFC networks, hence solving the bottleneck. Finally, we will also investigate the influence of different rollout parameters to make an optimal decision.

## Updating the Network

### *A. Evolutionary approach*

As already mentioned, a DSL network provides digital data transmission over the twisted pair (TP) copper wires of a traditional telephone network (Plain Old Telephone Service or POTS). These copper wires have a high attenuation and so there is a trade-off between copper length and bandwidth. Shortening the TP creates the possibility to introduce new DSL technologies with increased bit rates. Table 1 shows the downstream (DS) and upstream (US) bit rates together with the maximum TP length of several types of Asynchronous DSL (ADSL) and

Very high speed DSL (VDSL) standards. Decreasing the copper length also means the fibre comes closer to the user. This is already a first step in deploying optical fibre in the access network. With e.g. VDSL2, the maximum copper length measures less than 300m.

| Standard | Bit rate [Mbps] | | Max. TP length |
|---|---|---|---|
| | DS | US | |
| ADSL | 8 | 1 | 3.5 km |
| ADSL2 | 12 | 1 | 3 km |
| ADSL2+ | 24 | 1 | 1.5 km |
| VDSL | 6.5 | 1.2 | 1.5 km |
| | 13 | 13 | 1 km |
| | 26 | 3.2 | |
| | 26 | 26 | 300 m |
| | 55 | 15 | |
| VDSL2 | 100 | 100 | < 300 m |

**Table 1: DSL standards [2],[3]**

HFC networks evolved out of the original TV distribution networks and combine optical fibre with coaxial cable. An optical connection arrives in an optical node that feeds one service area (SA) with a shared coaxial network. The number of homes passed within the same SA is generally around 1100. Increasing the capacity requires reducing the SAs, thus increasing the number of optical nodes, and hence increasing the amount of fibre in the network. Data-Over-Cable Service Interface Specifications (DOCSIS) is the standard technology used by most cable operators to transmit data over a HFC network, and Table 2 shows the bit rates of the different DOCSIS standards. The combination of smaller SAs and new standards makes this network capable of offering triple play services in the near future.

| Standard | Bit rate [Mbps] (shared) | |
|---|---|---|
| | DS | US |
| DOCSIS 1.0/1.1 | 42-56 | 10 |
| DOCSIS 2.0 | 42-56 | 31 |
| DOCSIS 3.0 | 180 | 120 |

**Table 2: DOCSIS standards (HFC networks) [4]**

Both, DSL and HFC networks can be upgraded by bringing fibre closer to the users, and so increasing the bit rates of the current access networks. We indicate such a gradual rollout as an evolutionary approach.

### *B. Revolutionary approach*

Instead of a slow evolution towards FTTH, the revolutionary approach corresponds to a fast transformation. The new optical network will be future proof and has no capacity problems anymore. Optical components have reached a competitive price and the operational costs are lower than both DSL and HFC networks. Before being able to enjoy these advantages, network operators will have to invest a lot to build the infrastructure. Remark that the main costs will be the digging costs to replace the cables.

## Economic Model

An economic model has been developed to calculate and analyse the costs for updating the network, and this for both approaches. To compare these approaches while considering the two currently used access networks, this model will be applied to four different rollout scenarios.

### *A. Model*

Figure 2 shows the general structure of the economic model. The total digging and component costs, specified for different areas, can be calculated to obtain the CAPEX (Capital Expenditures) value. Together with the OPEX (Operational Expenditures), this results in the total cost. However, OPEX costs are not taken into consideration in the used model. Every considered scenario will result in the same FTTH network, which means only the intermediate steps will be different. To compare the scenarios, the difference in OPEX costs between the considered rollout options will have a very limited influence, which makes this simplification acceptable.

To make a correct cost analysis, the time value of money has also to be taken into account. Money received today is more valuable than money received in the future by the amount of interest that can be earned on this money. This results in the discounted total cost of the project [5]. By applying a cost based pricing method, we can calculate an extra monthly fee per customer that is necessary to finance the investments. For this purpose, the discounted total cost has to be combined with the duration of the project and the potential customer base. Both the discounted total cost and the extra monthly fee will be two important decision variables when evaluating the network upgrade.

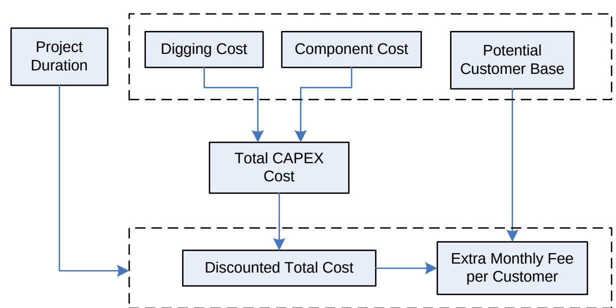


**Figure 2: General overview of the used economic model**

### *B. Scenarios*

The economic model will be used to evaluate four different rollout scenarios. The evolutionary and revolutionary approaches are both related to the two current access networks (DSL and HFC network). Table 3 shows a complete overview of the four rollout scenarios. In scenario 1, the cost is calculated to directly install a FTTH network starting from an ADSL network, while in scenario 2 there are two intermediate steps, in particular two VDSL network upgrades with a maximum copper length of respectively 1000m and 300m. Scenario 3 is analogue as scenario 1, but starts from the current cable network. In scenario 4, an intermediate cable network consisting of smaller SAs and using the DOCSIS 3.0 standard is considered.

| Scenario | Approach | Access network | Evolution |
|---|---|---|---|
| 1 | revolutionary | DSL | ADSL → FTTH |
| 2 | evolutionary | DSL | ADSL → VDSL1000m → VDSL300m → FTTH |
| 3 | revolutionary | HFC | Cable → FTTH |
| 4 | evolutionary | HFC | Cable → smaller SAs & DOCSIS 3.0 → FTTH |

**Table 3: Overview of the four rollout scenarios**

All the scenarios will end in a complete FTTH rollout in Belgium in 2020. The evolution of the network upgrades will follow penetration predictions based on the Gompertz model [6] (Formula 1), which is very suitable for technology adoption. The *b* parameter governs the rate of adoption which varies by technology and the *a* parameter gives the inflection point (see Figure 3).

$$y(t) = e^{-e^{-b(t-a)}} \quad \textbf{(Formula 1)}$$

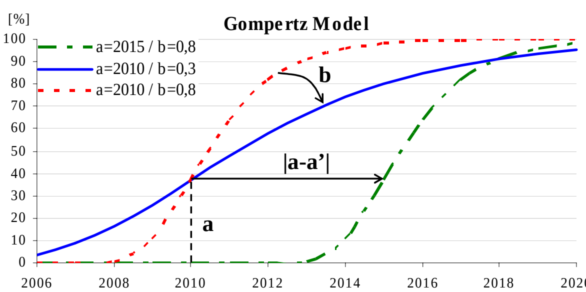


**Figure 3: Illustration of Gompertz parameters *a* and *b***

Finally, every scenario will be split into a rural, suburban and urban area (see Table 4). All calculations and results are then related to a specific area. So, it will be possible to investigate an arbitrary part of Belgium when one knows the population density or to compare some specific situations.

| Area | Population density [pop/km$^2$] |
|---|---|
| rural | <400 |
| suburban | 400-1000 |
| urban | >1000 |

**Table 4: Relation between area and population density**

**Input Parameters**

The input parameters from the economic model are discussed in more detail, and some general values that will be used further on are given.

*A. Digging Cost*

The digging costs include all costs to replace the old cabling by optical fibre. A first important factor to calculate the digging costs is the length of the cabling. For the copper wires, we based our study on the average copper distances in Belgium, and for the coax cables, we have used detailed maps from the main cable operator in Belgium, Telenet.

We have supposed that the new optical fibres exactly replace the old cabling, this means on the same place and installed in the same manner (underground/aboveground). To install a new optical fibre, there are several possibilities: the fibre can be buried directly, pulled in conduit/duct (both underground), or strung aerially (aboveground). The digging costs are dependent on the installation manner, and the underground digging costs in particular also vary between the different areas.

*B. Component Cost*

It is important to remark that the current component costs will decrease with increasing production volumes. To model this cost erosion, we use the extended learning curve model [7], which is an expression for cost versus time (Formula 2).

$$P(t) = P(0)\left[ n_r(0)^{-1}.\left(1 + e^{\left\{ \ln[n_r(0)^{-1} - 1] - \left[\frac{2.\ln 9}{\Delta T}\right].t \right\}}\right)^{-1} \right]^{\log_2 K} \quad \textbf{(Formula 2)}$$

The parameters in the extended learning curve model are defined by:

- *P(0)* the production cost in the reference year 0,
- $n_r(0)$ the relative accumulated volume in year 0,
- $\Delta T$ the time for the accumulated volume to grow from 10 % to 90 %,
- *K* the learning curve coefficient.

We will only consider two different parameter sets: one for the electrical components and one for the optical ones (see Table 5 and Figure 4).

| | $n_r(0)$ | $\Delta T$ | $K$ |
|---|---|---|---|
| Electronic | 0.1 | 10 | 0.9 |
| Optical | 0.01 | 8 | 0.8 |

**Table 5: Parameters in extended learning curve model**

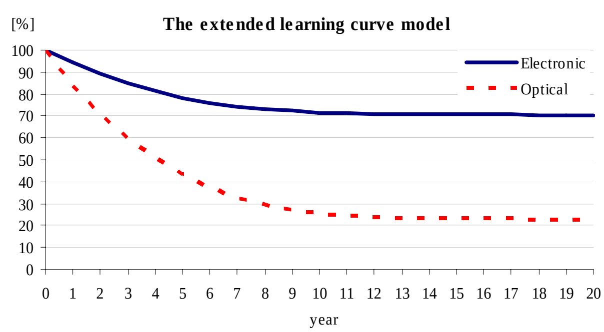


**Figure 4: Illustration of extended learning curve model**

*C. Potential Customer Base*

The potential customer base is derived from the penetration rate according to the Gompertz model, mentioned above. We indicate the total number of homes connected to the network (i.e. total number of homes multiplied with the penetration rate) by the term homes passed (HP). There will be made a distinction between the different geographical areas, e.g. the introduction of a new technology will be introduced earlier in an urban area than a rural one. This can be implemented in the model by adapting the parameters *a* and *b* in the model according to the considered area. Also for the different used technologies in scenario 2 and 4, diverse *a* and *b* parameter values are used to distinct the different phases (Table 6 and Figure 5).

| | Phase 1 | Phase 2 | FTTH |
|---|---|---|---|
| *a* | 2009 | 2012 | 2015 |
| *b* | 0.60 | 0.70 | 0.90 |

**Table 6: Example of the parameters used in the Gompertz model, Scenario 2 – Suburban**

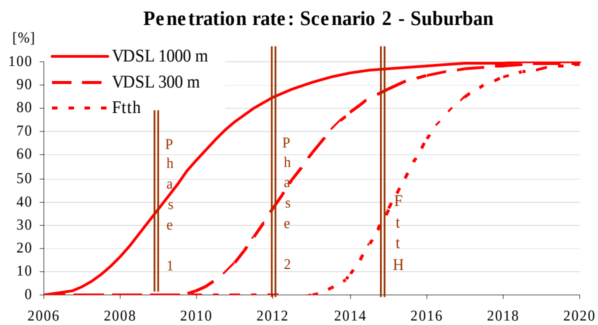


**Figure 5: Illustration of the penetration rate**

In our analysis, the commercial introduction of a new technology is determined by the inflection point, i.e. parameter *a*. From this year, an operator will offer the new technology to its customers (vertical lines on Figure 5). However, not every passed home will connect itself to the new network, and therefore we will use a certain take rate, defined as the percentage passed homes which are paying customers. Generally, the take rate is fixed on 30%, but at the end of this paper we have also varied this parameter.

*D. Project Duration*

The project duration has his influence on the distribution of the costs, and the time to get revenues. The earlier a project has to be finished, the higher the discounted costs will be and the less revenues that can be collected. Here, we have only considered revenues received before the project end date, which is fixed on 2020.

### Evaluation Parameters

To assess the feasibility of the new access network, two parameters will be evaluated: the discounted total cost of the project and an extra monthly fee required per customer.

*A. Discounted Total Cost*

The total CAPEX cost is the sum of the digging and component costs. Since we do not consider the OPEX cost, the total cost can then be equated with this total CAPEX cost. To make future costs comparable to current costs, we can calculate the discounted total cost by:

$$Discounted\ cost = \frac{C}{(1+r)^t} \qquad \textbf{(Formula 3)}$$

where:

- $C$ = future cost to be incurred,
- $r$ = discount rate,
- $t$ = number of years to be discounted.

The discount rate $r$ is fixed on 10% during the calculations.

*B. Extra Monthly Fee per Customer*

The discounted total costs will be allocated per user to calculate the extra price a customer must pay to finance the whole transition to FTTH. This value will also be dependent on the time frame that we use to refund the project, which is equated with the project duration in our calculations. We want to remark that we calculate an extra fee to finance the implementation of FTTH, which comes on top of the current DSL or cable subscription. However, from the operator side unavoidable investments to upgrade the traditional access network will disappear and from the user side one subscription to an FTTH network can replace several current subscriptions (e.g. internet access and TV distribution can now be delivered by the same triple play network).

### Results

Some general results are discussed in the next paragraphs. In the first calculations, we have used the input parameters as described above. At the end, the influence of some parameters is evaluated in more detail.

*A. (Discounted) Total Costs*

First, we will calculate the total costs of the different scenarios for the rollout of FTTH in Belgium. In Figure 6, the total CAPEX costs per year are shown.

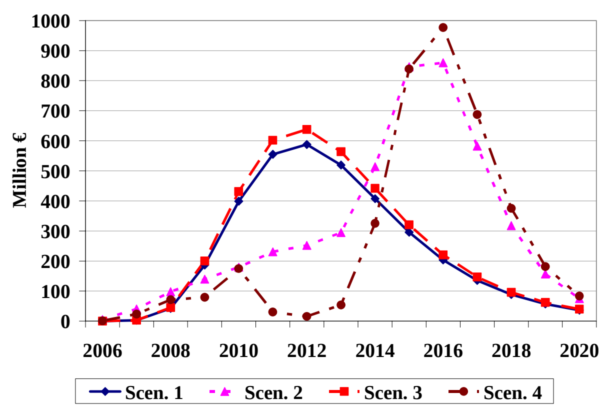


**Figure 6: Total yearly CAPEX cost of different scenarios**

As scenarios 1 and 3 suppose a direct transition to FTTH, they will show a larger investment in the first years of the considered period. The other two scenarios have intermediate steps, where extra equipment and digging costs must be considered. Scenario 1 has the lowest total cost of all as this scenario has only one step and thus requires a minimum of resources. If all costs are discounted, scenario 4 will be chosen due to delayed investments in time (Table 7).

| (M€) | Scen.1 | Scen.2 | Scen.3 | Scen.4 |
|---|---|---|---|---|
| Total cost | 3 517 | 4 589 | 3 809 | 3 918 |
| Discounted | 1 889 | 2 043 | 2 045 | 1 634 |

**Table 7: (Discounted) total cost of the different scenarios**

In the previous figures, no difference was made between the defined areas. When rolling out a new network, digging costs will play a decisive role, certainly in more rural areas. This can be seen in Table 8. In rural areas, fewer costs are spent on components as fewer homes will be passed, but this has less effect on the total cost than the digging costs.

| | Urban | Suburban | Rural |
|---|---|---|---|
| Digging costs | 100% | 164% | 343% |
| Component costs | 100% | 76% | 62% |
| Total costs | 100% | 140% | 267% |

**Table 8: Costs per area for Scenario 1**

When the diverse steps in the scenarios are considered, a clear difference in costs can be observed for introducing the different technologies. For scenarios 2 and 4, where intermediate stages are taken into account, the switch to the next phase has important repercussions depending on the regional characteristics. The last transitional phase to FTTH is always the most expensive step. In scenario 2 (Figure 7), the proportion of costs between the different phases is roughly the same, opposed to scenario 4 (Figure 8). This can be explained by the fact that in scenario 2, we assumed a fixed distance between user and optical fibre (phase I: 1000m, phase II, 300m). In scenario 4, we assumed a fixed service area per optical fibre. As service areas are smaller in rural regions than in urban areas, the cost for phase I (upgrading to DOCSIS 3.0) will be smaller.

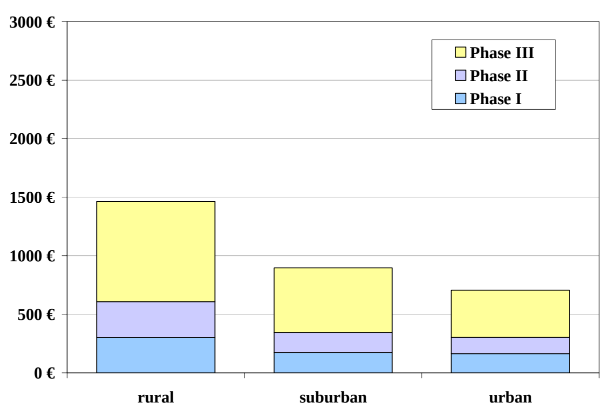


**Figure 7: Total CAPEX cost per home passed, compared per technology and area (Scen. 2)**

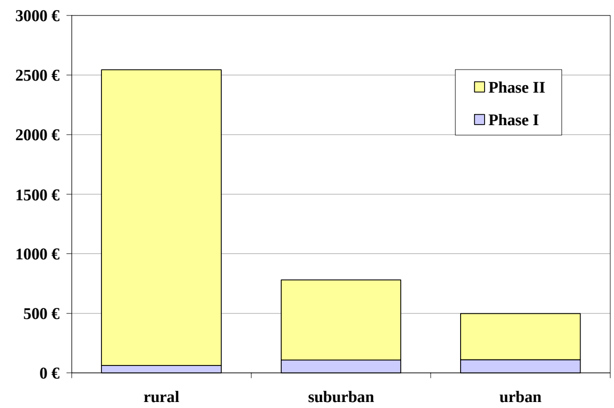


**Figure 8: Total CAPEX cost per home passed, compared per technology and area (Scen. 4)**

*B. Extra Monthly Fee per Customer*

The extra price a customer will have to pay for having FTTH can be calculated. This price will cover all costs for the network operator to rollout a FTTH network, according to the different scenarios and areas. We assumed that an extra monthly fee per customer of 20 € is the threshold for being acceptable. When all areas are taken into account, it is not feasible to make a rollout. When rural areas are excluded, costs are decreasing fast as digging costs are declining. Even when only urban areas are considered, this will not yet be viable (Table 9).

| Monthly fee (€) | Scen.1 | Scen.2 | Scen.3 | Scen.4 |
|---|---|---|---|---|
| All areas | 41.1 | 35.6 | 43.7 | 32.2 |
| Suburban + urban | 28.6 | 26.9 | 31.6 | 25.1 |
| Urban | 24.1 | 24.6 | 25.0 | 20.8 |

**Table 9: Extra monthly fee per customer**

We could see in the previous table that the underground rollout via buried cables is very expensive. If we consider a complete aboveground roll-out (inspired by the Japanese FTTH success story [8]), we see that these scenarios will be acceptable if we only consider the urban area case (Table 10). We remark that in this case the price per month in scenario 2 is significantly higher. This can be declared by the fact that now the component costs will get the upper hand, which is very disadvantageous in scenario 2 with the two intermediate VDSL steps.

| Price/month (€) | Scen.1 | Scen.2 | Scen.3 | Scen.4 |
|---|---|---|---|---|
| Urban | 10.9 | 17.0 | 11.1 | 12.4 |

**Table 10: Aboveground roll-out in urban areas**

*C. Influence of some model parameters*

Finally, we have also made a thorough analysis of the influence of some model parameters: the Gompertz parameters and the take rate are studied in more detail.

The Gompertz parameters are controlling the introduction and penetration rate of the new technologies.

When these parameters are adapted, differences in the total cost can be observed as technology will be earlier or later introduced. In Table 11 the results can be seen for scenario 1 when parameters *a* (the infliction point) and *b* (adoption rate) are modified. The original values are: $a$ = 2010; 2011; 2012 and $b$ = 0.6; 0.5; 0.45 for respectively urban, suburban and rural rollout. The effect of decreasing parameter *a* has two opposite consequences: an increase in discounted costs as the network is rolled out at an earlier stage (decreasing feasibility), and a decrease in price per month as a faster breakthrough of FTTH will result in a larger potential customer base (increasing feasibility). Visa versa results can be found for an increase of *a*. The effects of a variation of parameter *b* is smaller than for *a*. The changes are the result of the network size at the end of the project, as a decrease of *b* will result in an unfinished network at the end of the foreseen period.

| (%) | Total cost | Discounted total cost | Extra monthly fee |
|---|---|---|---|
| $a$-2 | +5.3 | +27.3 | -4.1 |
| $a$+2 | -5.2 | -20.9 | +15.4 |
| $b$/2 | -6.9 | -4.0 | +7.8 |
| $b\times 2$ | +1.9 | +3.9 | -6.4 |

**Table 11: Influence of the Gompertz parameters *a* and *b***

Figure 9 shows the influence of the take rate on the extra monthly fee per customer. This take rate could not directly be controlled by the network operator, only by commercial campaigns for attracting new customers. As the take rate falls below the expected figure, this will have disastrous consequences for the network provider as the customer is not willing to pay much more for FTTH.

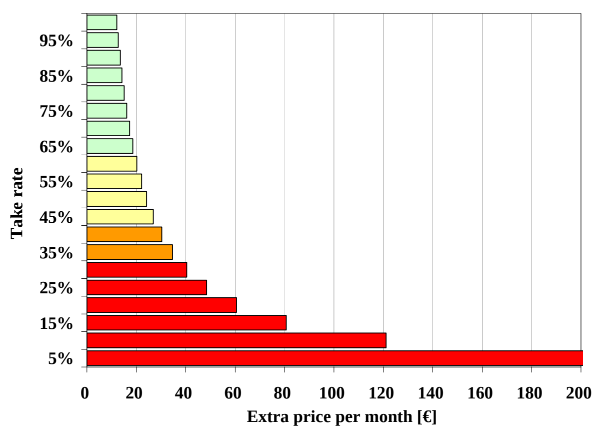


**Figure 9: Take rate vs. extra price per customer (Scen.1)**

## Conclusion

This study's aim was to make a comparison between different rollout scenarios for FTTH in Belgium, assuming a complete rollout in 2020. A complete rollout in Belgium is according to our economic model not realistic. Only if the urban area is considered, and if digging costs can be reduced, a feasible rollout can be guaranteed. Several parameters must be taken into account, e.g. the take rate as well as the possible time for introduction of the technology to make sure that the introduction of FTTH in Belgium becomes a success.

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## References

1. Point Topic: http://www.point-topic.com
2. DSL forum ,The new ADSL standards, 2003
3. V. Friedman, VDSL Technology Issues, 2000
4. CableLabs: http://www.cablelabs.com
5. S. A. Ross, R. W. Westerfield, J. F. Jaffe: Corporate Finance, McGraw-Hill, 2002
6. L.K. Vanston and R.L. Hodges, Technology forecasting for telecommunications, 2004
7. B.T. Olsen and K. Stordahl., Models for forecasting cost evolution of components and technologies, 2004
8. Yano Research Institute, FTTH market in Japan, 2005

Version: November 2006