"Value network evaluation"

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Abstract:

Within this deliverable, we combine the costs and revenues from WP5 and D6.2 to evaluate different business models and scenarios. We focus on the passive infrastructure (PIP) and active equipment (NP), as well as on the cost and consequences for providing open access. We furthermore investigate the impact of competition on the business case, and look how demand aggregation, longer planning horizons, duct reuse and flexibility options can improve the business case for both actors. Finally, we also looked into other sources of revenues, so-called indirect effects that could help to enhance the incentive to deploy for market players or increase the willingness to pay of end-customers.

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Executive Summary

This task brings costs and revenues together to evaluate the business case for the Physical Infrastructure Provider (PIP) and the Network Provider (NP). By establishing revenues models using the input from D6.2, and by dividing the total cost calculated by WP5 in between PIP and NP responsibilities, we are able to make relevant conclusions about the economic viability of the business case for these two players.

It is clear that, under normal market conditions, the business case for the PIP is almost never viable. We therefore suggest several improvements, like aggregating demand to ensure a certain take-up from the start of deployment, reusing existing ducts to lower the trenching costs, extending the planning horizon to include also the revenues in a further future, etc. These proposals lead to significant improvements in the dense urban and urban scenarios, deploying in a rural area however never works. Another option is to explore the indirect benefits of the network: the benefits for other sectors than telecom itself. Identifying these benefits and quantifying then, both from a bottom-up as well as top-down approach, can increase both the incentive for market players to deploy, or can increase the willingness to pay for end-users.

The business case for the NP is much more optimistic, that is if the cost for the Customer Premises Equipment (in-house cabling and ONT) is excluded. When assuming a high take-up for NGOA technologies (which is not unrealistic when considered that these technologies will be there only in 2020), there is a reasonable business case in the order of the €10 per customer per month that resulted from the case study revenue analysis.

Having different actors on different layers requires an open access interface. This deliverable models this open access interface on three network layers: dark fibre, wavelength and bitstream and calculates the needed costs related to equipment, management and processing, and business. Offering dark fibre open access increases the monthly fee per customer with €1.70, whereas wavelength open access will never be economically feasible because of the diseconomies of scale and bitstream open access adds €0.30 to the monthly cost per customer (but allows only competition in between SPs, not NPs).

Offering this open access interface enables the interaction between multiple players on different levels in the value chain. Using the MACTOR approach and a game theoretic model, we evaluate the objectives, power relations and strategic actions of these different market players in various settings. We can conclude that the best option for a municipal infrastructure provider is to deploy an open network, to which alternative network operators and the traditional telcos will migrate. However, real options analysis shows that if the transaction costs are above 15% of the yearly revenue, the municipal provider will suffer from a negative payoff in all cases.

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Abbreviations

3G	Third Generation
AAA	Authentication, Authorization, and Accounting
ADSL	Asymmetric DSL
ANP	Active Network Provider
AOB	Alternative Operator Board
AON	Active Optical Network
ARPU	Average Revenue Per User
ASP	Application Service Provider
ATM	Asynchronous Transfer Mode
AWG	Arrayed-Waveguide Grating
CAN	Consolidated [or Central] Access Node
CapEx	Capital Expenditures
CEO	Chief Executive Officer
CO	Cable Operator
CPE	Customer Premises Equipment
Equip	Equipment
Infra	Infrastructure
CPEV	CPE Vendor
CSP	Content Service Provider
CWDM	Coarse Wavelength Division Multiplexing
DCF	Discounted Cash Flow
DOCSIS	Data-Over-Cable Service Interface Specification
DSL	Digital Subscriber Line
DU	Dense Urban
DWDM	Dense Wavelength Division Multiplexing
EC	European Commission
EU	European Union
FTTB	Fibre-to-the-Building
FTTC	Fibre-to-the-Cabinet
FTTH	Fibre-to-the-Home
GDP	Gross Domestic Product
GIS	Geographic Information System
GNA	GlasvezelNet Amsterdam
GPON	Gigabit PON
GPRS	General Packet Radio Service
HC	Homes Connected
HC	Housing Company
HD	High Definition
HE	High-End
HFC	Hybrid Fibre Coax
HH	Household
HP	Homes Passed
HPON	Passive Hybrid WDM PON

ICT	Information and Communication Technology
IDC	International Data Corporation
IGP	Individual Fibre Pair (dutch: Individueel Glasvezel Paar)
IP	Internet Protocol
ISP	Internet Service Provider
IT	Information Technology
KPN	Koninklijke PTT Nederland (Royal Dutch Telecom)
LL	Link Level
LLU	Local Loop Unbundling
LRIC	Long Run Incremental Cost
LT	Long term
LTE	Long Term Evolution
MACTOR	Matrix of Alliances and Conflicts: Tactics, Objectives and Recommendations
Mbps	Megabits per second
MDU	Multi Dwelling Unit
MIAM	Multi-Issue Actor Model
MINP	Municipal Infrastructure and Network Provider
MIP	Municipal Infrastructure Provider
MNO	Mobile Network Operator
MPLS	Multi-Protocol Label Switching
N/A	Not available
NDM	Network Device Manufacturer
NE	Nash Equilibrium
NG AON	Next Generation AON
NGOA	Next Generation Optical Access
NP	Network Provider
NPV	Net Present Value
O	Objective
OA	Open Access
ODF	Optical Distribution Frame
OECD	Organisation for Economic Co-operation and Development
OLO	Other Licensed Operator
OLT	Optical Line Termination
ONT	Optical Network Termination
ONU	Optical Network Unit
OpEx	Operational Expenditures
OPTA	Onafhankelijke Post en Telecom Autoriteit
OSI	Open System Interconnection
P2MP	Point-to-MultiPoint
P2P	Point-to-Point
PA	Public Authority
PCP	Physical Connection Point
PDA	Personal Digital Assistant
PIC	Photonic Integrated Circuit
PIP	Physical Infrastructure Provider

PON	Passive Optical Network
PoP	Point of Presence
PPP	Public Private Partnership
PTS	Post and Telecom Agency Sweden
PVC	Permanent Virtual Connection
QoE	Quality of Experience
QoS	Quality of Service
Reg.	Regulator
RGW	Residential Gateway
ROA	Real Option Analysis
ROI	Return On Investment
ROT	Real Option Theory
RU	Rural
SCB	Statistical Bureau of Sweden
SDSL	Symmetric Digital Subscriber Line
SDU	Single Dwelling Unit
SEK	Swedish krona
Serv. Prov.	Service Provisioning
SME	Small and Medium Enterprises
SMP	Significant Market Power
SP	Service Provider
ST	Short term
TCE	Transaction Cost Economics
TCO	Total Cost of Ownership
TDMA	Time Division Multiple Access
Telco	Telecommunication Operator
TG	Technology Giants
UDWDM	Ultra Dense WDM
UR	Urban
VAT	Value Added Tax
VDSL	Very-high bit-rate DSL
VLAN	Virtual Local Area Network
VoD	Video on Demand
VPN	Virtual Private Network
VVA	Vergoeding voor Abonnement - Fee for Subscription
WACC	Weighted Average Cost of Capital
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WR + FF	Feeder Fibre WR WDM PON variant
WR + WSS	Wavelength Selective Switch WR WDM PON variant
WR WDM PON	Wavelength Routed WDM PON
WS WDM PON	Wavelength Selected WDM PON
WSS	Wavelength-Selective Switch

1. Introduction

It is clear that the next big step in fixed telecom market is the upgrading of the current networks to all-fibre networks. This deployment of fibre goes hand-in-hand with the search for new business models in which multiple actors cooperate to deliver the network that is too expensive to deploy on their own, and with the development of new technological solutions, both on passive as well as active optical networks, that help in better exploiting the virtually unlimited speed of the fibre cables. Based on the expected costs (from WP5) and revenues (see D6.2), a quantitative evaluation and comparison of the proposed business models and value networks (see D6.1) was performed and documented in this D6.3. Different cases, taking into account penetration of existing broadband and/or multimedia services, economies of scale, technological solutions, etc. will be evaluated. An evaluation will be done for all key actors making use of a multi-actor analysis. Finally, competition and strategic decisions will be considered.

1.1 Research objectives

The goal of this document is to provide the reader with more insight on the profitability and economic impact of the business case for a FTTH (Fibre-to-the-Home) deployment, while focusing on the different actors (physical infrastructure provider, PIP, and network provider, NP) involved. Different scenarios will be evaluated, so that a good overview of the different geographical, demographical and economic situations in Europe can be achieved.

The following list of specific research questions will be answered:

- From the total cost of the system (calculated in WP5), how much is paid for by the PIP, how much falls under the responsibility of the NP?
- How much revenues are needed per customer in different scenarios for the PIP to have a positive business case? How much revenues are needed per customer in different scenarios for the NP to have a positive business case? How much should the NP pay the PIP? How much should the SP pay the NP?
- What is the impact of economic decision parameters, like the WACC (Weighted Average cost of Capital)?
- How could the business case for the PIP and the NP be improved? What is the impact of start penetration? What is the impact of the demand profile?
- Is there a case for infrastructure competition (i.e. multiple PIPs)? Is there a case for competition on the network layer?
- How can you offer open access on top of the PIP layer, and how much will this cost? How can you offer open access on top of the NP layer, and how much will this cost?
- What is the impact of churn?
- What are the power relations in between the different players in the field?
- How can flexibility throughout the planning process reduce the risk for a FTTH business case?
- What are the indirect revenues on top of the direct ones? How can they be quantified?
- How do the value networks look like in real-life cases?
- What is the impact of regional parameters?

1.2 Structure of the document

These research questions will be tackled in the following chapters:

Chapter 2 gives an overview of the different ways of opening the value chain, so that competition on NP and/or SP layer becomes feasible. Apart from describing open access on fibre, wavelength and bitstream layer qualitatively, the chapter also deals with a description of the entailed costs.

Starting from the revenue scenarios built in D6.2 [54], Chapter 3 details the revenues that will be used in this deliverable for the quantitative evaluation of the business cases for the PIP and NP.

As mentioned before, this deliverable will perform analysis for multiple scenarios, in order to cover the most important types of regions and solutions in Europe. Chapter 4.2 therefore describes the parameters and their variations.

In Chapter 4, the actual business cases are evaluated. The costs are divided in between PIP and NP, and the needed revenues for both players are evaluated for multiple scenarios. Improvements are suggested for both business cases, and the impact of open access interfaces on the costs and needed revenues is investigated.

Chapter 5 looks into competitive analysis by investigating the power relations in between the different market players using a MACTOR (Matrix of Alliances and Conflicts: Tactics, Objectives and Recommendations) approach, and by calculating Nash and Pareto equilibriums for different games, in which public and private players can opt for multiple strategies.

The flexibility and uncertainty of the NGOA (Next Generation Optical Access) deployment is studied in Chapter 6, using real options theory. A thorough introduction to the theory itself is also provided.

Another way to improve the business case, especially for public players, is to include the effects of indirect benefits, frequently also referred to as the ‘uncaptured value’ of FTTH. In Chapter 7, these effects are identified and quantified using two methods: bottom-up and top-down.

Finally, Chapter 8 concludes this deliverable.

2. Opening up the value chain

Within OASE, different business models have been identified. However, they have only been implicitly defined so far, based on figures like Figure 1. All models are constituted of three (potentially integrated) conceptual network layers: physical infrastructure, network and service layer. These conceptual network layers indicate the responsibilities taken by the different actors. The actors on these layers are typically called resp. physical infrastructure provider (PIP), network provider (NP) and service provider (SP).

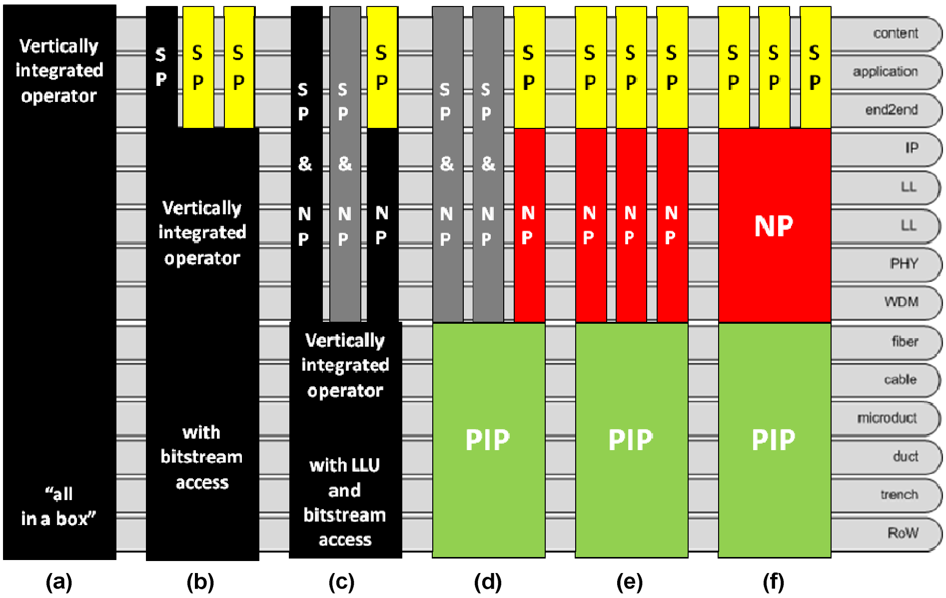


Figure 1: Conceptual business models, as described in D6.1 [57]

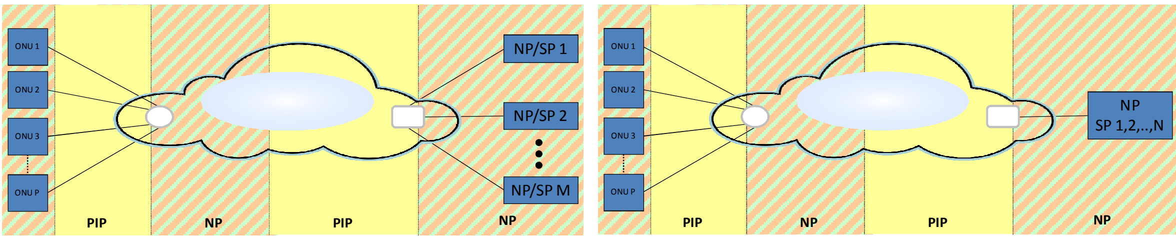
When accurately defining a business model for providing an optical access network, however, we should go into more detail and definitely consider the aspects described in the following subsections. When investigating open access models, we should look into the level at which the network is opened, which open access interface is used, and how much extra cost it entails. On the other hand, we have to consider which roles are taken up by which parties, i.e. what part of the network deployment and operations falls under the responsibility of the PIP or the NP. It should be noticed that, although we look into the possibility of having multiple SPs, a detailed cost-benefit analysis for this actor falls beyond the scope of this project. Finally, we will not evaluate the business models for all architectures, but only focus on those that fits the requirements as set up in collaboration with WP2 and WP3.

2.1 Layer at which the network is open

Opening the network at some network layer aims at allowing competition on the higher layers. We open the network at some specific network layer, we provide a "*provisioned element*" on that layer to all users of that layer (meaning actors on the layer above).

2.1.1 Mapping of conceptual layers to actual network layers

Conceptually, we can open the network either at the PIP level (allowing NP competition) and/or at the NP level (allowing SP competition), as indicated on Figure 2. In practice, however, there is a multitude of options. A mapping of the different relevant levels to the OSI (Open System Interconnection) network layers is given in Figure 2. It is important to exactly mention the provisioned element rather than only the conceptual level in order to define the business model.



(a) opening on PIP level (NP competition) **(b) opening on NP level (SP competition)**

Figure 2: Opening the network

Opening at the fibre layer means that different parallel fibres are available in the same cable / trench infrastructure, and that each NP therefore has at least one dedicated fibre to reach its customers. The provisioned element is the fibre. The network is opened at the PIP level. This model allows NP competition. The main advantage of opening at the fibre layer, is that it is technology agnostic. Its main disadvantage is the higher fibre count.

Opening at the wavelength layer means that every NP has access to one or more dedicated wavelength to reach the customers. The provisioned element is the wavelength and the model is opened at the PIP level. Note that the mapping between customers and the wavelengths required to reach them is dependent on the architectural design. In order to allow a user to connect to multiple NPs simultaneously, multiple transceivers are required. Those form the so-called provisioning interface. This model allows NP competition.

Wavelength open access is a fairly cheap and easy option (depending on technology), by installing limited extra equipment to divide the wavelengths among the NPs on the central office side, and among the end-customers on the CPE side. The main disadvantage is that this way of open access is not technology-agnostic. Dependent on the PON architecture used, different equipment should be installed, and should therefore also be replaced when switching NPs or migrating to next-generation options.

Opening at the bitstream level means that there is a provisioned element on the OSI network layer 2 (Ethernet or even TDMA) or layer 3 (MPLS, IP). Here, the network is opened at the NP level, so that SP competition is allowed. It is a limitedly complex way of providing open access (no problems arise from the co-existence of multiple operators' equipment), albeit that it only allows open access on top of the NP. It therefore only allows competition on SP layer, while the other two options allow for competition on NP layer.

Layer:	Provided element:
3 (Network Layer Open Access)	Basic network service provided e.g. IP layer service over cable to support MPLS-based VPN
2 (Data Link Layer Open Access)	Dark fibre and link-layer electronics at each end e.g. Ethernet-based VLAN, or ATM-based PVCs
1 (Physical Layer Open Access)	Dark fibre leasing Optical Layer open access (CWDM or DWDM) in PONs
0	Conduit and Collocation Facilities

Bitstream (layers 3 and 2) — Fibre & WL (layer 1)

Figure 3: Opening on different network layers and the associated provisioned elements

2.1.2 Unbundling versus open access

We distinguish between unbundling and open access based on the existence of a vertically integrated operator.

- *Unbundling* refers to the case in which a single actor is exploiting both a particular layer and the layer on top of that, while still allowing the co-existence of other actors on top of its own passive infrastructure/network (models (a), (b), (c) in Figure 1).
- *Open access* refers to the situation in which the lower layer is provisioned in a non-discriminatory way to different actors on the layer above (model (d), (e), (f) in Figure 1). This is typically the situation in a newly deployed network where split responsibilities can be one of the objectives from the start. The main difference with unbundling is that the actor responsible for the lower layer does not act in the layers above. For example, unbundling on the bitstream level means that the actor offering the connectivity at the network layer, the NP (potentially integrated with the actor on the physical layer, the PIP) is not offering any services at the service layer (no SP is integrated with the NP here).

Both unbundling and open access can exist on a multitude of network layers, as indicated in the previous section. The *provisioning interface* is the first point where different NPs/SPs (at least 2) are brought together on the same device (e.g. fibre cable, ODF, splitter, AWG etc). Depending on the situation, it is called the *unbundling or open access interface* respectively.

2.1.3 Number of competitors per layer

It is important to note that the providers on the different conceptual layers (PIP, NP, and SP) don't necessarily cover the same geographic areas.

If we consider the models presented in Figure 1 to reflect the situation in a single geographic area, situation (e) would represents a situation in which case a single building is connected by three different NPs on top of a single PIP, so that there is true competition for this customer on NP level. In order to support fibre open access, this would require sufficient spare fibre being deployed, and there must be a PIP that is willing and able to allow access to its fibre network. Note that a multi-fibre infrastructure is needed if you have two NPs competing in the same geographical area. In reality, having competition on NP layer within the same geographical area is not expected, although not impossible. In Amsterdam, KPN and BBNed are both NP within the same geographical area, and in France, there is a law that obliges the PIP to deploy multiple fibres to every building.

This is a fundamentally different situation from the case where multiple NPs are active on top of a single PIP but they don't connect the same buildings or are even geographically totally split. The easiest way to represent this situation is to use model (f) in Figure 1. This corresponds to the model deployed by Stokab (Stockholm).

2.2 Business and operational requirements from the different actors

The responsibilities on the three conceptual layers indicated above (PIP, NP, SP) are in practice taken up by different kinds of actors (see Annex A for a description of real-life case studies). These actors differ in their background, knowledge and objectives. Where a PIP can be seen as a real infrastructure provider (very similar to a provider of another type of utility networks like gas, water of even roads), an NP is an actual telecom player with a background as an incumbent or new entrant in the telecom domain, specific telecom knowledge and working on shorter timeframes (5 to 10 years rather 20 of more years for the PIP).

2.2.1 Specific NP and PIP requirements

Typical requirements from the perspective of the NP include the following. The first two requirements (multi-NP support and inter-NP isolation) can be considered strict requirements as they will be required by any NP in the field. The last one (no master NP) is strict in an open access scenario, however, in an unbundled scenario, the unbundled operator would naturally take up this role of master NP, so that here this requirement is not existing.

- *Multi NP support.* Multiple NPs per network and even network area should be possible, so that each end-user choose between different NP. However, once the choice is made, the end user will be connected to that one NP, until the contract ends and a new NP is selected. This means that there is a limited set of NPs offering network connectivity in a certain area (from the existing networks studied – Annex A – we see that the maximum number of NPs is about 3 to 5) and that an end-user can freely choose between them. Note that this requirement only holds for the open access schemes that allow for multiple NPs, i.e. the fibre and wavelength layer. Since bitstream open access only allows for competition on Sp layer, the requirement doesn't hold there.
- *Inter NP isolation.* A rogue ONU (a misbehaving ONU – deliberate or not) should not be able to effect the service of any other customer of a different NP. This means that while hybrid ONUs that affect other ONUs in the same NP domain are allowed, ONUs that effect ONUs of other NPs are not. This is a strong requirement that was confirmed when talking to AOB members, with long experience in multi-operator open networks.
- *No master NP*. A dedicated NP (which would otherwise become a kind of 'master NP') should not take up any coordination activities. If there is a need for coordination player this function should not lie with one of several NPs offering service in the same area, it should rather be taken up by the PIP (or another independent third party). In an open access scenario, this fact was also supported by a discussion with AOB members, due to the consequent loss of credibility of the open access network being open to all under fair and non-discriminatory conditions. In an unbundling scenario, there should definitely be a coordinating rule set in place. This rule set needs to be defined between all players within one dedicated area. This agreement should include all relevant technical (incl. e.g. resource allocation), process related as well as business aspects / interfaces required for providing services to the customers. In the best case, there is a basic framework already defined by a public authority.

From the perspective of the PIP, on the other hand, there is typically the intention to remain *technology agnostic*, which is perfectly in-line with the PIP character being an infrastructure provider. However, in some case this might be conflicting with the NP requirement not to have a master NP, for instance in the case of WDM-PON (which is currently out of favour among e.g. our AOB (Alternative Operator Board) members on the ground that it implies maintenance of WDM equipment for the PIP). When the provisioning interface (unbundling/open access interface) is owned by the PIP to maintain neutrality to NP/SPs, the PIP may become technology-specific over some or all of its infrastructure.

2.2.2 Resulting actor responsibilities

In D5.3 techno-economic studies, the total cost of ownership of FTTH architectures is classified into 5 categories according to actor responsibilities. For more details and a concrete overview of the entire cost classification, we refer to the TONIC tool itself.

- Network Provider costs (NP) include any active equipment in the CAN and remote node, such as OLT, reach extenders, Ethernet switches, etc. Optical fibre distribution frames for system connections are also considered as part of NP cost.
- PIP Infrastructure (PIP Infra) includes fibre cables, ducts, installation, trenching, etc.
- PIP Equipment (PIP Equip) mainly covers passive components such as power splitters, wavelength splitters, fibre patching, distribution and cross-connect frames (ODF), etc.
- CPE infrastructure (CPE Infra) refers to the cost of in-house and in-building cabling, optical sockets and their installation. It is listed as an individual category because a separate actor (e.g. housing corporations) can be responsible to take the cost of this part.
- CPE Equipment (CPE Equip) includes the ONT cost as well as its installation, which end-users are partly responsible for.

2.3 Short-listed architectures

D3.3 describes a multitude of different architectures in support of the open access business model. Especially on wavelength open access there are many different architectural solutions possible. In D2.2 and D6.4, the list of requirements as seen in chapter 2.2.1 has been concluded.

The last requirement on - *There should be a coordinating rule set in place* - leads to two different types of PIP, a transparent and an opaque. The difference between the two is that the opaque PIP includes optical devices (e.g. splitters, AWGs, and WSSs) in its physical infrastructure. This puts requirements on the architectures that want to utilize the PIP's services.

The second requirement - *inter NP isolation* – impacts mainly the PON type architectures by a higher dependency on optical devices with higher isolation, like AWGs, WSSs, and inter leaver filters.

Bitstream open access can be accomplished over all architectures, but in order to meet both fibre rich and poor scenarios, only two will be selected, one for each option.

All architectures described in WP3 were evaluated on the criteria described above (see section 7 in D3.3), and only the ones fulfilling all the requirements sufficiently, were withheld. The resulting short list of open access architectures is:

- Fibre open access (transparent PIP)
    - fibre rich
        - Green field infrastructures which maximises on fibre count
    - Point-to-point on fibre and optical level
- Wavelength open access (Opaque PIP)
    - Usually fibre poor
        - Brown field infrastructures that optimizes on fibre count
    - Includes optical devices
        - Optical devices – e.g. optical splitters, AWGs, WSSs

- Legacy installations are normally point-to-multipoint on optical level (i.e. splitter based), while new installations can be point-to-point (i.e. purely AWG or WSS based)
    - WDM PON
        - Wavelength routed (WR) WDM PON
            - AWG and multi feeder fibre based
    - Hybrid WDM PON
        - Passive hybrid WDM PON
- Bit-stream open access
    - WR WDM PON
        - A "pure" optical P2P WDM PON
            - No optical splitters for shared medium applications
    - NG AON
        - Active remote node with WDM backhauling

The following chapters will go through these in more detail but D3.3 covers this in even more depth.

2.4 Cost of open access

The goal of this chapter is to describe the impact on costs if one opens the value chain in order to stimulate competition on network and service layer. One way of describing is to identify additional cost building blocks compared to the vertically integrated case (Figure 4).

In general the costs are related to the interfaces between the real actors within the value chain of an open access business model. We distinguish between three levels of open access: bit-stream level, wavelength level and fibre level. Three different levels are related to different architectures as described in chapter 2.3.

The additional cost for open access can be split in different building blocks: equipment related cost, management related cost and business related cost (Figure 4).

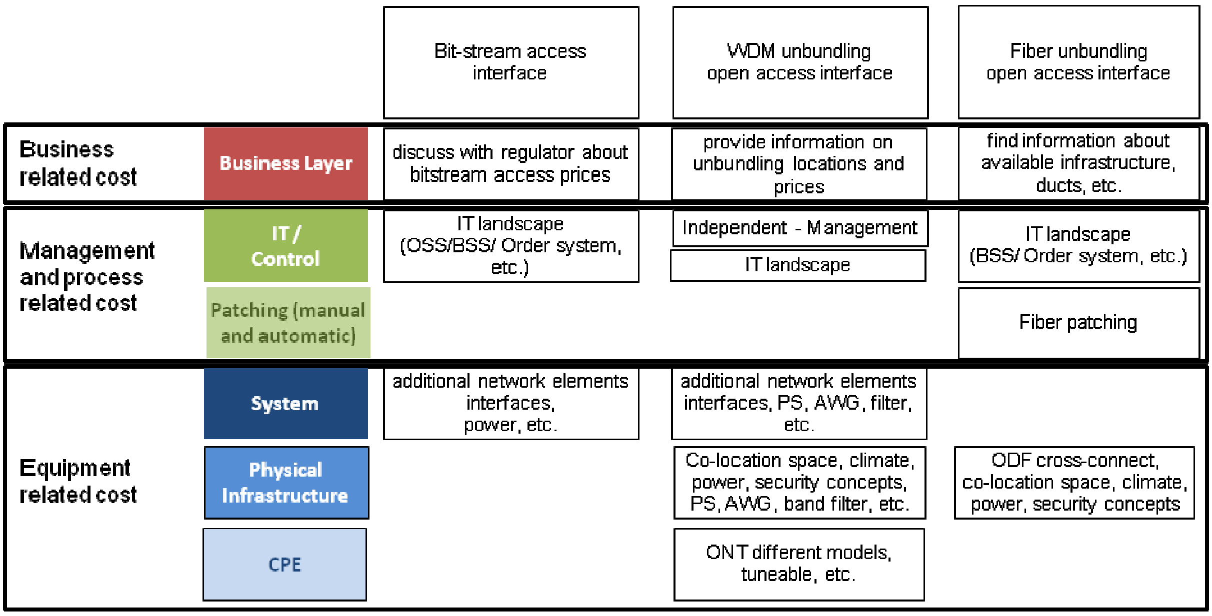


Figure 4: Open access cost building block model related to equipment, management and business (note that the wholesale perspective is considered here, see section 2.4.3)

2.4.1 Equipment related cost (differs per architecture and layer on which the network is open)

In order to provide open access, extra equipment and infrastructure should be foreseen that can connect the PIP to the different NPs in a fair, secure and transparent way. These costs should in most cases be made upfront, i.e. one should make the decision to include the open access possibility at the moment of deployment. Of course, adding the possibility later is also possible, but will inevitably entail decommissioning costs as some of the current equipment would need to be replaced.

This section will investigate what changes need to be performed on the architectural layout (we base ourselves on input from WP3), and what costs these changes would bring. As mentioned before, the costs will depend on both the layer at which the network is open and the architecture deployed. The section is therefore subdivided in three: open access on dark fibre layer, wavelength layer and bitstream open access. Although the costs for patching don't include extra equipment, they are described in this section, because they depend on the architecture under study, and are therefore easier explained next to the right figure. Theoretically however, they belong in the section on management and process related cost (section 2.4.2).

As WP6 focuses only on the no node consolidation scenario, we will only evaluate open access possibilities for this area size. However, where the impact of the node consolidation could be significant, we will qualitatively describe it.

2.4.1.1 Scope of open access studies

All equipment described in the previous sections and especially the provisioned elements need to be physically located in one of the identified PCPs (for the definitions of the PCPs, see D3.1 [55]). Based on the applied business model and open access schemes, we can differentiate between several options.

In case of a residential offer, the residential user interface is typically located in the home (PCP2), whereas the service provider interface is in the local exchange (PCP5), central exchange (PCP6.1), aggregated central exchange site (PCP6.n) or in the core sites (PCP7), depending on the scenario. As we consider here the scenario without node consolidation, this is typically PCP5.

- In case an open access PIP will own the fibre infrastructure in the full OASE scope (PCP2 to PCP5), ensuring the PIP is technology agnostic, the network is not opened in an intermediary PCP, this is called *end-to-end open access on the fibre layer*. Actual changing of NPs will be harder in case they do not agree on using the same technology (as this would require the end users to change their equipment, see also section 4.5.1.3). The network opens up
    - At the customer side: in PCP2 (home)
    - At the network side: typically in PCP 5 (possibly 6 or 7 depending on scenario)
- In case the network is opened at the fibre level and there are different NPs, the fibre network is opened in an intermediary PCP. The unbundled part (PCP2 till PCP5) is typically owned by the unbundled actor (incumbent), this is *local loop unbundling on the fibre layer*. Here the network opens up in PCP2 (home) and PCP5 (local exchange).
- In case of *bitstream end-to-end open access*, the entire access and aggregation network (PCP2 till PCP7) is covered by the single PIP/NP. Here the network opens up in PCP 2 (home) and PCP7 (core). This is similar to the previous case, but here we have a single PIP/NP, where in the previous case we have a single PIP and potentially different NPs (covering the entire OASE scope).

- In case of *local loop unbundling on the wavelength layer*, the network opens up in PCP 2 (home) and PCP5/6 (depending on consolidation scenario). Again the fibre between PCP2 and PCP5 is owned by the unbundled actor, the provisioned element to the different NPs is the wavelength, and the provisioning interface depends on the actual architectural solution.

In case of a backhauling/business offer, the backhauling service interface can be anywhere from PCP3 to PCP 6.x depending on the scenario. In case of open access on the fibre layer, it will naturally be PCP3, PCP4 or PCP5. In case of open access on the bitstream layer (Ethernet or MPLS) it will be PCP5 or PCP6.

Note that we will not include this business offer in detail in our calculations, however, the potential additional revenues resulting from this are included in the quantified results for the PIP business case, in section 4.3.2.3.

2.4.1.2 Open access on the fibre layer

The first option for offering open access is located on the fibre layer, and the scope of fibre open access is PCP2 to PCP5 (possibly to PCP7 in case of full node consolidation). In this type of open access, each NP has control over a dedicated fibre to each of its customers. Within WP3, two possibilities for this open access were defined: a (1) mono-fibre and (2) a multi-fibre infrastructure between PCP2 and a PCP enabling access to the fibre.

In case of the multi-fibre infrastructure, there is a fibre from every NP to every customer, even if the customer is not subscribed to that NP. This option falls beyond the scope of the OASE requirements (see section 2.2), where it was defined that one customer is only subscribed to one NP at a time.

For evaluation in this deliverable, we will only work with the mono-fibre infrastructure, in which there is one dedicated fibre in between the PCP2 and the PCP enabling access (Figure 5). Based around discussion with WP5 and in lieu of their results (presented in D5.3) showing a significant increase in cost required for the necessary infrastructure at the cabinet level to provide open access, we do not consider the cabinet to be a suitable location for fibre OA. Therefore, we consider only the PCP2-PCP5 scenario within this deliverable.In case a customer wants to change NPs, the customer's fibre should be patched to the right NP's ODF. For a more in-depth discussion on the technical specifications, please refer to D3.3 [53].

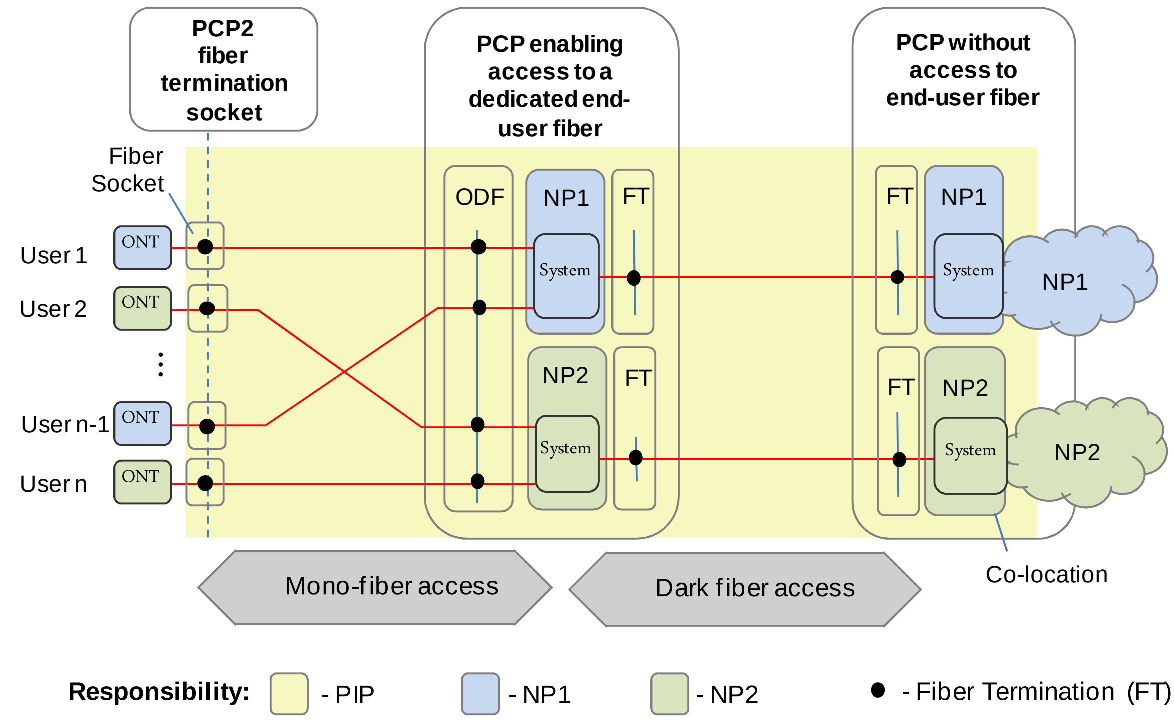


Figure 5: Schematic overview of fibre open access (mono-fibre approach)

<u>AON as reference architecture for open access on fibre layer.</u>

The most likely architecture for fibre open access is AON. The provisioning interface will be an extra ODF, whereas the provisioned element is the fibre. Figure 6 shows an example diagram of ODF model for fibre open access. The incoming fibre cable is terminated at an ODF of which the PIP has ownership. On the system side, the network equipment from different NPs is connected to their own ODFs and located at their own premises or system racks which can be only accessed by themselves. The open access interface is an extra ODF with full cross-connect function acting as a bridge between fibre termination side and system side. It is only accessible by PIP or another neutral third party, i.e. the actor that is responsible for performing the physical provisioning. This implementation secures the fibre patching activities without touching either the incoming fibre termination part or the outgoing network system side.

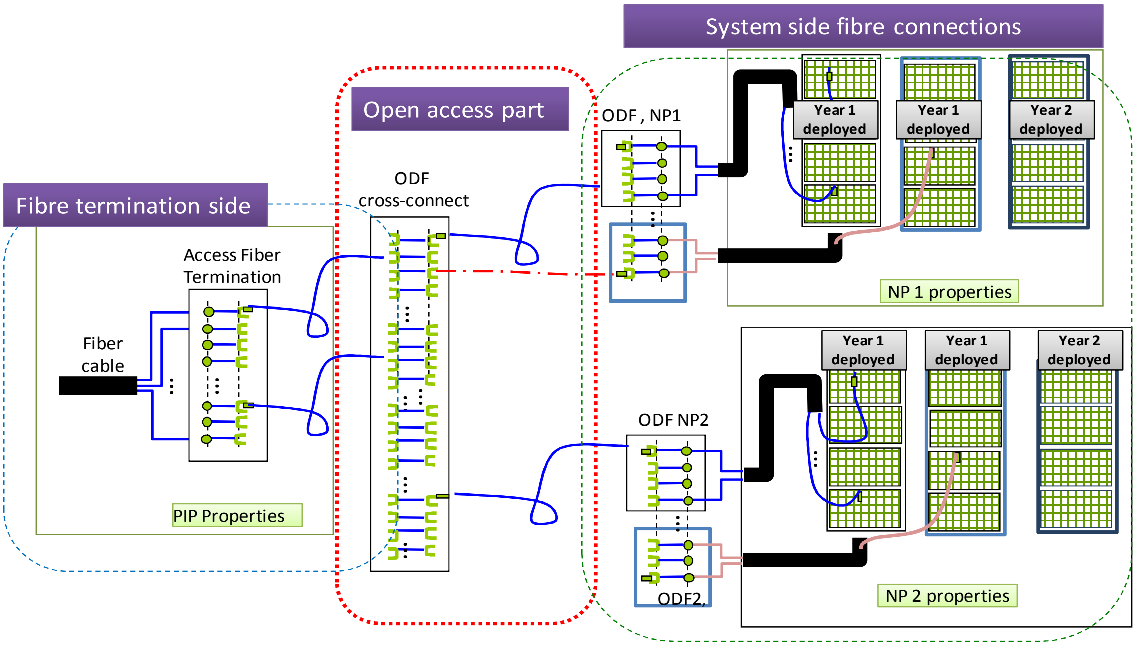


Figure 6: Overview of how to provide open access on fibre level for AON

The extra equipment that is needed is shown in Figure 7:

- A cross-connect ODF at the OLT location (PCP5 in case of no node consolidation)
- Physical patching costs for switching users from one NP to the other one. This physical patching contains the patching time, patching materials and the travelling to the right PCP.

Of course, there still are the logical patching costs required to logically connect the new or changing customers to the NP. This logical patching includes the registration of all administrative tasks and execution and testing of semi-automated tasks.

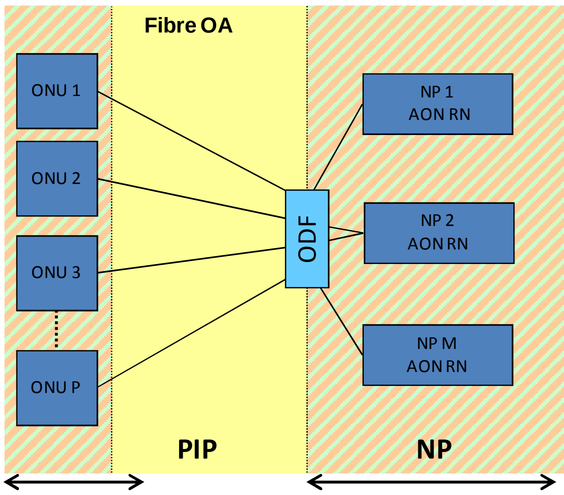


Figure 7: AON Open Access on fibre layer

The costs for this extra equipment and operational services are summarized in Table 1.

We assume a full upfront deployment of the open access infrastructure and equipment (in this case, this is only the ODF) to allow for a fair comparison with the wavelength open access case (see next section). The installation of the NP equipment itself, however, scales more linearly with the uptake of customers in the case of AON, so this advantage will still be shown in the final results (see section 4.5.1).

Table 1: Overview of costs for providing open access for AON

Location	Type	Cost	More information
PCP5	ODF	€890,000	Assuming an upfront installation of the ODF for 100% of potential customers
PCP5	patching	€100-150	Cost per patch (physical and logical), including travel, technician, patching cable, connector etc.

Impact of opening up at different PCPs

Opening up the network on the fibre layer can, in theory, be done at multiple Physical Connection Points: PCP3, PCP4 or PCP5 (for the no node consolidation scenario). In practice, however, opening up the network at PCP4 requires the placement of a cabinet with an ODF at this location as, in a P2P network, fibre is simply buried at this location. This creates a substantial increase in the cost and it is difficult to divine a benefit that may be realised through this mechanism in a P2P network. Therefore, we consider PCP5 to be the only PCP with open access potential.

The impact of the location of the open access interface on the OpEx cost of open access is however limited, and mainly depends on the number of customers that are served in that point. The patching cost is not limited to the cost for patching itself, but also includes the travel needed to go to the right PCP to perform the patch. If multiple customers can be patched at the same time, one can save a significant number of the travel times and distances, and hence also on the cost.

An example for fibre open access on AON is shown in Figure 8 (in Cost Units, as used in TONIC).

Travel / connection	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
Travel to PCP5 time /connection	0.05 Ph	0.05 Ph	0.05 Ph	0.05 Ph	0.05 Ph	0.05 Ph	0.05 Ph	0.05 Ph	0.05 Ph	0.05 Ph
Travel to PCP5 car cost and fuel consumption /conr	3.33 km	3.33 km	3.33 km	3.33 km	3.33 km	3.33 km	3.33 km	3.33 km	3.33 km	3.33 km
Travel to PCP4 time /connection	0.32 Ph	0.32 Ph	0.32 Ph	0.32 Ph	0.32 Ph	0.32 Ph	0.32 Ph	0.32 Ph	0.32 Ph	0.32 Ph
Travel to PCP4 car cost and fuel consumption /conr	4.71 km	4.71 km	4.71 km	4.71 km	4.71 km	4.71 km	4.71 km	4.71 km	4.71 km	4.71 km
Travel to PCP5 total cost (CU) /connection	0.08 CU	0.09 CU	0.09 CU	0.09 CU	0.09 CU	0.10 CU	0.10 CU	0.10 CU	0.11 CU	0.11 CU
Travel to PCP4 total cost (CU) /connection	0.45 CU	0.47 CU	0.48 CU	0.50 CU	0.51 CU	0.53 CU	0.54 CU	0.56 CU	0.57 CU	0.59 CU
Fiber patch / connection										
patching+installation (CO/CAN PCP5/6) time	0.25 Ph	0.25 Ph	0.25 Ph	0.25 Ph	0.25 Ph	0.25 Ph	0.25 Ph	0.25 Ph	0.25 Ph	0.25 Ph
patching+installation (RN PCP4) time	0.20 Ph	0.20 Ph	0.20 Ph	0.20 Ph	0.20 Ph	0.20 Ph	0.20 Ph	0.20 Ph	0.20 Ph	0.20 Ph
patching+installation (CO/CAN PCP5/6) cost	0.34 CU	0.35 CU	0.36 CU	0.37 CU	0.38 CU	0.39 CU	0.40 CU	0.41 CU	0.42 CU	0.44 CU
patching+installation (RN PCP4) cost	0.27 CU	0.28 CU	0.28 CU	0.29 CU	0.30 CU	0.31 CU	0.32 CU	0.33 CU	0.34 CU	0.35 CU
cable+connector / connection	0.13 CU	0.13 CU	0.13 CU	0.13 CU	0.13 CU	0.13 CU	0.13 CU	0.13 CU	0.13 CU	0.13 CU
patching cost PCP5	0.55	0.56	0.57	0.59	0.60	0.62	0.63	0.65	0.66	0.68
patching cost PCP4	0.85	0.87	0.90	0.92	0.94	0.97	0.99	1.02	1.04	1.07
administrative tasks	1.18	1.21	1.25	1.29	1.33	1.37	1.41	1.45	1.49	1.54
total costs patching @PCP5	**1.73**	**1.77**	**1.82**	**1.88**	**1.93**	**1.98**	**2.04**	**2.09**	**2.15**	**2.21**
total costs patching @PCP4	**2.03**	**2.09**	**2.15**	**2.21**	**2.27**	**2.33**	**2.40**	**2.47**	**2.54**	**2.61**

Figure 8: Impact of open access PCP on the cost for patching

2.4.1.3 Open access on wavelength layer

The second option for open access in between the PIP and the NP is to allocate wavelengths to the different NPs. Each end-customer can subscribe to one NP, and should therefore correctly be configured to only receive the wavelength(s) of this NP. Opening up at wavelength layer is mainly possible in passive optical networks, although it can be combined with fibre open access for AON networks. In this deliverable, we will only study the architectures that were selected based on the business requirements (see section 2.3): HPON and WR WDM PON.

Before describing these architectures and their open access options, we however need to make an important remark that clearly gives a disadvantage of wavelength open access vis-à-vis fibre open access. In case of wavelength open access, you need to know upfront how many NPs will compete on top of the passive infrastructure, since the dimensioning of the open access equipment depends on this number. In the case of open access on fibre, there is no theoretical limit on the number of NPs that can use the physical infrastructure provider: adding a new "NP-ODF" at the network system side and connecting that to the "open access ODF" is possible at any moment in time.

Passive hybrid WDM/TDM PON (HPON) as a reference architecture for open access on wavelength layer

The first architecture selected from the shortlist is Passive Hybrid Time and Wavelength Division Multiplexing PON (HPON). Here the provisioning interface is the ODF, the provisioned element is the feeder fibre.

Figure 9 represents how open access is offered. Every single NP (M in total) sends information for different customers on different wavelengths by the use of an AWG or power splitter. The information is sent on a dedicated feeder fibre per NP, using an ODF (typically in PCP6, PCP5 in the case of no node consolidation). In the AWG (typically in PCP5) the information is split per group of customers (N groups). In a following step the information is sent to all individual customers (P customers per group) using a power splitter (typically in PCP4). The customer needs to tune to the right wavelength in order to select "his" NP (tuneable ONUs are assumed). Note that, because of the use of power splitters, the requirement of inter-NP isolation cannot be guaranteed.

The choice between an AWG or power splitter at the NP termination side, should be made based on the choice between Photonic Integrated Circuit (PIC) based OLTs and tuneable OLTs. When using a PIC based OLT (that is automatically coupled to an AWG), the overall cost is cheaper, but less flexible, as the number of provided wavelengths per NP depends on the number of NPs. When considering a limited number of NPs of 3 to 5 maximum which seems to be realistic when referring to the case studies in Annex A of this deliverable), the number of wavelengths per NP would never become so low that not every NP will be able to serve every customer. However, when limiting the number of NPs to 3 to 5 maximum, there will never be a problem. We therefore opt to work with the PIC based OLT combined with the AWG at PCP5 (or PCP6). For more technical information about the use of different types of OLTs, we refer to the deliverables of WP3.

Another remark to be noted here is the impact of the node consolidation on this open access solution. In the case we are studying here (no node consolidation), PCP5 and PCP6 are collocated, so the extra costs of adding feeder fibres in between the M:N AWG and the ODF are negligible. However, if a node consolidation (from 7500 to 4000 or 1000 nodes) would be evaluated, an extra feeder fibre should be added per NP in the LL5 (i.e. the section of the network between PCP5 and PCP6), which would of course entail an additional cost, depending on the scenario under study.

Figure 9 shows the final architecture layout that will be quantitatively evaluated in WP6, so no node consolidation and using a PIC based OLT combined with an AWG at the network system side.

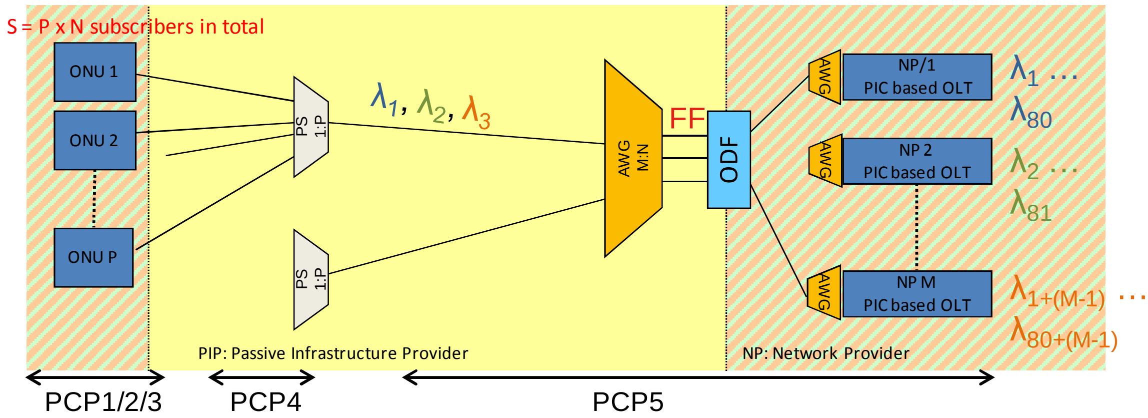


Figure 9: Schematic representation of open access on wavelength layer for HPON

The extra equipment required by a HPON architecture to offer wavelength open access can then be summarized:

- At the OLT location, an extra ODF which allows interconnecting the different NPs to the right fibre (customer) within the same cable.
- For the node consolidation scenario, each NP requires one feeder fibre. The cost of this fibre will depend on the length as well as on the cable size (not applicable for WP6 evaluation).
- At the AWG location, we will use an M:N AWG instead of the 1:N AWG, where M is the number of NPs.

Given these components and the scenario considered (e.g. dense urban area without node consolidation, and 3 concurrent NPs), the cost associated to offering open access can be evaluated as shown in the following table:

Table 2: Overview of costs for providing open access for HPON (assuming dense urban, no node consolidation and 3 NPs)

Location	Type	Cost	More information
PCP5	AWG	€3,600	3:N AWG instead 1:N AWG, 1.2* AWG (Mx1). This cost given is the increase in cost over the standard AWG.
LL5	Feeder fibre	€0	One extra feeder fibre per NP, but not applicable when PCP5 and PCP6 are collocated. = 1/3 LL5+2*splicing
PCP6	ODF	€900	An additional ODF which will have three times the number of ports as the number of AWGs.

WR WDM PON as a reference architecture for open access on wavelength layer

The second architecture to be studied in the case of wavelength open access is WR WDM PON (Wavelength Routed Wavelength Division Multiplexing Passive Optical Network). Although there are multiple options to provide open access on wavelength layer for this architecture (see also D3.3 [53]), two options were selected to be evaluated here techno-economically.

WSS based wavelength open access

In this architecture the provisioning interface is the Wavelength Selective Switch (WSS). The provisioned element is the wavelength, so that each NP disposes of a single wavelength.

Every single NP sends information for different customers on different wavelengths by the use of an AWG or power splitter. The information of all NPs (M in total) is then put together on the single feeder fibre by the WSS (typically in PCP6, which is collocated with PCP5 in case of no node consolidation). Every NP is using a part of the spectrum (some wavelengths), note that the spectrum distribution between NPs is dynamic based on the use of the WSS. The AWG at the remote node (typically PCP4) is then splitting the signal for the customers (N in total) on different fibres. In case a customer wants to change NP, the NP needs to provide the right wavelength.

The argumentation for choosing between an AWG or power splitter at the NP termination side made for HPON, holds too for this architecture. We therefore opt to work with the PIC based OLT combined with the AWG at PCP5 (or PCP6), see also Figure 10. For more technical information about the use of different types of OLTs, we refer to the deliverables of WP3.

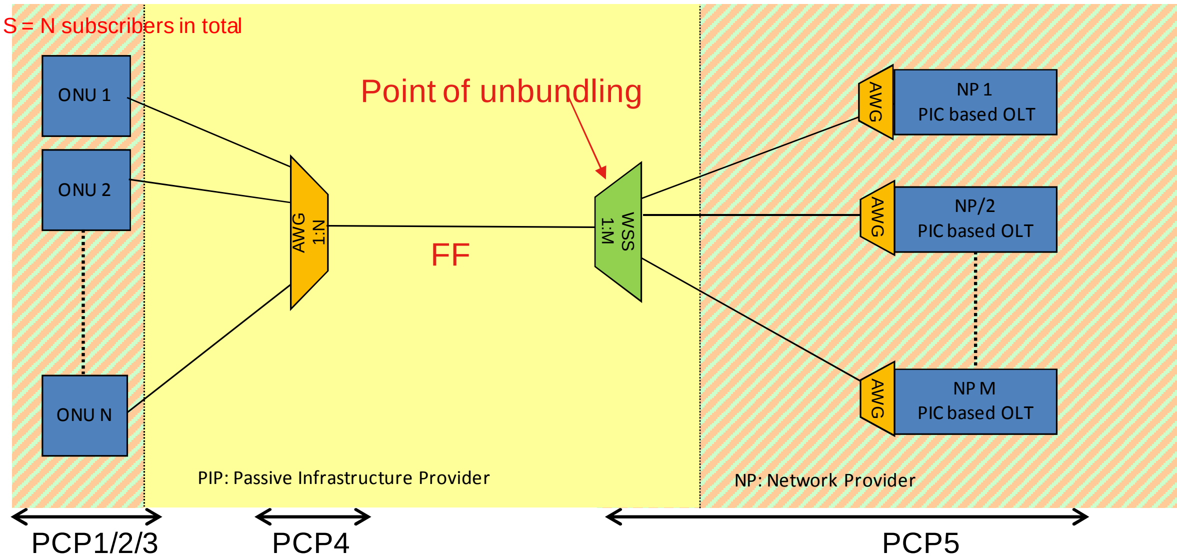


Figure 10: Schematic representation of WSS wavelength open access for WR WDM PON

The costs for this WSS wavelength open access are summarized in Table 3.

Table 3: Overview of costs for providing WSS wavelength open access for WR WDM PON

Location	Type	Cost	More information
PCP5	WSS	€2,673,510	Assuming an upfront installation of the ODF for 100% of potential customers, one customer per AWG.
PCP5	WSS Energy Cost	€13,702 per year	Utilising 2020 energy costs.
PCP5	WSS Failure Costs	€281,785 per year	
PCP5	ODF	€24,000	OA ODF Cost, needed to interconnect between NPs and the WSSes

Feeder fibre wavelength open access

This second open access solution of WR WDM PON is very similar to the HPON solution since it also requires adding LL5 fibre, adding an ODF at the OLT location and replacing the AWG splitter as shown in Figure 11.

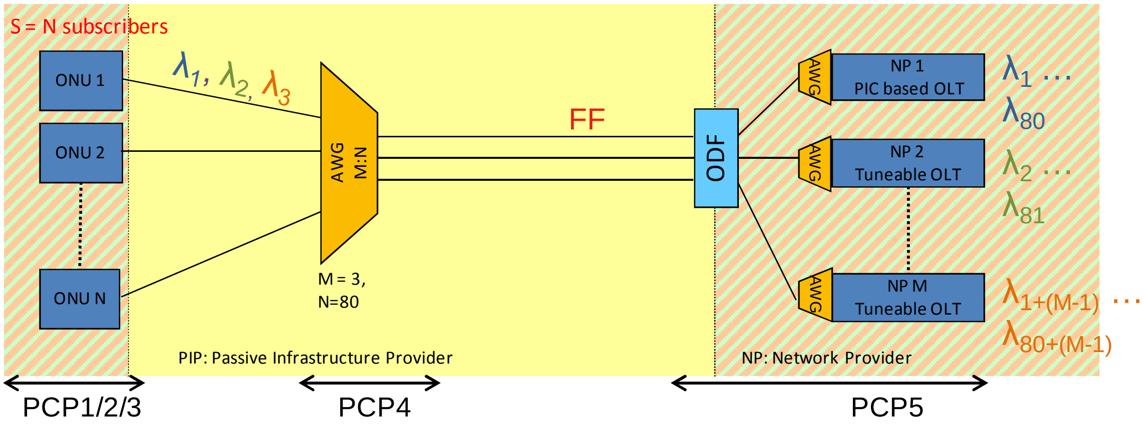


Figure 11: WR WDM PON open access with node consolidation

Hence, the cost modelling is also similar to the HPON scenario; for more details we refer the reader to the results from WP5. The actual numbers are summarized in Table 4.

Table 4: Overview of costs for providing feeder fibre based wavelength open access for WR WDM PON (assuming dense urban, no node consolidation and 3 NPs)

Location	Type	Cost	More information
PCP4	AWG	€292,320	3:N AWG instead 1:N AWG, 1.2* AWG (Mx1)
LL5	Feeder fibre	€0	One extra feeder fibre per NP, but not applicable when PCP5 and PCP6 are collocated. = 1/3 LL5+2*splicing
LL4 + LL3	Fibre	€70,800	Triple the volume of fibre to get to PCP4. This will not triple the cost due to the economies of scale in fibre cables.
PCP6	ODF	€16,000	The OA cost will triple, but there is no need to interconnect so a standard will suffice. Therefore the additional cost is twice the ODF cost.

As you can see, the reduced fan-out per AWG results in a significant increase in cost when compared to the HPON solution above.

2.4.1.4 Open access on bitstream layer

Open access on bit-stream layer is a potential mechanism for any architecture, area type and business model. The advantage is the reduced management and administration effort with the possibility of sharing infrastructure, like switches, in the highest possible manner. On the other hand, the freedom of choice in the definition of services will be limited and some features could not be supported, e.g. QoS schemes or security issues. Details about the impact on the business model are given in section 4.5.3.

The main purpose of the NP business (and open access bit stream) is the operation of a connectivity network on top of the infrastructure with an increase of isolation between service providers utilizing the shared infrastructure on an electrical forwarding level and on the control and management level (see D3.3 [53]). It provides service providers with virtual pipes between the distribution point at core, regional or local level (PCP5, 6, 7 or another peering point at the core) and the customer, represented by an ONT. From operational point of view, the NP is responsible for correct administration of the virtual pipes in the SP facing equipment and the ONT, the continuous operation of virtual pipes and the maintenance in case of failures. Here the provisioned element is bitstream access. The requirements listed in chapter 2.2.1 could be fulfilled with bitstream access depending on the architecture used and the corresponding implementation. With isolated control and management the current “black box” problem could be alleviated in bitstream open access networking where the operator of the shared infrastructure has full control over the network while the service provider usually has little insight in the state of the shared infrastructure. For example, a fully-fledged management interface could allow the dynamic and flexible support of QoS schemes and provide sufficient OAM mechanisms as well. This is subject to further studies and not detailed in D3.3.

The impact on the cost side of the NP/PIP business is two-fold. First the NP could choose an optimal technology (e.g. GPON) and therefore optimizes the roll-out of the PIP (e.g. P2MP), too. So a reduction of some percentages of cost will be possible (see section 4.4.1 and 4.4.2). Second, an interface for service providers will be required allowing the physical transport (e.g. an Ethernet interface, cross connect functionality for collocation space, power, etc. detailed in section 2.4.1.5), configuration of devices (e.g. IT interface to BSS / OSS systems see section 2.4.2) and a general business part allowing negotiation of contracts, distribution of information, billing, etc. (detailed in section 2.4.3).

Overall, one could assume that serious scaling effects exists, if a player reuses the model for NP operation and cost might reduce significantly for the business related parts, the IT parts, but not for the pure technical part except in cases with consolidation of numerous areas (but here additional costs have to be taken into account, even if they are lower compared to total installation and operation costs from several service providers). Overall, one can assume that the transaction cost part is the same for all technologies and architectures under investigation in OASE.

2.4.1.5 Additional infrastructure cost

All open access costs described in the previous sections relate to the system or the infrastructure itself. However, there are clearly other infrastructure related costs like co-location space, power and cooling, etc.

Depending on how open access is implemented, there are different requirements for floor space, power, and air-conditioning.

- Looking at the layered model with one NP, only co-location of SP equipment is needed. The NP is distributing the SP signals without the SP needing to install their equipment in different CAN locations. In principle, there is a need for one large location in which all the SP present on the network place their equipment.
- This should be compared to an unbundling situation (typical of ADSL) in which competing operators need to place equipment in each CAN that they want to reach. The co-location cost in a larger central location is difficult to model. In principle, it may be lower than in the case of a considerably large number of smaller locations in an open access.

Hence we decided to neglect any open access cost or gain for co-location, in our simplified model.

2.4.1.6 CPE cost

Open-access CPE may be more costly because customised interfaces cannot be used and termination of services from different SPs must be guaranteed. However, costs connected to change of service providers in an open access scenario have the potential to be lower than the case of an integrated provider with regulated unbundled access, for which a new CPE generally needs to be shipped to the end user.

2.4.2 Management and process related cost

The second building block in the open access cost, next to the equipment related cost, is the management related cost. One basic assumption is that all wholesale core processes (provisioning, failure and maintenance) are the same compared to the retail business of an integrated operator [61]. This includes as well all kinds of patching which are related to the provisioning process of a physical or logical connection for a bitstream product. The analysis for these patching costs depends on the architecture under study. Therefore, these costs were already described in the previous section on equipment costs (section 2.4.1).

One open cost building block would be the overall needed software and IT hardware infrastructure. This is strongly related to the size of the wholesale department for instance and the size of the operator involved especially. We did not investigate this specific topic any further, since it is difficult to receive any valid input material on it.

2.4.3 Business related cost

Based on the insights from Transaction Cost Economics (TCE) costs, the business related costs are divided in two groups – transaction costs and production costs. Transaction costs are the business related or management costs. A transaction cost is a cost related to making an economic exchange. The central claim of TCE is that transaction costs are minimized [91].

Transaction costs strongly impact the decision of a firm whether or not to vertically integrate. The costs and difficulties associated with markets transaction sometimes favour internal supply and sometimes market procurement, leading to either vertical integration or opening up the value chain.

Note that, by opening the network on some layer (fibre/wavelength/bitstream) two types of interfaces have to be considered and can be described as follows:

- **Wholesale**: One actor is offering lower layer capacity (fibre/ wavelength /bitstream) to customers on higher layers. Especially SMP operators will have to fulfil these regulatory decisions. In case of bitstream access, there exists a good example of the NGA Forum in Germany with the consensus that open access requires clearly defined interfaces and processes, in order to realise network overarching services in general [51].
- **Wholebuy**: The actor is using lower layer capacity for offering his services to broaden their product coverage in areas without own network resources on a certain layer. For him there are costs related to using (or even finding) the lower layer capacity offer.

In this work we focus on the wholesale side, as the actor offering an open access/unbundling solution will have additional costs compared to the vertically integrated situation.

2.4.3.1 Classification of transaction costs

Transaction costs have been described in economic literature by Williamson [92]. Transaction costs typically consist of 3 parts: search and information costs, bargaining costs and enforcement costs.

- **Search and information costs** are related to the amount to which the open access and unbundling process has been standardized and clearly documented. The different actors involved should be aware of the requirements of the other actors. A PIP wanting to deploy a network should ideally dispose of a database of existing infrastructure (empty ducts, available fibre deployments, etc). An NP should have a clear view on the existing interconnection points and the requirements and possibilities to deploy its own network equipment there.
- **Bargaining costs** are related to all negotiations needed in order to settle the contracts. For a new entrant this cost can be minimal in case of a regulated unbundling scenario, as it will be clear which terms to comply to. For an incumbent there might be some bargaining cost related to the discussion with the regulator about the unbundling tariffs. Negotiations on the used cost-sharing keys can be required. On another level, also negotiations with the local authorities on permit granting can be needed.
- Finally, there are the **enforcement costs** required to make sure that everything works according to the agreements made. In a standalone rollout, there is only a need to monitor the integrated player. In joint rollout, the other parties will need to be monitored as well, again increasing the transaction costs.

It is clear that these transaction costs limit the gains resulting from other cost reductions for a competitive unbundled or open access roll-out, and it is here that policy can have a large impact.

Janjua indicates that fibre deployment will make the market procurement preferable to internal supply for an NG network operator [43].

We can go one step further and consider a joint infrastructure roll-out between different utility networks (telecoms, energy, gas, water). Already, some countries push towards joint rollout by issuing regulation. More recently, the European Commission organized a public consultation on possible measures to reduce the cost of high speed communication infrastructure [27]. Here again, we observe transaction costs that should be minimized. E.g. the search transaction costs can be reduced by using integrated Geographic Information Systems (GIS), whereas a one-stop-shop for permit granting could drastically reduce bargaining costs.

2.4.3.2 Measuring transaction costs

Different authors have tried to measure transaction costs in empirical studies as the cost for locating trading partners and executing transaction [88], [6]. Alternatively, the difference between the price paid by the buyer and the remaining amount for the seller can be observed [23], [8].

Within OASE, we have tried to estimate and quantify some of the transaction costs by reviewing the structure of companies active in the open access market, and by interviewing senior managers.

The business costs identified in Figure 4 generally consist of marketing, sales, bid management, product management and information management. These costs typically range between 8% and 15% of turnover for PIP and NP. This ratio varies from case to case and depends on how open the network is. As a rule of thumb, PIPs who achieve large levels of point-to-point dark fibre lease to private businesses (hence increasing revenue, in some case by 100%) generally tend to do so by devoting larger resources to marketing and sales.

- We could then use a general model in which 10% (inline) of the NP to PIP fee is considered as transaction cost, and 20% (worst case) of the revenue from point-to-point dark fibre lease is considered transaction cost.

- Similarly, for an NP, a 10% of the SP to NP fee is considered as transaction cost, and 20% of the revenue from point-to-point bit stream connection is considered to be transaction cost.

These costs are generally higher for the SP, in which case billing is also an important component. These costs are however related to the interface with the end-user and are therefore not to be considered as transaction costs. On the other hand, interface costs towards the NP, which are indeed transaction costs, are more difficult to estimate. These would include the portion of time project managers need to devote to interface external NPs, as well as hardware and software costs for the equipment interface. We were unfortunately unable to quantify those costs. On the other hand much of this cost accrues from different NP and SP using different vendor equipment currently not built with open access applications in mind. As open access becomes more widespread, interconnectivity issues are progressively being addressed. Moreover standardisation discussion (both in terms of technical and business interfaces) is currently on-going at different forums (e.g. Open Network Forum or Stadsnätfabriken in Sweden).

- We hence propose using a simple model in which a transaction cost of 15% of SP revenue in 2020, declining to 5% in 2030.

Because of the uncertainty of the actual value of the transaction costs, they have not been included in the open access evaluation in chapter 4.5. However, their impact is studied in the work on the cost of flexibility in section 6.2.

2.5 Conclusion

Within this chapter we have studied the business impact of opening up the value chain in case of an (NG)OA offer.

Starting from the description of the three conceptual layers (physical infrastructure, network and services), we indicated the difference between open access and unbundling scenarios. The former are typically new deployments designed for allowing competition on higher layers from the start, the latter originate from vertically integrated scenarios that have been opened up because of later regulatory intervention.

Based on discussions with various actors in the field, different business and operational requirements have been identified for physical infrastructure providers as well as network providers. The OASE architectures have been benchmarked with these requirements resulting from an effort in WP3, leading to a short-list of architectures for quantitative evaluation for open access on the different layers.

Finally, the cost of open access has been described consisting of equipment related costs, management related costs and business related costs.

Actual calculation for the cost of opening up at the different layers for different considered architectures in some specific scenarios are to be found in section 4.5.

3. Direct revenue model

This chapter will focus on the direct revenues, i.e. the revenues that the service providers receive directly from the end-customers through monthly subscription fees. New business models (see Figure 1) evolve towards a vertical disintegration of the value chain into three basic roles: Service Provider – SP, Network Provider – NP and Physical Infrastructure Provider – PIP. Although paid only to the SPs, the direct revenues from the end-customers should also be used by the network and physical infrastructure providers as a return for their upfront investment and operational expenditures. This chapter will describe the total revenue potential, as well some estimates about the revenue potentials for the different layers (SP, NP and PIP).

3.1 Total revenue potential from the end-user for offering broadband connectivity

The following figure shows the model building blocks to quantify the 4 direct revenue scenarios for modelling the total direct revenue flow for the PIP and the NP in the timeframe 2011-2030.

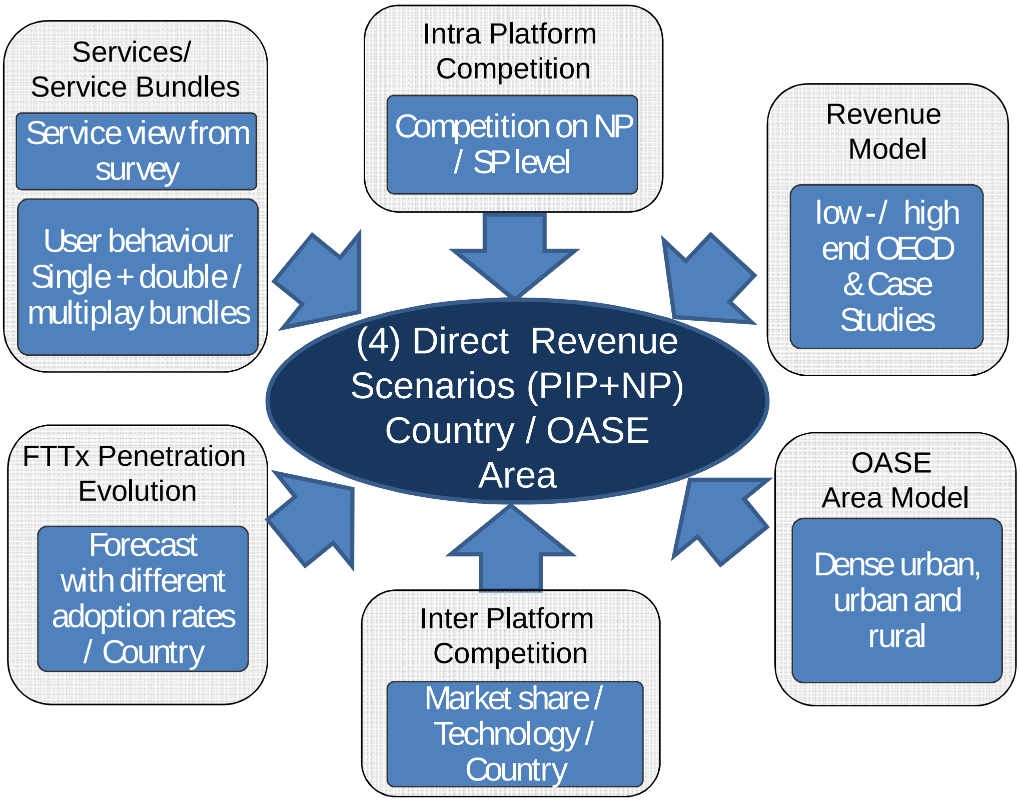


Figure 12: Direct revenue building block model

In D6.2 ([54]) 4 FTTx direct revenue scenarios have been defined based on different levels of competition: inter- and intra-platform competition. Inter-platform competition refers to competition in between different networks, operating different technologies (e.g. DSL, cable, wireless). Intra-platform competition, on the other hand, includes competition on top of one physical infrastructure (e.g. multiple NPs on top of one PIP). We observed a wide range of inter-platform competition (from xDSL, cable and wireless networks) on a country as well as case study level for the Netherlands, Germany and Sweden, which is modelled by two extreme cases: either the DSL and cable players keep their market shares and the FTTH player is taking only the new customers, or the DSL and cable players lose their market share completely to the FTTH player. For inter-platform competition (between different FTTH networks), we assume that there is only one single fibre PIP active in all cases. Therefore, this assumption is also made in our revenue scenarios.

We define basically 4 revenue scenarios, based on all combinations between high and low inter-platform competition and high and low intra-platform competition.

1. Low competition from other technologies, low intra-platform competition
   This is the reference scenario in order to identify the maximal revenue potential. In this scenario, almost all customers will migrate to the monopoly FTTH network. It's highly optimistic since DSL is almost everywhere available in Europe, but it might be possible in cases where fibre could substitute from the beginning all other fixed technologies.
2. Low competition from other technologies, high intra-platform competition
   Once the fibre infrastructure is deployed the market entry barrier for additional active NPs will be much lower. Therefore two NP‘s will be assumed here. Inter-platform competition is considered to be negligible.
3. High competition from other technologies, low intra-platform competition
   The impact of alternative technologies will be analysed. The proposition is that, even in 2030, several access technologies are competing with each other. This heterogeneous situation leads to much less revenue potential expected for every player.
4. High competition from other technologies, high intra-platform competition
   A realistic situation comes into the place, where all technologies (DSL, cable, FTTH and wireless) compete, but also multiple NPs on one FTTH infrastructure.

3.1.1 Top down: Country wide approach translated into OASE areas related direct revenue potential model

For the quantification of the competition scenarios we apply three different adoption rates based on the analysis in D6.2 that are shown in the following figure.

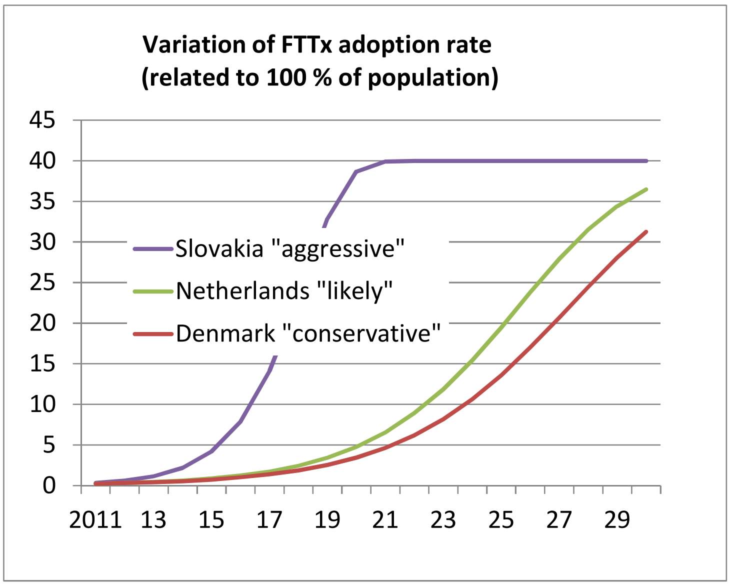


Figure 13: Generic FTTx penetration evolution related to 100% of the population

The calculation for the revenue scenarios starts with the generic FTTx penetration evolution which is normalised to population. The OASE techno-economical and business case evaluations are based on households and therefore we normalise the values to this approach. For simplification we use the intermediate value from Germany which means one household consist of 2.03 people.

Table 5: Population and household relationship for the three different penetration evolutions and the related Countries under evaluation [54]

	Population (millions)	No. of Households (millions)	HH factor
The Netherlands	16.7	7.26	2.30
Germany	81.7	40.30	2.03
Sweden	9.4	4.95	1.90

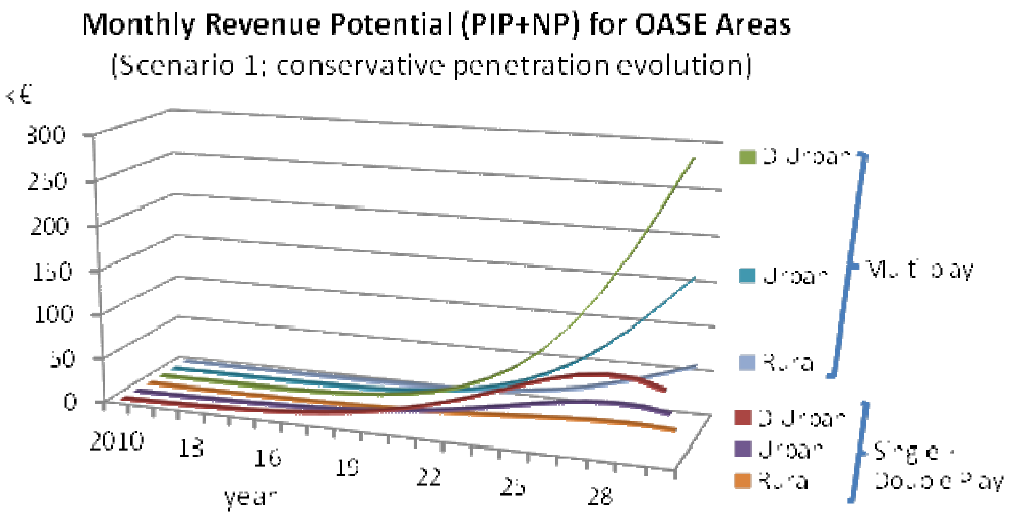
In principal we use the same approach as in D6.2 for the Country wide revenue calculations. The difference is that now the OASE area potential customer definition will be used to derive the potential revenues per scenario, per penetration evolution type and per area.

The resulting values are presented within the following figures. Because the resulting revenue potentials for scenario 2 and 3 are very similar (either two NPs compete with each other without being pressured by other technologies, or only one NP on the fibre infrastructure faces high technology competition in a single area), the results for scenario 2 are not shown.

In general all revenue potentials distinguish between the two services bundle which are

1. “Single + Double Play” referring to only voice (single play) and voice combined with Internet access (double play) bundle and
2. “Multi play” includes all triple play services like voice, internet and video and other like gaming for instance.

Each service bundle revenue potential is shown for the OASE service areas separately but always in the order of D Urban, Urban and Rural. Of course the “Multi play” bundle always leads to higher revenue potentials than the “Single + Double Play” category.



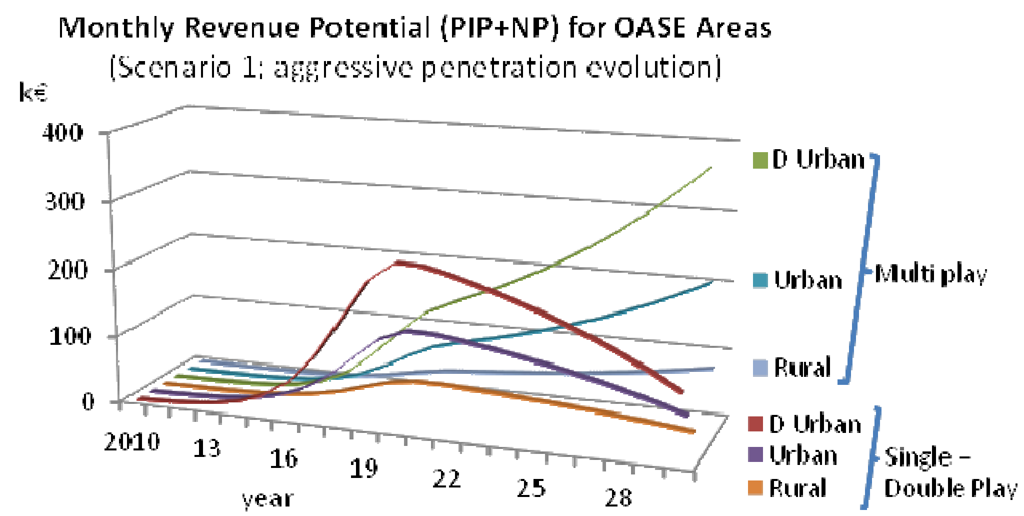
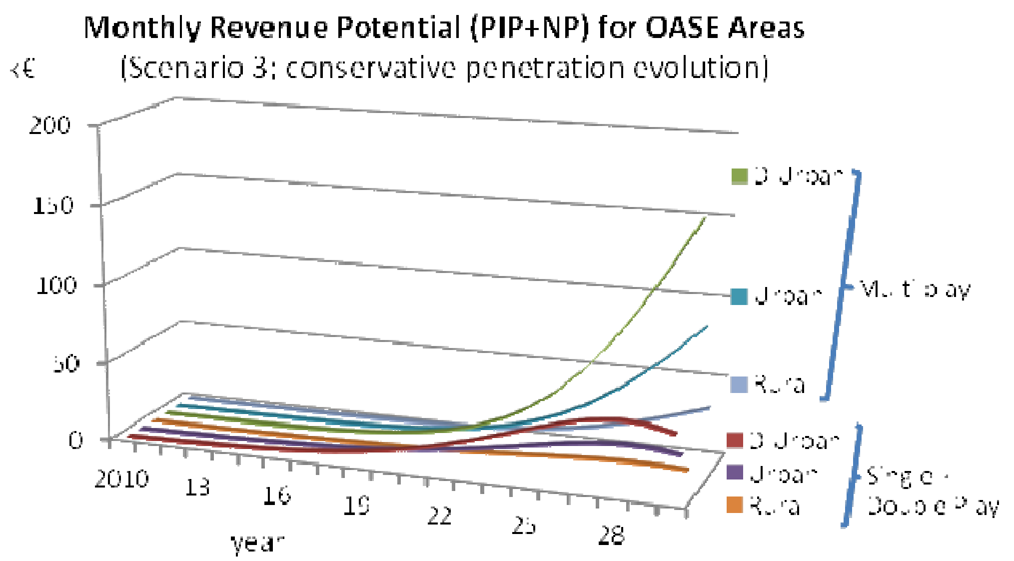


Figure 14: Scenario 1: monthly revenue potential for OASE area according to "conservative" and "aggressive" penetration evolution



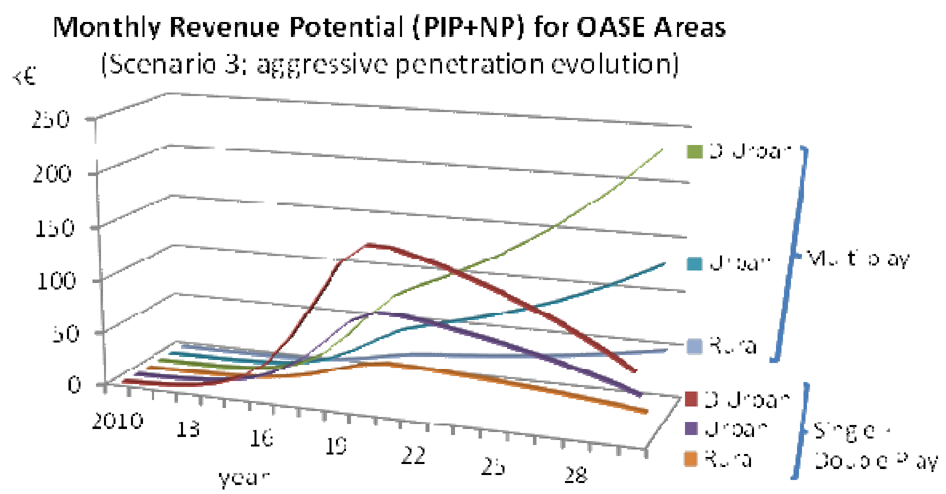


Figure 15: Scenario 3: monthly revenue potential for OASE area according to “conservative” and “aggressive” penetration evolution

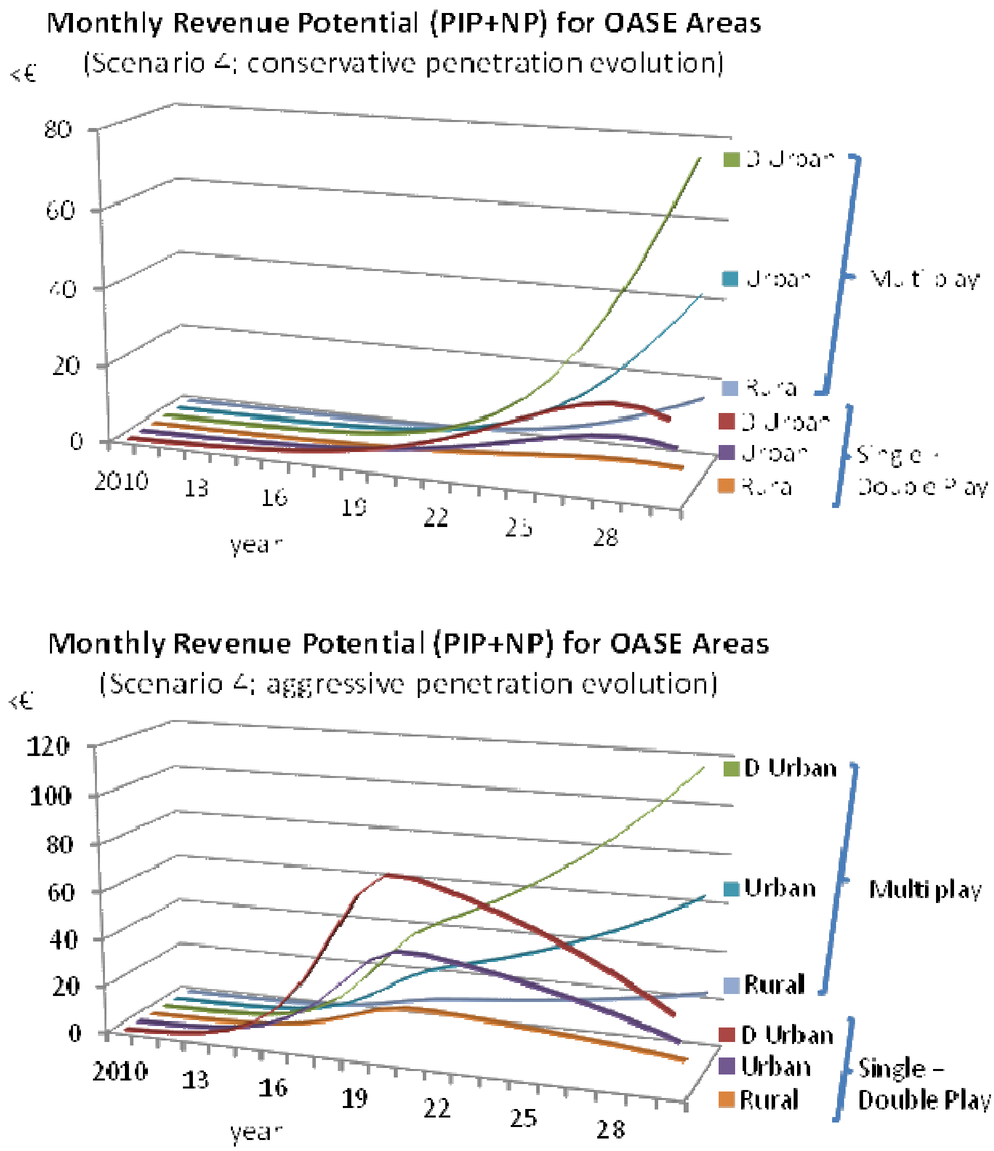


Figure 16: Scenario 4: monthly revenue potential for OASE area according to “conservative” and “aggressive” penetration evolution

From the figures above, we clearly see the impact of the adoption curve, as well as the competition level, both on inter- and intra-platform. We can therefore conclude that a reliable estimate of future developments is needed when investigating the business case for FTTH deployment.

3.1.2 Bottom up: Benchmark of selected provider

The previous chapter, which we use as a reference total revenue model, has some limitations if we consider smaller areas. Especially the penetration evolution can be expected as different. This chapter starts from more regional projects and providers and combines these input values with our penetration curves. One input is publically available from Benoît Felten, CEO of Diffraction Analysis, who gave a presentation at the FTTH Council conference this year in Munich [29]. He presented the demand for FTTH/B of selected projects and providers in relation to the time since these products were offered and introduced the linear black curve (Figure 17).

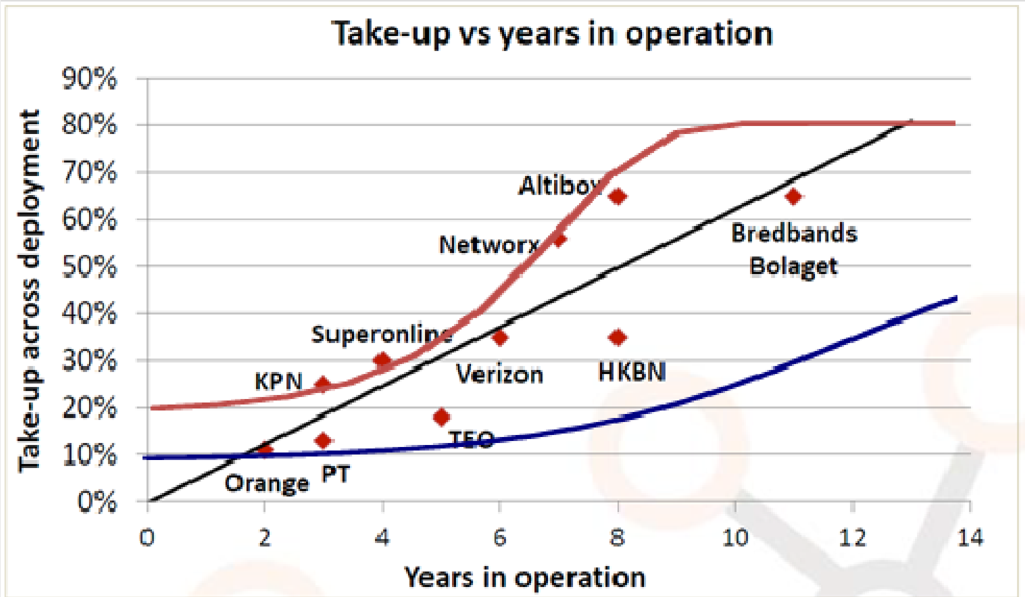


Figure 17: Take-up versus years in operation of selected FTTH/b project's and providers [29]

If we take our "likely" penetration curve and adjust the start penetration at 10% (i.e. if we assume some level of upfront demand aggregation), we have one lower limit (blue curve) which fits into the different presented examples after several years in operation. To introduce the upper limit (red curve) the "aggressive" penetration evolution can be adjusted at 20% start penetration.

Table 6: Regionalisation impact on revenue potential model cumulated over 20 years for one example urban OASE area

Penetration Evolution	Start Penetration	OASE Area	Scenario	Cumulated Revenues 2011 - 2030 [Mill €]	Delta compared to the reference case
likely	0%	urban	1	1,43	
	0%		4	0,423	
	10%		1	1,99	39,16%
	10%		4	0,59	39,48%
aggressive	0%	urban	1	3,1	
	0%		4	0,97	
	20%		1	4,2	35,48%
	20%		4	1,33	37,11%

The impact is shown exemplarily on the OASE urban area type. The increase of 10% combined with the likely curve leads to about 39% increased cumulated revenues over 20 years. Applying the upper limit turn out ("aggressive" increased by 20% start penetration) we observe between 35 and 37% increased revenue potential over the period of 20 years.

Figure 18 shows the impact on regionalisation of the different areas for scenario's 1 and 4. Only one example the likely evolution increased by 10% start penetration has been chosen here.

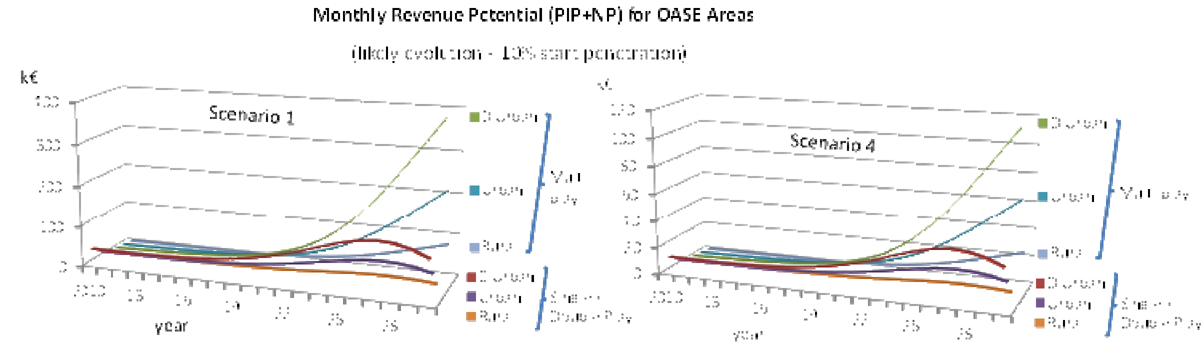


Figure 18: Monthly revenue potential (PIP+NP) for OASE areas with likely evolution increased by 10% start penetration rate

However, these revenues were calculated based on expected charges from the end-customers. With the evolution towards vertically disintegrated business models, revenue sources for the different layers separately are needed to evaluate or benchmark our results. These revenue sources will be described in the next sections.

3.2 Revenues for the PIP and the NP: sources of input

Apart from the input gathered from our case studies, it is very hard to find actual numbers describing the revenue potential for the three layers (SP-NP-PIP) separately. The total income (i.e. the total sum of monthly customer subscription fees) can be easily found from digging into operators' offers, but only little is known about how this amount of money is divided amongst the different players on the market scene. This section will provide some ideas of starting values for the revenue for the PIP and NP separately.

3.2.1 Regulated DSL pricing

One possibility is to compare revenues for a FTTH infrastructure provider with the charges OLO's (Other Licensed Operators) currently pay to the incumbent for unbundling. The revenues for the NP layer can analogously be subtracted from the DSL pricing for bitstream access. Since the regulated DSL prices vary across EU Member States, we try to get some overview by focusing on three representatives countries: Germany, the Netherlands and Sweden (Table 7).

Table 7: Regulated prices for DSL for Germany, the Netherlands and Sweden

	Germany	The Netherlands	Sweden
Customer to SP (VAT included)	Not regulated	Not regulated	Not regulated
SP to NP (VAT excluded)	Not regulated	€19.68[1] [46]	Not regulated
NP to PIP (VAT excluded)	€7.17-10.8[2] [12]	€6.54-7.59[3] [62]	Not regulated

[1] Wholesale access for non-shared VDSL bonding (prices for shared and ADSL are lower)

[2] Dependent on MDF (access between end consumer and central office) or SDF (access between end consumer and street cabinet)

[3] Idem

3.2.2 Regulated fibre pricing

Analogously to regulated prices for unbundling and bitstream access, some countries have regulated prices for access on dark fibre, as well as wholesale access on NP level.

For instance, in the Netherlands, OPTA (the Dutch National Regulatory Agency) and Reggefiber agreed on prices for ODF access [67]. They charge a fixed upfront price and a monthly tariff per customer. These depend on the number of customers and the initial CAPEX per home passed (represents the difference between upfront investment for different areas – rural versus dense urban). The exact charges can be found in Table 8 and Table 9. Table 8 details the upfront connection fees per Area PoP (column 3), the VVA per Area PoP (Vergoeding voor Abonnement – Fee for subscription) for using the room for placing equipment in a collocation PoP or City PoP (columns 4 and 5).

Table 8: Upfront tariffs (dependent on the number of IGPs - Individual Fibre Pairs – Individuele Glasvezel Paren)

Collocatie tarieven per Area PoP > 2.880 IGP per Area PoP				
Area PoP type	Aantal IGP per Area PoP	Aansluitbijdrage per Area PoP	VVA Collocatie per Area PoP	VVA City-ring per Area PoP
1	Tot 2.880	1 x € 3.075,47	1 x € 512,58	€ 615,09
2	2.880 – 5.760	2 x € 3.075,47	2 x € 512,58	€ 615,09
3	5.760 – 8.640	3 x € 3.075,47	3 x € 512,58	€ 615,09
4	8.640 – 11.520	4 x € 3.075,47	4 x € 512,58	€ 615,09
5	11.520 – 14.400	5 x € 3.075,47	5 x € 512,58	€ 615,09
N[1]	(N-1) x 2.880 – N x 2.880	N x € 3.075,47	N x € 512,58	€ 615,09

Table 9 gives an overview of the monthly charges per end customer, both the real charges (row 1) and the maximum charges (row 2).

Table 9: Monthly charges per IGP (Individual Fibre Pair), so per end-customer, dependent on the CAPEX per home passed

ODF tarieven					
	Gebiedstype				
	CAPEX 775-825	CAPEX 825-875	CAPEX 875-925	CAPEX 925-975	CAPEX 975-1025
Huur IGP (per Eindgebruiker) per maand	12,30	13,07	13,84	14,61	15,38
Tariefplafond	14,86	15,63	16,40	17,17	17,94

Furthermore, the wholesale tariffs (prices charged by the NP to the SP) are also publicly available for the Dutch incumbent KPN. They charge service providers €19.00 per month per line (VAT exclusive). Wholesale prices for non-shared Fibre-to-the-Office are much higher, around €97 [46].

3.2.3 Case studies

Another source for gathering revenue data for the different layers, are the case studies we investigated [54]. Although not all the cells can be filled, some information and good estimates could be gathered from these studies. Table 10 gives an indication of these prices (unless mentioned otherwise, prices are per month and per end customer).

Table 10: Prices charged for the different layers in the case studies (N/A denotes not available)

	Stockholm	Norderstedt and	Bavaria	Amsterdam

		Hamburg		
Customer to SP (VAT included)	€18-45	€26-55	€35-55	€33-100
SP to NP (VAT excluded)	N/A	N/A	N/A	Around €19
NP to PIP (VAT excluded)	€5-7 per customer OR €200 per km	N/A	N/A	€12-15

These different sources of revenue flow that are used to cover PIP and NP investment in real-life countries and specific investigated cases, can then alter be compared to the needed revenues per layer that result from our analysis (see further in section 4).

3.3 Direct revenue flow towards the service provider

As OASE doesn't focus on the cost-benefit analysis for services and applications, the following revenues will be presented just to complete the picture for the whole value chain. Based on the IDC worldwide new media market model forecast from Aug. 2011 [42] we see for Western Europe the mean additional monthly revenues per customer.

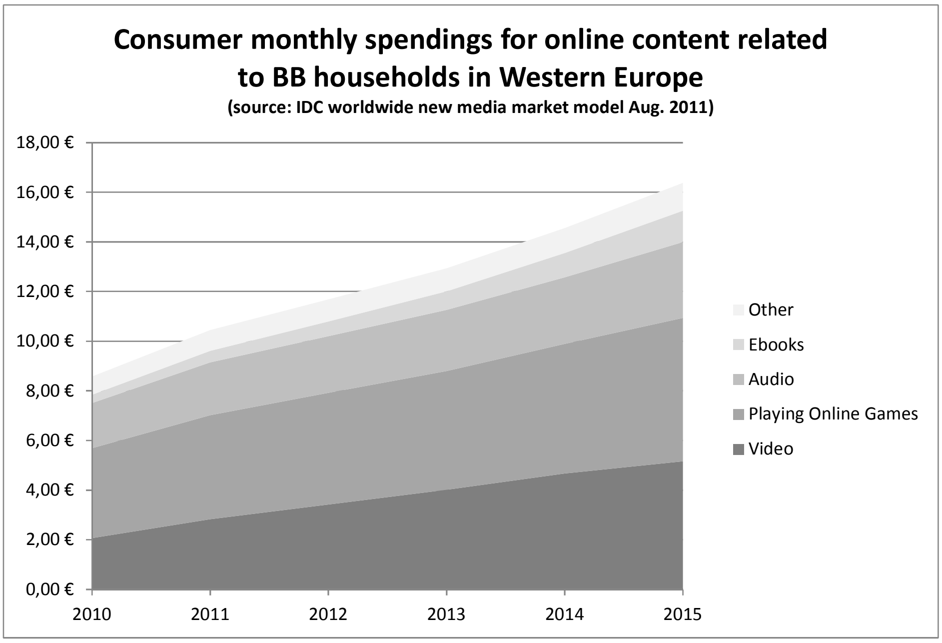


Figure 19: Consumer monthly spending for online content related to BB households in Western Europe

Figure 19 shows the evolution of these revenues differentiated into video, audio, online playing games, eBooks and other categories in Euro using the Oanda exchange rate from the 18.04.2012 [52].

4. Profitability studies

4.1 Introduction

While the previous sections were more focused on setting up the scenarios and gathering the right input data and parameters, this section will evaluate the business case for various scenarios, actors and business models.

Because of the evolution towards more open access business models, and because the investment level and payback period differ strongly for the passive infrastructure and the active equipment, we chose to evaluate the business case for these different business layers separately. An evaluation of the cost for the system as a whole is performed in D5.3 [61], and will therefore not be repeated here. After having introduced the parameters for the reference scenarios (section 4.2), we will first focus on the business case evaluation for the PIP, in which we make a distinction between P2P and P2MP deployments (section 4.3). Secondly, the business case for the NP is evaluated, if as there were only one NP on top of the PIP (section 4.4). Finally, section 4.5 investigates the impact of offering open access possibilities on the business cases for both PIP and NP, and look into the competition on the NP layer and the effect of churn.

As mentioned before, the OASE project doesn't focus on the SP layer, but does calculate the transaction cost between NP and SP, allowing competition on the SP layer.

4.2 Scenario description

As an extension to the work done in WP5, the goal of quantitative evaluation in WP6 is to understand the cost-benefit trade-off for different actors involved in a certain scenario. For this purpose, a scenario is defined based on the following parameters

- **Area covered**. We consider either urban, dense urban or rural areas, based on the reference areas put forward by WP5 [56]. The type of area is defined based on the population density: less than hundred of subscribers/km^2 is considered as rural area; less than thousand of subscribers/km^2 is considered as urban area, whereas more than thousand of subscribers/km^2 is considered as dense urban area (Table 11).

Table 11: Parameters for the area types (note: HH = households)

Area type	Number of HH	Surface (km^2)	Household density (HH/km^2)	Total trenching length (km)	Trenching length per HH (m)
Dense urban (DU)	15,600	5	3,120	12,950	6.75
Urban (UR)	8,640	24	360	14,040	19.00
Rural (RU)	3,060	57	54	7,840	16.50

- **Network architecture.** Apart from the traditional architectures (GPON 1:32 and AON), different next-generation architectures have been proposed within the project, which are [55]:
    - WDM PON: There are three variants of WDM-based access technologies: Broadcast-and-select WDM PON, wavelength-routed WDM PON and UDWDM PONs.

- Hybrid WDM/TDM PON: There are two variants: passive hybrid and wavelength-switched hybrid variants.
- Two-stage WDM PON
- Next generation Active Optical Networks (NG AON): Two variants have been defined: Home run and Active star.

- **Adoption curves**. We consider three possible adoption curves: likely, conservative and aggressive, based on the reference curves described in D6.2 [54].

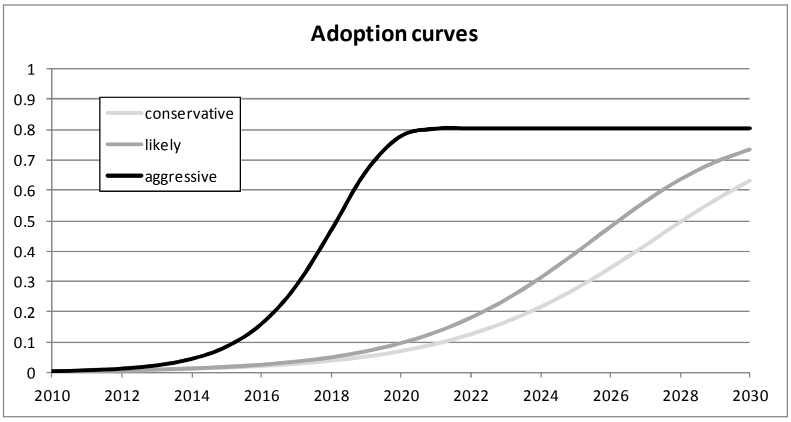


Figure 20: The adoption curves for the reference scenarios

- **Revenue models**. We base ourselves on revenues from real-life case studies, regulatory price settings and other relevant sources. Revenues are then directly defined by the combination of the revenue model and the adoption curve. For more details, we refer to chapter 3 of the current deliverable.
- **Discount rates**. Discount rates represent the expected return for the investment at hand, and should reflect the risk level of the investment. We assume a discount rate of 5% for the PIP, 10% for the NP, and leading on average to 6.5% for the total system in the reference scenarios, but also perform some studies on the impact of these discount rates on the outcome of the business case.
- **Deployment strategy**. This can be green-field or brown-field (S to XL), see [56] for more info.
- **Competition**. The number of competitors per network layer is based on practical cases. We do not consider more than one fibre PIP. The number of NPs in a certain area is limited to a small amount (max 5, typical 2 or 3).

Costs. Costs are directly defined by WP5 based on the combination of architecture and area. Analysis of different scenarios within WP6 aims at comparing costs and revenues, for different scenarios, i.e. combinations of the parameters described above.

4.3 Evaluation of the business case for the PIP

The provision of NGOA will, by definition, require an end-to-end fibre connection between the customer and the Network Provider's equipment. Figure 21 below shows a case where a single entity has installed the entirety of the fibre in the network. When considering multi-dwelling units in urban and dense-urban environments, this will involve negotiating access to buildings to install ducts and fibre. This has advantages and disadvantages. Best practice can be observed and well-documented by a single actor, where multiple organisations might lead to inconsistencies and a variable quality of installed equipment. However, negotiating access to the buildings in order to install fibre is likely to be a convoluted process complicating (and thus increasing the cost of) any fibre deployment.

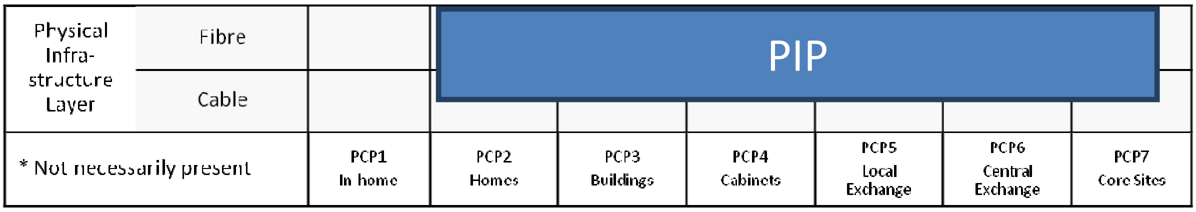


Figure 21: End-to-end connectivity with a single PIP

An alternative can be seen in Figure 22. In this scenario, the connectivity within a MDUis installed by the owner of the building. This can happen through renovation of existing properties or through the introduction of fibre connectivity into new-build designs which will result in future building projects being fibre-enabled.

In order to provide end-to-end connectivity within this scenario, the PIP and the building provider must work together. Where in the previous scenario there was a cost for negotiating access for installation, here we may find additional costs for negotiating transit rights for the fibre that's available.

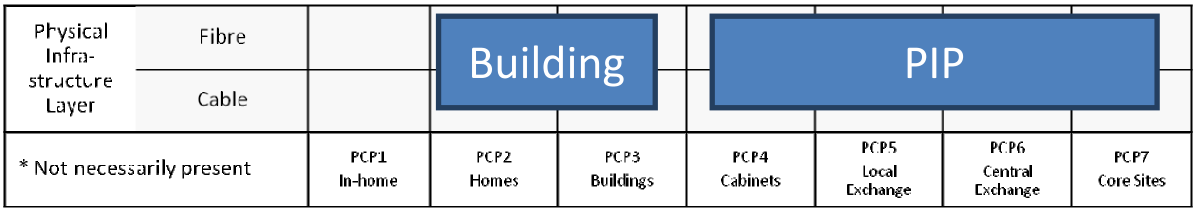


Figure 22: End-to-end connectivity requiring cooperation.

It is important to note that, outside of considerations of economy of scale, these two scenarios do not differ in installation cost. The same amount of ducting and cable must be installed in both scenarios to provide connectivity. However, they imply significant differences in the way that they may be monetized.

In the first scenario in Figure 21, the single PIP must charge customers a monthly fee that will guarantee a positive ROI considering the penetration curve under study. This has the implication that income will only be generated from connected customers.

The second scenario detailed in Figure 22 is significantly more interesting. For example, if we consider the case of a new-build property where fibre was installed by the construction company during construction, the cost of the final network segment between PCP2 and PCP3 will be factored into the sale price of the dwelling. In this scenario, the monthly fee required to support the PIP will be reduced because this section of the network will have been paid for already. Alternatively, the building owner may renovate to provide fibre access and recoup this cost through rental fees. In this scenario, the cost of the in-building network will be borne by all occupants, irrespective of whether they choose to take an FTTH service or not. We can envision this as a 100% penetration curve for this network segment. Alternatively, access to these fibres may be negotiated by the PIP, with the PIP paying the building owner a few for their usage. This is similar to the “single PIP” scenario in Figure 21, but with additional overhead for contract negotiation and the uncertainty inherent in a multi-actor scenario.

Therefore, while the cost of the scenarios may be identical, their expected costs to the customer may be significantly different. It is uncertain which of these scenarios is the most likely. Certainly, for newly built properties, adding fibre during the building phase results in significantly decreased costs as fibre can be installed at the same time as the electrical and other utility installations. However, from internal consultation, it is clear that paying the building owners for leasing of privately-held fibre optics is not attractive to operators.

Because of the uncertainty on the way the in-building cost is recouped, we will first detail the PIP cost from PCP3 onwards; from the customer's front door in case of SDU, from the basement in case of MDU. Following this, the 20 year business case for the PIP will be analysed, including an evaluation of the necessary customer charges to support the PIP. The needed cost for recouping the in-building infrastructure will later be analysed. Finally, the total needed CPE revenue will be evaluated, which then includes in-building infrastructure, the ONT and its installation – see section 4.4.

4.3.1 P2P deployment of fibre infrastructure

In this first analysis, we will analyse the business case for a P2P deployment of passive fibre infrastructure, for all adoption curves and OASE reference areas. The parameters used are summarized in Table 12.

Table 12: Overview of the parameters used for the PIP P2P business case analysis

area	dense urban, urban, rural
adoption curve	likely, aggressive, conservative
revenue	PIP DSL and Reggefiber
discount rate PIP BC	5%
discount rate NP BC	not applicable
discount rate total system	not applicable
planning horizon	20 years
topology	P2P
Duct reuse	Greenfield deployment

4.3.1.1 TCO for the PIP

Deploying the passive infrastructure requires a huge initial investment that consists of manual labor cost for trenching and costs for fiber cables, ducts and micro-ducts. The combination of this outside plant cost with the upfront cost for installing the necessary, passive, equipment in the central office and street cabinets (e.g. ODF racks), results in the total Capital Expenditure (CapEx) for the PIP. Of course, there are also costs during the lifetime of the infrastructure: a cable may break, which requires digging and splicing to repair, and renting costs for the floor space in the central office have to be paid every year. These yearly recurring costs are grouped as Operational Expenditures (OpEx). The total cost of ownership (TCO) of the physical infrastructure clearly reflects the differences in number of users and average distance covered per user (Figure 23). As the PIP cost is nearly entirely driven by upfront, distance based trenching cost, there is negligible impact from the adoption curves, therefore, only the results for the likely curve are shown here. When considering the cost for the physical infrastructure spread over all potential customers (cost/home passed = cost/HP), we clearly see that this is growing with a decreasing household density and therefore decreasing trenching cost per household. Note that the cost/HP in the dense urban area (€572) is doubled in the urban area (€1094) and tripled in the rural area (€1764). The TCO for the physical infrastructure, on the other hand, also shows the impact of the total amount of customers per area. Here we observe that the overall cost for the rural area (€5.40 million) is significantly smaller than that for the urban area (€9.45 million), only based on the significantly lower number of customers. The cost for the dense urban area (€8.92 million) is only slightly smaller than for the urban area.

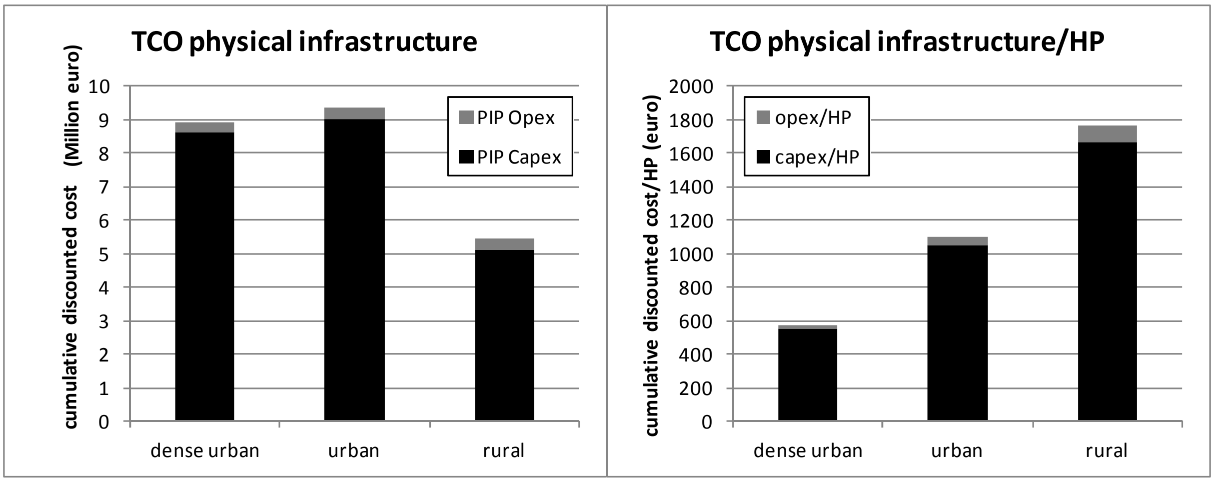


Figure 23: Total Cost of Ownership for the PIP and per HP for a P2P fibre deployment, cumulative and discounted over 20 years (for likely adoption curve)

When considering the OpEx/CapEx ratio for the different areas (Figure 24), we see it growing with the trenching distance covered. This is clear because the OpEx is mostly driven by the fibre repair cost in case of a cable cut.

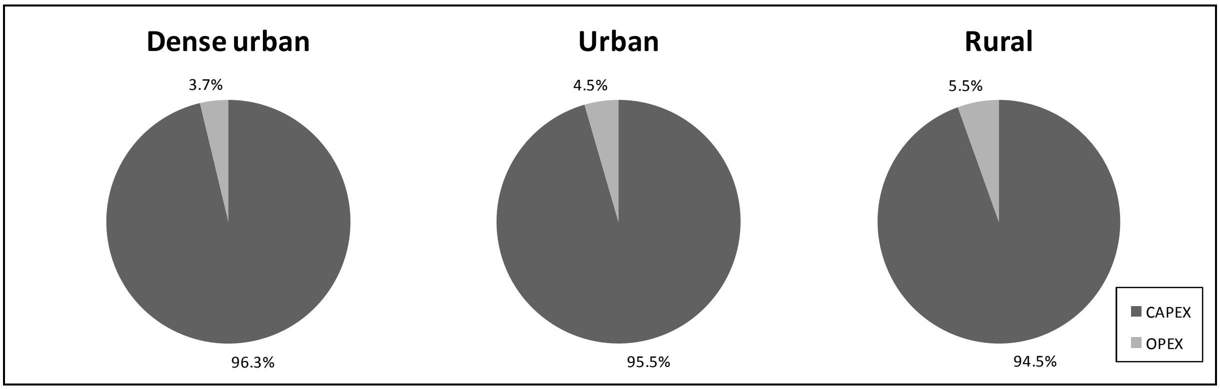


Figure 24: CapEx - OpEx split for the PIP for the dense urban area and likely adoption curve (cumulative and discounted over 20 years)

4.3.1.2 Possible revenues for a Physical Infrastructure Provider

Chapter 3 already described the possible revenues the PIP could receive by renting out dark fibre infrastructure. In this results section, we will work with two revenue sources: typical DSL unbundling values and specific fibre lease prices used by Reggefiber in the Netherlands (in agreement with the Dutch NRA, OPTA). When taking the average DSL unbundling prices described in section 3.2.1, we arrive at an average revenue per user per month of about €10. This price will then be used throughout this section as a benchmark.

The Reggefiber revenues on the other hand are based on both an upfront charge, fixed monthly charges per NP and monthly charges per customer. A summary of these revenues for the different areas is given in Table 13. For more info on these revenues, we refer to section 3.2.2.

Table 13: Revenues for the PIP as charged by Reggefiber

	Dense urban	Urban	Rural
Connection charge	€18,453	€9,226	€6,151
Monthly charge fixed	€4,304	€2,767	€2,254
Monthly charge per customer	€7.39	€14.49	€25.39

When combining the revenues described above with the three typical areas (dense urban, urban, rural) and the three adoption curves (conservative, likely, aggressive), the total revenue potential for each scenario can be defined (Figure 25). For regulated revenues in case of DSL, we have assumed a fixed fee per customers (low €7, high €10), which obviously leads to a growing revenue with the population per area and the adoption curve. For the case of the regulated prices for fibre unbundling, however, the Reggefiber scheme was used, which is not that straightforward. As the prices are based on the so-called CapEx-ranges, relatively higher revenue is obtained for the areas with lower household density and therefore higher trenching distances.

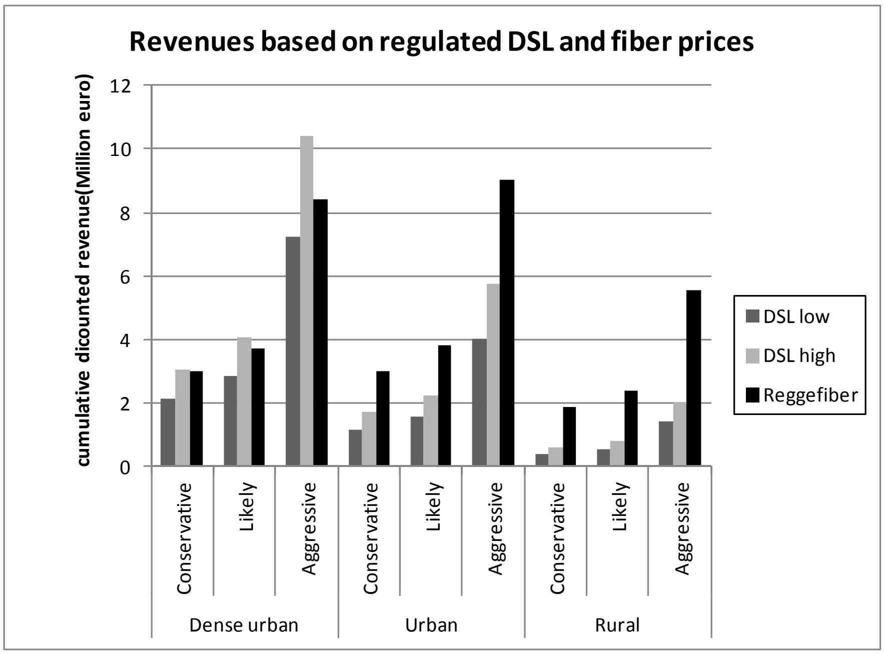


Figure 25: Total Revenue potential for the PIP (cumulative and discounted over 20 years)

4.3.1.3 PIP business case over 20 years

With the assumption at hand, the business case for the PIP over 20 years is only viable in a dense urban area with aggressive adoption (Figure 26). This means that in all other case the monthly revenue of €10 for the PIP, which was assumed as the high-end (HE) of the expected revenues, does not suffice to cover for the costs.

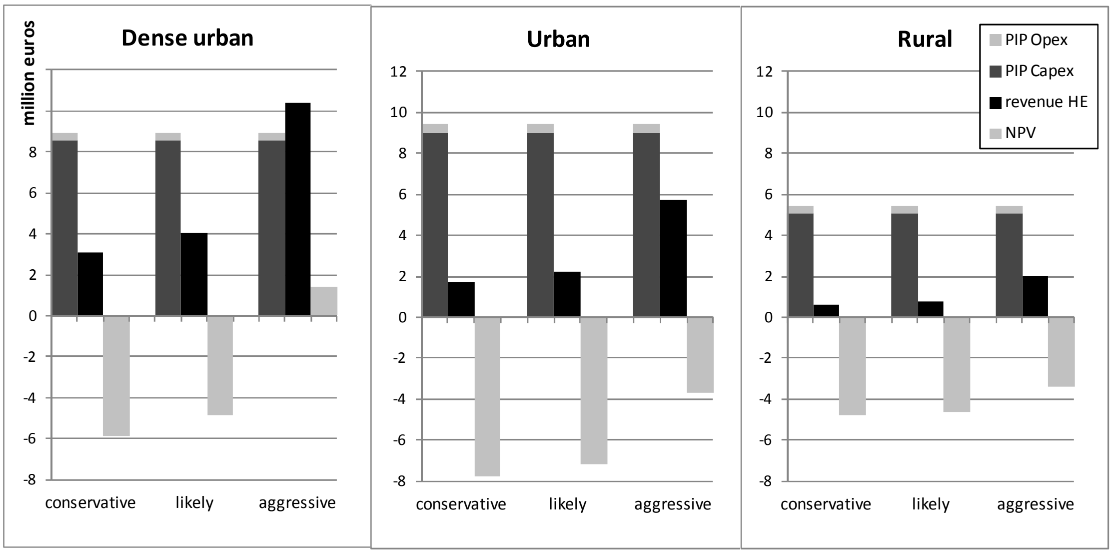


Figure 26: cumulative costs, revenues and NPV

It should be mentioned that, although the cost model is relatively detailed and accurate, it does not take administrative and other overhead costs into account. This should be kept in mind when analyzing the results of the business case: obtaining a zero-NPV will most probably not be economically viable.

4.3.1.4 Estimated payback time

Discounted cash flows for the three areas and three adoption curves (Figure 27) indicate that we only have a payback which is lower than 20 years (2010-2030) in the case of aggressive adoption in a dense urban area.

This observation can be interpreted in two ways. Either the observed time frame of 20 years (or the combination of the time frame of 20 years and the used discount rate of 5%) is not appropriate for the evaluation of an infrastructure project as considered here; or 20 years is the right timeframe indeed and the business case simply does not fly based on the current regulatory prices, so that we cannot assume that anyone with ever invest in it under market conditions. In section 4.3.2 we will study some potential improvements to the business case as it described here.

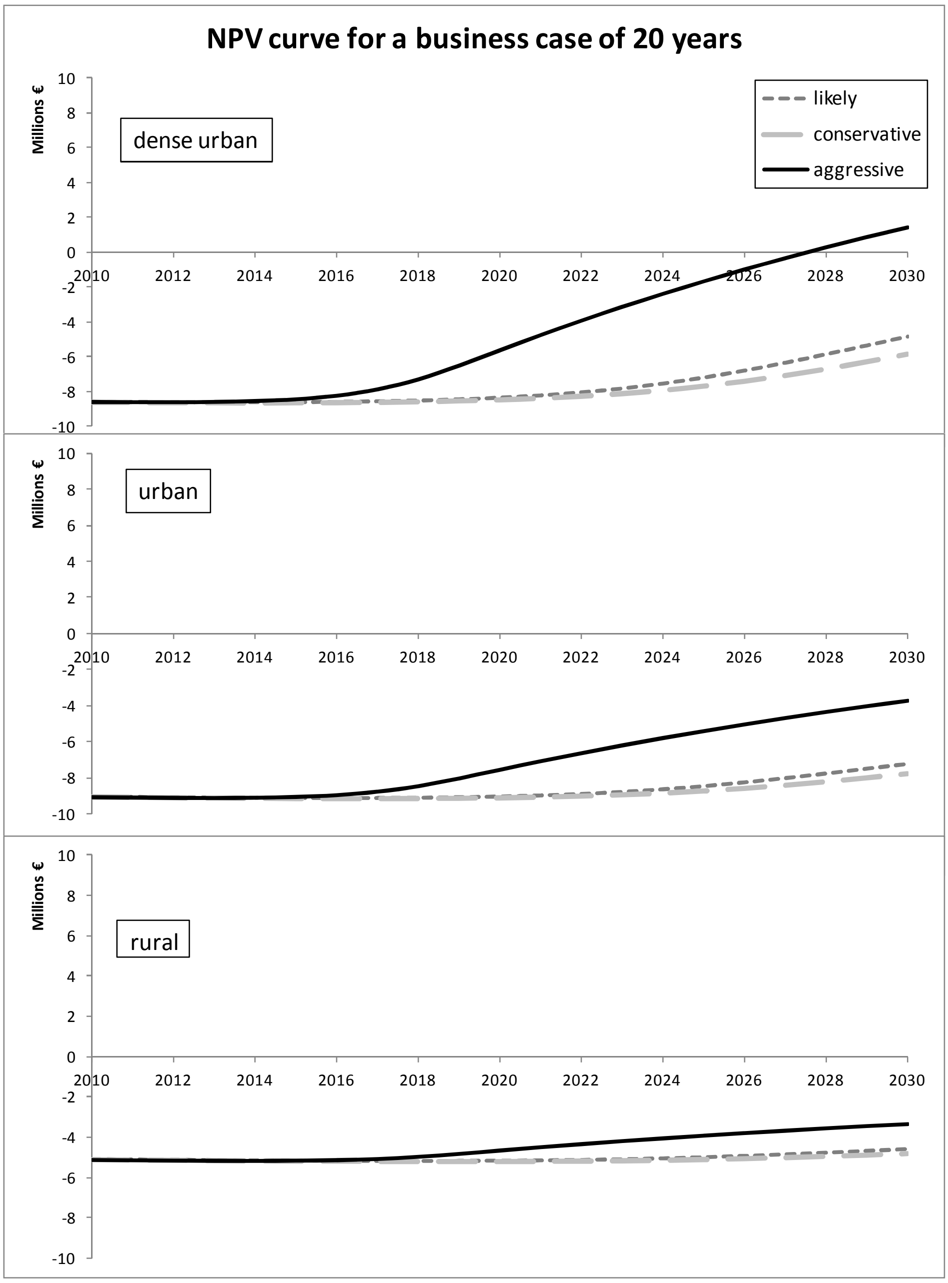


Figure 27: NPV curves for the nine scenarios assuming an ARPU of €10 flowing towards the PIP

4.3.1.5 Revenue needed per home connected

In the previous sections, we have calculated the PIP business case starting from known revenues. However, the reverse calculation can give another insight in the problem: we can calculate the revenues needed (per subscriber and per month) based on the known TCO. The following formula is used:

$$\sum_{i=1}^{20} 12 * X * absolute\ adoption_i * 1 \frac{1}{(1+r)^i} = TCO\ over\ 20\ years$$

where X = *revenue per user per month*

r = *the discount rate*

The obtained required monthly revenues per home connected for the break even case (Figure 28) confirm our previous results: only in the dense urban area with the aggressive adoption curve the needed revenue per user and per month (€8.6) is lower than the DSL price cap of €10. In all other scenarios, a much higher monthly revenue is needed (for urban at least €16.5, for rural even €26.5, both for the aggressive adoption curve)!

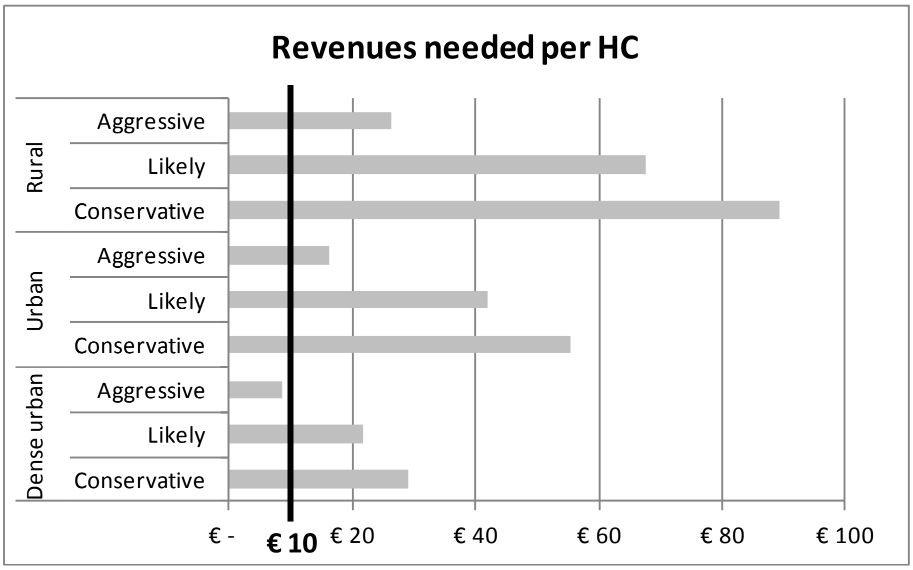


Figure 28: Revenues needed per subscriber per month (business case with planning horizon of 20 years)

4.3.1.6 Impact of variable revenue, better reflecting costs

All results above indicate that the business case for the PIP is very difficult. Based on the assumed an average revenue of max €10 per month per customer, the case is only profitable in a dense urban area with aggressive adoption. In the other scenarios, the estimated payback time clearly exceeds the considered 20 years.

One explanation is in the fact that fixed revenues per customer for the PIP, independent from the area, do not reflect the cost base. Therefore, in order to reduce risk PIP pricing should better reflect costs by charging based on distance like the Stokab model [30] or by at least differentiating between some area types like the Reggefiber model (Figure 25).

Figure 29 shows the cumulative costs and revenues according to the regulated prices used by Reggefiber. It is clear that using these pricing schemes, which do depend on the area, improves the business case for the less densely populated area (urban and rural), a lot. However, the business case is never positive, when the extra administrative and overhead costs would be taken into account.

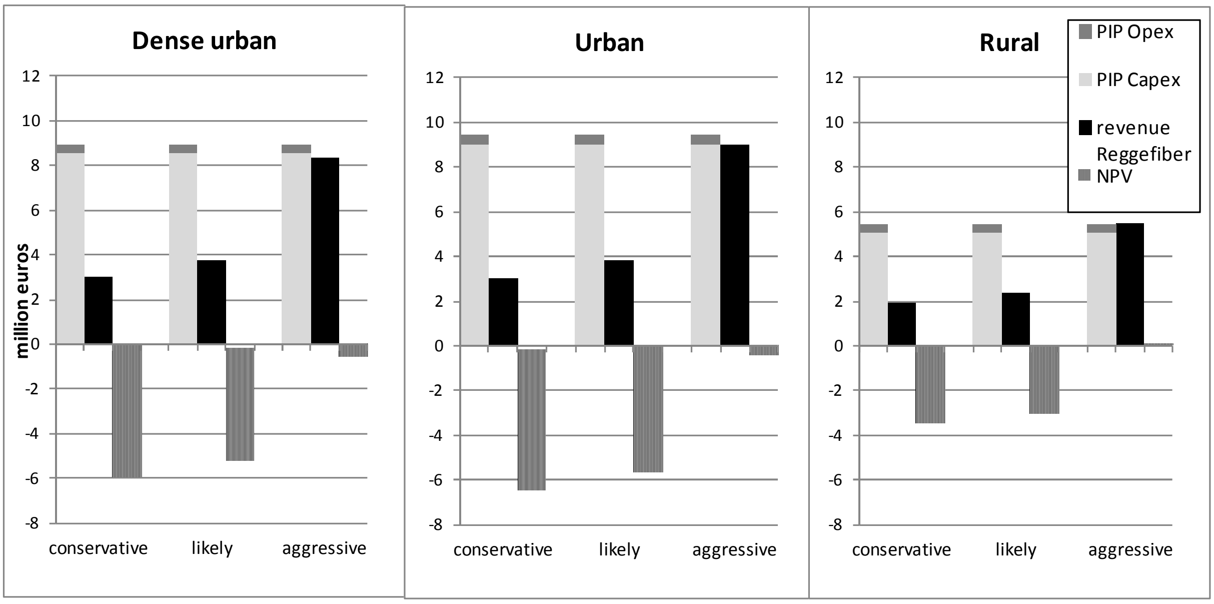


Figure 29: Cumulative costs and revenue according to Reggefiber's assumptions, as well as resulting NPV (cumulative and discounted after 20 years)

Using pricing schemes adapted to the region under study could make a lot of sense to improve the business case for the PIP, but is not an option to extend to the higher layers of NP and SP, or even the end-customers: it is a question whether it would be fair to charge people in rural areas triple the price for the same internet capability as offered in densely populated cities…

4.3.2 How to improve the business case?

Since the results from section 4.3.1 indicate rather negative business cases, other sources of revenue or other means to improve the business case should be found. This section proposes some specific measures that could be taken to make the investment in a passive infrastructure a good choice from an economic point of view.

4.3.2.1 Impact of demand aggregation

The business case for the PIP is especially difficult because of the combination of a high upfront cost and revenues that have a very slow uptake. One solution could be to have the revenues sooner in the project lifetime. Demand aggregation is a process in which interested customers sign a cooperation agreement before the deployment is started. In this way areas can be chosen in which there will be a guaranteed uptake from the start. For example, Reggefiber expects a level of 30-40% demand aggregation before starting the deployment [13]. We have modelled the impact of demand aggregation of 20 or 40% on the adoption curve, by adding this percentage to the expected adoption. However, we assume that the curve doesn't exceed the original maximum adoption percentage of 81.20%.

In the dense urban case, also the original aggressive curve led to a positive business case, which is clearly strengthened by an additional demand aggregation. For the urban area, we see that the negative NPV of minus €4 million is halved by demand aggregation of 20% and nearly equalled out by a level of demand aggregation of 40%. The rural case remains difficult though.

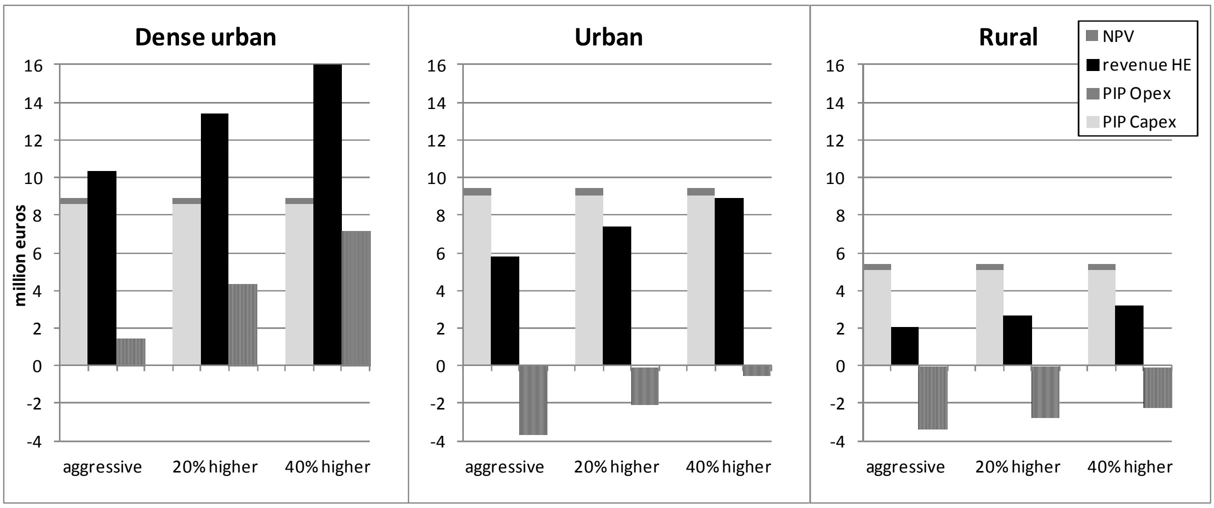


Figure 30: Cumulative costs, revenues and NPV in case of aggressive adoption curves, as in their original forms as well as with a level of demand aggregation of 20 and 40%

4.3.2.2 Impact of duct reuse

It is clear from Figure 24 that the majority of the PIP costs, and by extension of the entire FTTH deployment cost, is in the CapEx. More specifically it is in the ducting costs, as the cost for trenching and ducting is significantly higher than the cost for the fibre itself [15]. In case some parts of the ducts can be reused, this will therefore lead to a significant reduction in the necessary cost outlay.

Actual duct reuse can take different forms. Of course, “old” telecom ducts used in the copper network or the FTTC network can be an option, but for example in Paris, fibre was deployed in sewer systems [83]. In the EC guidelines for access networks, the bottom-up approach was suggested as an investment vehicle (for more detail, see D6.4 [59]). This can also facilitate access to publicly owned infrastructure such as ducts, and therefore drastically reduce this cost.

To quantify the effect of possible duct reuse on the business case for the PIP, we compared three scenarios:

- a Greenfield deployment, where no ducts can be re-used,
- a “small” scenario, where between 25% and 70% of the ducts in the feeder fibre section can be re-used, and 15 to 20% in the distribution cable section of the network
- a “large” scenario, with a duct re-use of 35 to 80% in the feeder fibre section, and about 20 to 40% in the distribution cable section.

The variances in duct reuse are explained by a different estimation of the available ducts in the different areas: the available ducts will be much higher in a dense urban region, where most probably, an existing telecom network is already present, while the availability and/or quality of current telecom network in rural areas might be much lower.

Figure 31 shows the impact of the three levels of duct reuse on the TCO, which clearly is significant. Because of the higher duct reuse in the dense urban area, the savings that can be achieved are also higher. Reusing ducts makes the business case better, but still not economically viable for deployment in an urban or rural region.

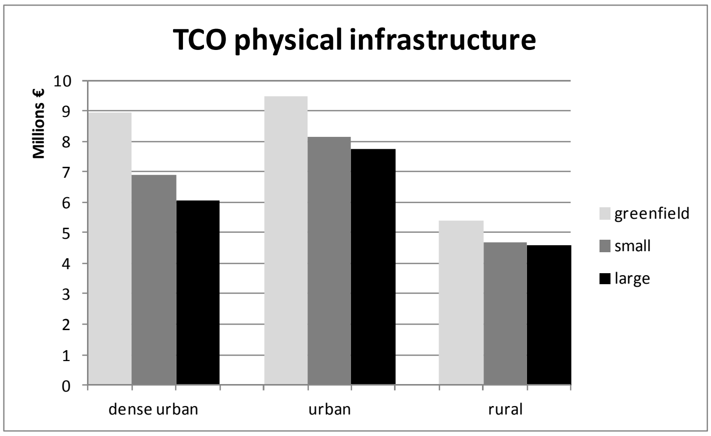


Figure 31: TCO for the PIP (cumulative and discounted after 20 years), for three levels of duct reuse (according to the aggressive adoption forecast)

However, while this is useful in reducing the necessary capital outlay, it must be stated that this should not affect the cost that the PIP must charge to network providers. If we imagine a PIP that has yet to deploy a FTTH network but has some access to ducts, it is easy to envisage that the PIP would charge other businesses for access to these ducts. For example, before deployment, a business customer or mobile network operator might wish to use this duct segment and they would be charged accordingly. Therefore, when this section of duct is utilised in the deployed FTTH network, network providers that utilise it should be charged accordingly.

This is extremely important for considerations of state aid. For example, as reported in D6.4 [59], in the UK state aid is being provided in rural scenarios for the provision of broadband. This state aid uses a gap funding model, where the amount contributed by the state is equal to the gap between the market value of the project and its projected cost. However, if the projected costs include a reduction in charge based on duct re-use (available at zero cost only to the incumbent) this means non-incumbents could never compete even with gap funding.

Therefore, while duct reuse reduces the capital outlay (as discussed in D5.3 [61]), it should not be used for business case optimisation.

4.3.2.3 Additional revenue sources

Results up till now have assumed PIP revenues based on a per customer fee (of maximum €10), in some cases differentiated based on the associated cost (Reggefiber model) combined with an expected adoption for advanced broadband services. However, there can be additional revenues for a physical infrastructure provider, for instance because the dark fibre deployed can also be of interest to other telco and non-telco customers than those in the access market described above. These revenues can be significant, as Stokab reported they can add up to 50% of their total revenue [11], and similar figures are reported by AOB member Karlstad Stadsnät, and around 70% among the members of Skånet, a federation of 35 municipal networks in Southern Sweden.

Possible additional revenues can come from large businesses or public institutions (like administrations, hospitals, schools, etc.) that want to lease an end-to-end dark fibre connection, and use their own active equipment for lighting it up. This ensures a safe and secure connection between multiple establishments of one enterprise (e.g. a bank). If a FTTH network is present, it can also be used as a backhaul network for Next-Generation wireless offerings, like LTE or WIMAX. The base stations of these networks can be connected to the fixed fibre network, and the wireless operators pay their fair part of the lease. For instance, Skånet currently secures €10 million annually from LTE customers, and this is expected to grow substantially in the near future.

4.3.2.4 Prolonging the planning horizon

Since the passive infrastructure that is currently providing internet to all, the incumbent's copper network or the cable operator's HFC (Hybrid Fibre Cable) network, has been deployed decades ago, and still hasn't reach the end of its lifetime, it is likely to expect that the same holds for the fibre cables. It thus makes sense to prolong the planning horizon, since it's very likely that the fibre infrastructure will generate revenues for more than 20 years. Furthermore, prolonging the business case will also extend the adoption curve, leading to a higher adoption potential in a later stage of the project (Figure 32). These revenues are not captured in the initial business case with a lifetime of 20 years.

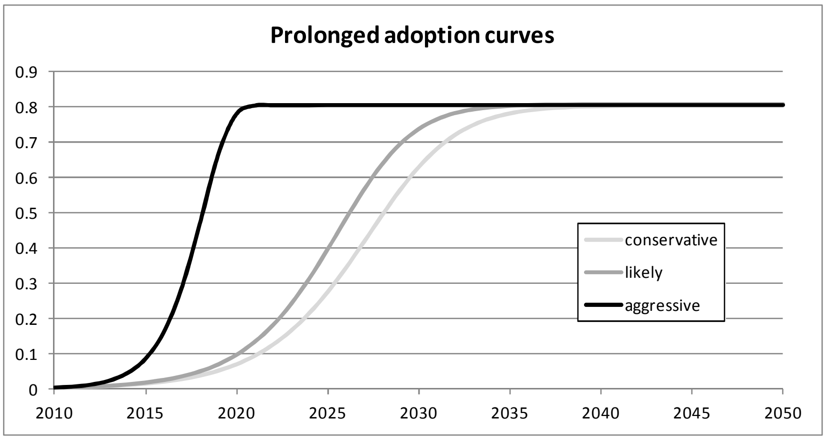


Figure 32: Prolonged adoption curves

When considering discounted cash flows over a period of 40 years (2010-2050, Figure 33), we observe a discounted payback time of less than 40 years in the dense urban scenario, independent from the adoption curve. Also for an aggressive adoption in the urban scenario, we see a positive case in less than 40 years.

When comparing needed monthly revenues over 20, 30 and 40 years for all scenarios (Figure 34), we see that the €10 clearly satisfies the condition of a break even PIP for the dense urban area for all adoption curves after 40 years.

The difference between the business case for 20 years and 30 years is much higher than going from 30 to 40 years. This can be explained by two effects. First, in 2030, the adoption curve hasn't reached its maximum potential, so more customers will subscribe in 2030-2040 (while the number of new subscribers between 2040 and 2050 is negligible). Secondly, the further in the future the revenues are paid, the higher the effect of discounting, and thus the lower the impact on the cumulative revenue. Therefore, we decided not to look beyond a business case of 40 years.

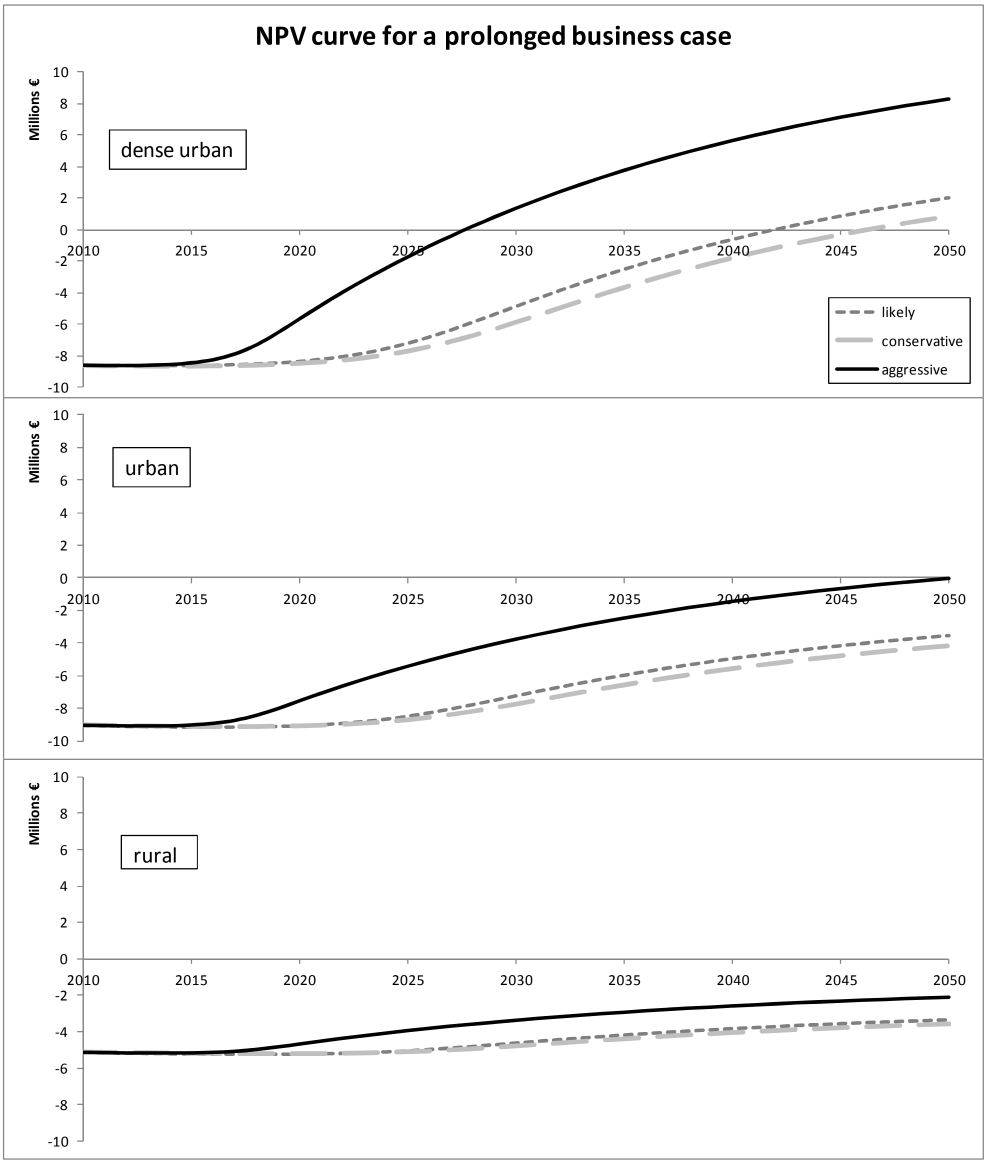


Figure 33: NPV curves for prolonged business cases

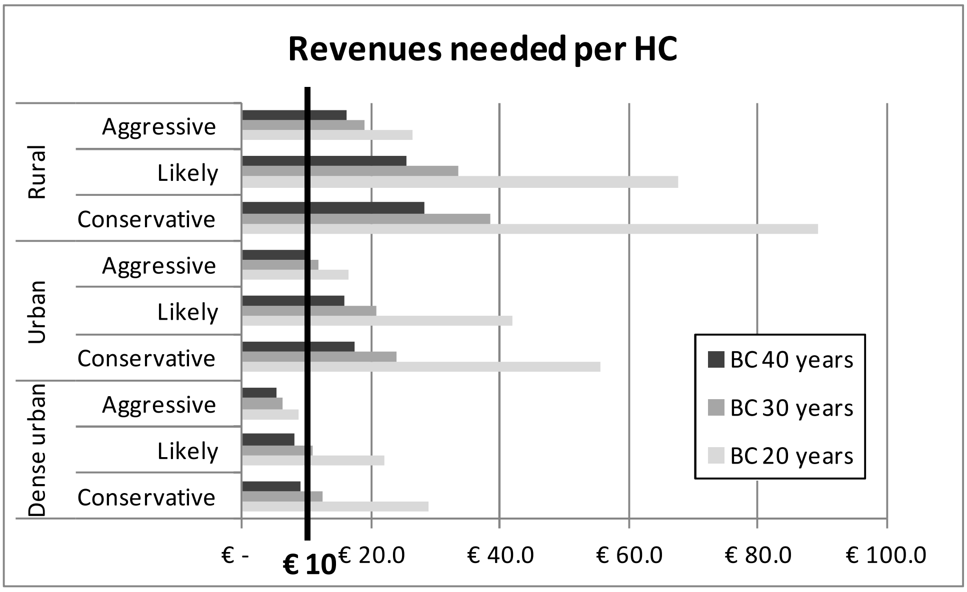


Figure 34: Revenues needed per subscriber per month (for 20, 30 and 40 years planning horizon)

4.3.2.5 Physical infrastructure: in-building versus access network

Thus far we have considered the case where the in-building cost is not included in the PIP solution. However, as mentioned in the introduction, it is possible that the PIP may be directly responsible for this cost or may be responsible for paying another entity for access rights. It is therefore interesting to examine these alternative scenarios. In contrast with the more-likely scenario of the in-building model being recouped by rent or initial sale price (rather than negotiated access from the PIP), we consider the effect of including this cost on the service charge in the chart in Figure 14 below, which shows a Greenfield scenario with a 20year planning horizon and a 5% discount rate for an P2P architecture.

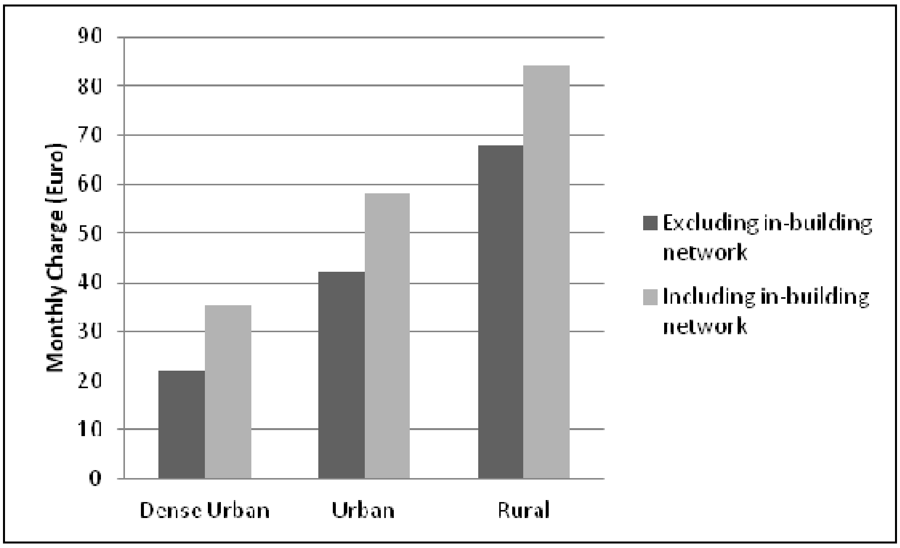


Figure 35: The impact of including the PCP2-PCP3 segment in calculations

From these results it is clear that this segment of the network is responsible for a significant proportion of costs in some scenarios, due to the volume of infrastructure required and its associated maintenance. In Dense Urban scenarios, for example, this can increase the necessary PIP charge from €22 per month to around €35.09 per month.

However, due to the limitations of the geographic model upon which these results are based; the increased costs of such a scenario may be overestimated in Urban and Rural scenarios. This is due to the decreased proportion of multi-dwelling units and the increased prevalence of single-occupancy houses. In the latter scenario, there is no practical distinction between PCP2 and PCP3, although this was made in the techno-economic model in order to provide consistency between scenarios. However, within any multi-dwelling unit (dense urban, urban, or rural) there is clearly a significant increase in cost associated with the need to directly pay for fibre connectivity.

4.3.3 P2MP deployment of fibre infrastructure

Thus far, we have dealt with a P2P PIP scenario as this offers the largest number of business opportunities by which the network may be monetised. However, it is also possible to deploy a point-to-multipoint (P2MP) network. In contrast to the P2P example where each customer has a dedicated fibre channel as far as the local exchange, P2MP employs passive optical devices in the cabinets in order to aggregate multiple customers onto a single fibre.

For example, an AWG may be deployed in the cabinet in order to aggregate wavelengths, resulting in a smaller number of fibres required between the cabinet and the local exchange. An example of this can be seen in Figure 36 below.

Figure 36: P2P vs. P2MP deployment

In order to assess the difference in cost we analyse a Greenfield scenario without node consolidation utilising the WP6 likely demand curve. As differences between dense urban, urban and rural settings might prove interesting, we will analyse for these areas. The cost will be presented as the charge necessary to the customer to pay for the PIP (in €/month). This cost includes the in-building model, representing the scenario identified in Figure 21.

The results can be seen in Table 14 below. For all scenarios, the P2P deployment is more expensive than the P2MP (13% increase in dense urban, 5.2% in urban, 4.5% in rural).

Table 14: P2P vs. P2MP costs for the PIP

Scenario	Cost (€/month)
Dense Urban P2P	8.4
Dense Urban P2MP	7.9
Urban P2P	16.1
Urban P2MP	15.3
Rural P2P	25.2
Rural P2MP	24.1

4.3.4 Impact of economic decision parameters

The evaluation of the PIP project is so far based on a fixed discount rate (5%) without any analysis of the parameter as such. The discussion about the important input parameters and the potential range of values for the discount rate based on the weighted average cost of capital (WACC) can be found in Annex C. Therefore, an analysis of the impact of the WACC range is given hereafter.

Based on the analysis of Annex C, the WACC will be varied from between 0% to 15%, whereas the most probable range will be between 0% and 10% The result based on the complete cost (including CPE) is shown below.

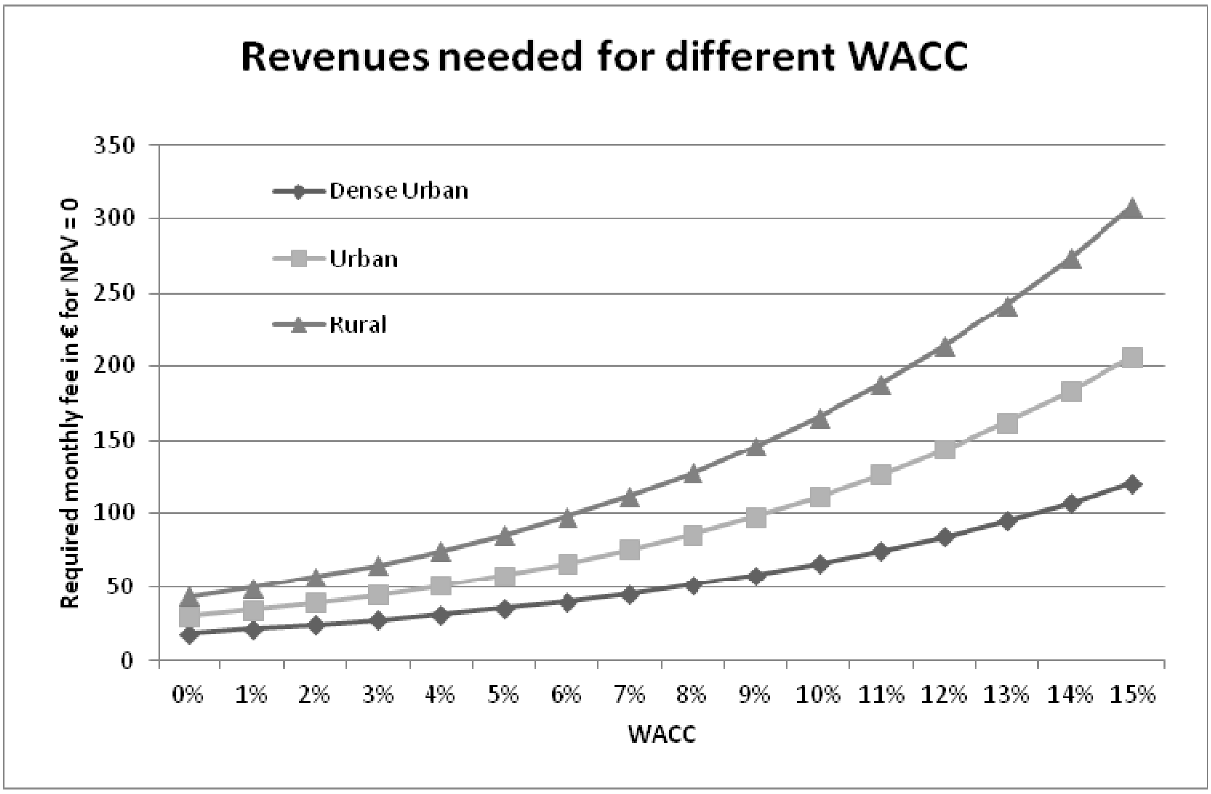


Figure 37: Required monthly fee in € for different area types and WACC (NPV = 0, excluding CPE for the likely adoption curve)

It can be seen that the curves have an exponential slope, which was expected. The level of required monthly fee varies:

- Dense Urban: €18 to €120
- Urban: €30 to €206
- Rural: €43 to €308

It can be concluded that this will end up in a non-profitable business case in most cases for the WACC, only the cases for Dense Urban area type and a WACC between 0% (€18) and 4% (€31) seems to be in a reasonable level. In addition it can be concluded that the most probable range for business case calculations of 0% to 10% has numerous question marks and it is highly recommended to look for other financing options (like the indirect benefits which will be discussed in section 7).

4.3.5 Conclusions on PIP business case

This first quantitative evaluation section provided the business case results for a physical infrastructure deployment, for both P2P and P2MP topologies. We analysed shortly the total cost of ownership for the infrastructure, thereby making the distinction between one PIP covering all PCPs and the case where a separate in-building PIP provides the cabling inside MDUs. The portion of the total cost consumed by the in-building part of the passive network can reduce the total cost by up to 30%. It is logical to exclude the cost for the in-building infrastructure when calculating the business case for the PIP for two reasons. First, the TONIC model assumes MDUs in every area, whereas for urban and rural areas, the portion of MDUs in the total amount of households will most probably be limited, especially in rural areas. Secondly, real-life cases (e.g. in Sweden) show that frequently, the housing organizations invest in the in-building infrastructure and recoup this cost by increases the rental fees amounting to a couple of euro a month.

When investigating the business case for the physical infrastructure in the reference case parameters (see section 4.3.1), while excluding the in-building infrastructure, it is clear that the needed revenues are much too high to fill the investment pit in a 20 year timeframe. Based on an average revenue of max €10 per month per customer, the case is only profitable in a dense urban area with aggressive adoption. In the other scenarios, the estimated payback time clearly exceeds the considered 20 years. The calculations show that there is at least a monthly revenue needed of €16.5 per customer per month for an urban deployment, and even €26.5 monthly per user to cover a rural area.

Taking a closer look at the business case assumptions, we have indicated several potential refinements that improve the case. Demand aggregation ensures a significant market share and therefore revenue immediately after deployment by having interested customers sign a cooperation agreement upfront. A level of demand aggregation of 40% can nearly make all scenarios in urban and dense urban areas profitable. Taking advantage of duct reuse has an important impact on the cost base: and leads to significant decreases of the trenching costs. Another option is to look for other types of customers than the pure residential ones: additional revenues from public institutions or businesses (both large, medium and small enterprises as well as mobile operators) can help to improve the case.

Furthermore, as we are considering an infrastructure investment, it might make sense to prolong the planning horizon beyond 20 years. A discounted payback time of less than 40 years was observed in the dense urban scenario, independent from the adoption curve. Also for an aggressive adoption in the urban scenario, we see a positive case in less than 40 years. Despite all measures discussed above, the business case for the PIP in rural areas seems to be unfeasible. The use of public funds might be required here.

As there are multiple possible actors to take up the role of Physical Infrastructure Provider, and taking into account their different financial and economic background, it makes sense to evaluate the impact of the weighted average cost of capital (WACC) on the business case for the PIP. From the analysis, we can conclude that it is difficult to assess the impact in general terms as it depends mostly on concrete situation (e.g. relationship to parent company, negotiation power, type of industry, desired value step to be taken, etc.). Available databases suggest an industry WACC between 4% and 10%, for financial institutions and even higher WACC of 11%-13%. Public authorities (on a national level) could lend money at rates varying about 1%-8% (assuming Greece is currently out of scope with 17%).

Taking a variation of WACCs of 0% to 15% leads to a huge impact on the needed revenue per user per month (e.g. in the dense urban case varying between €18 and €120).

4.4 Evaluation of the business case for the NP

In this section, we will investigate the business case for a network provider, who is responsible for deploying, activating and operating the active equipment on top of the passive infrastructure. We make the distinction between the traditional architectures (AON and GPON 1:32) and a selection of NGOA architectures (see section 2.3). For the traditional architectures, we consider a planning horizon of 10 years (from 2010 to 2020), since this corresponds more or less to the typical lifetime of active equipment. For the NGOA architectures, we take a planning horizon of 20 years, and consider migration from the traditional ones to the NGOA in 2020 (so that each architecture covers a lifetime of about 10 years).

This section deals with the business case of one NP, meaning that we make abstraction of open access possibilities and competition on NP layer for now (this will be taken up in the section 4.5). We therefore only consider service provisioning costs for new customers (as customers cannot change NPs), and churn on the NP layer is set to zero. Although churn on the service provider layer (SP) is possible, it will not be taken into account here in the evaluation of the NP business case; because we assume that this extra provisioning cost is covered by the SP or paid on a separate basis by the end customer.

We will focus on the evaluation for the business case for the NP for traditional architectures (AON and GPON 1:32) over a planning horizon of 10 years. We will calculate the NPV and needed revenues per customer for the NP for the nine combinations of regions and adoption curves (dense urban/urban/rural x conservative/likely/aggressive) as described in section 4.2**.** Furthermore, we investigate the impact of the CPE cost (which includes the cost for in-house cabling and the ONT and its installation), and look for alternatives to improve the business case. So depending on the scenario under study, the total NP cost contains NP CapEx (Central Office equipment and installation), NP OpEx (operations and recurring costs like energy, maintenance and fault management), Service Provisioning (actual connection of the customers) and CPE costs (in-building infrastructure and ONT, as well as operational expenditures related to those).

4.4.1 AON

The first architecture under study is AON: an active optical network in which each end-customer is served by a dedicated fibre from the central office. We will first give an overview of the TCO for an NP, to continue with the evaluation of the NPV and needed revenues for multiple scenarios.

4.4.1.1 TCO for the NP

When evaluating the TCO for the NP (Figure 38), it becomes clear that this cost is much lower than the cost for the PIP (see section 4.3.1.1). It is furthermore much more influenced by the actual customer uptake, which can be explained by the fact that the NP only installs new equipment the moment it is needed (i.e. when new customers subscribe), while the PIP deployed everything in the beginning of the planning horizon.

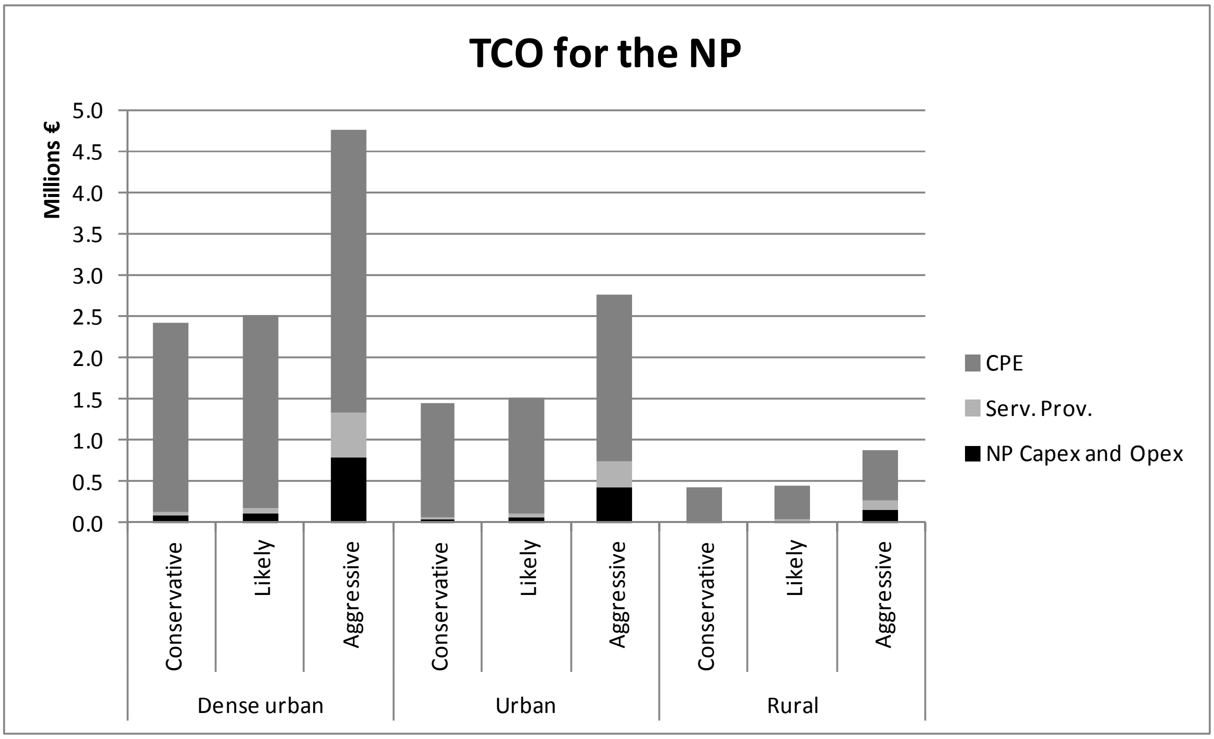


Figure 38: TCO for the NP, including NP, CPE and Serv. Prov. cost (cumulative and discounted with 10% after 10 years)

The share each of the three costs takes up is also interesting to evaluate in more detail: the CPE cost is definitely the highest, and doesn't vary too much with the adoption curve, while this impact is more visible in the NP and Serv. Prov. cost.

This can be explained by investigating the cost breakdown in more detail. As mentioned before, the CPE cost consists of the cost for the in-house cabling and the cost for the ONT (including installation). While the ONT cost is incurred only when the end-customer actually subscribers, the cost for in-house cabling (better understood as in-building cabling: providing the cables between households in Multi-Dwelling Units) is largely upfront (e.g. when one house organization decides to fibre up all its buildings). The ONT related costs in the CPE will therefore be impacted more by the adoption, while the upfront in-house cabling installation is to a large extent independent from the adoption curve (Figure 39).

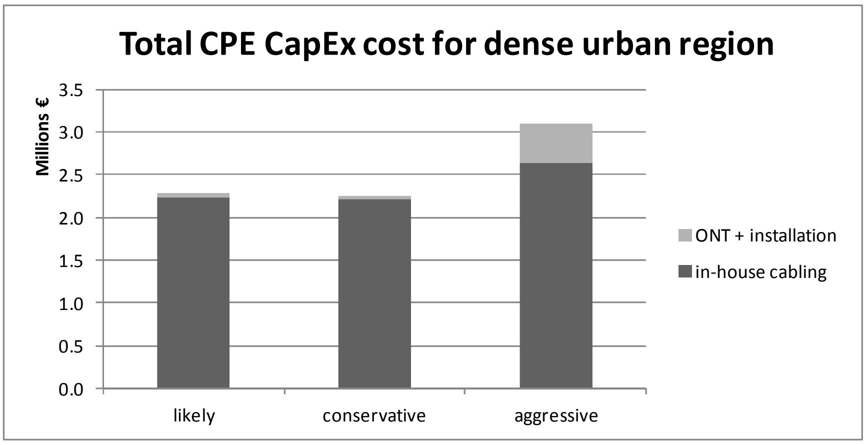


Figure 39: Cumulative and discounted CPE cost for the dense urban region (10 years period, discount rate of 10%)

The impact of the adoption curve on both CapEx and OpEx costs of the NP, as well as on the service provisioning is shown in Figure 40 (an example for the dense urban area and aggressive adoption curve). The S-shaped adoption curve can be clearly seen from this graph and thus reflects the time-dependent expenses of the NP. It is exactly this time- or customer-dependency that differentiates the business case of the NP from that of the PIP: for a large part, the NP costs will only be made from the moment he has ensured revenue, while the PIP has to hope for a high subscription rate to recoup its huge upfront investments. This leads to a higher uncertainty for the PIP business case, which therefore is subject to higher risk.

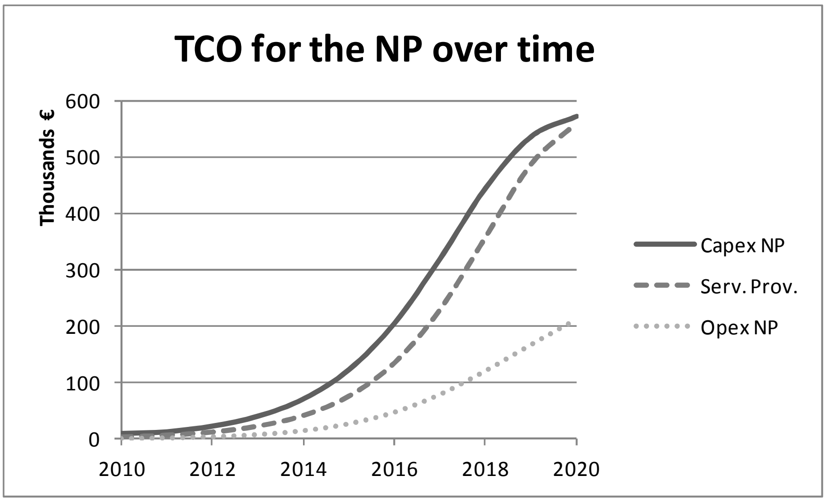


Figure 40: Cumulative and discounted NP and service provisioning cost for the dense urban area, aggressive adoption curve

4.4.1.2 Evaluating the business case for the NP

Keeping the cost analysis as described above in mind, this paragraph will investigate the business case for the NP, i.e. will compare the costs with the expected revenues.

When using estimated monthly customer revenue of €10, Figure 41 shows that the business case for the NP is not economically viable. The NPV is negative in all scenarios, and doesn’t seem to improve on the long run. This can be explained when returning to the cost breakdown described in the previous paragraph: the large investment pit in the beginning of the planning period is due to the in-house cabling cost that the NP makes upfront, while the extra costs incurred later in the planning period are due to the ONT costs and installation. Although amelioration is seen at the end, it doesn’t cover for the high initial pit. The curves are quite similar for the different areas and adoption forecasts (Figure 41), it’s only the debt of the curve that is different. As will be concluded later is this paragraph, this can be explained by the dependency of the overall NP cost on the number of subscribers.

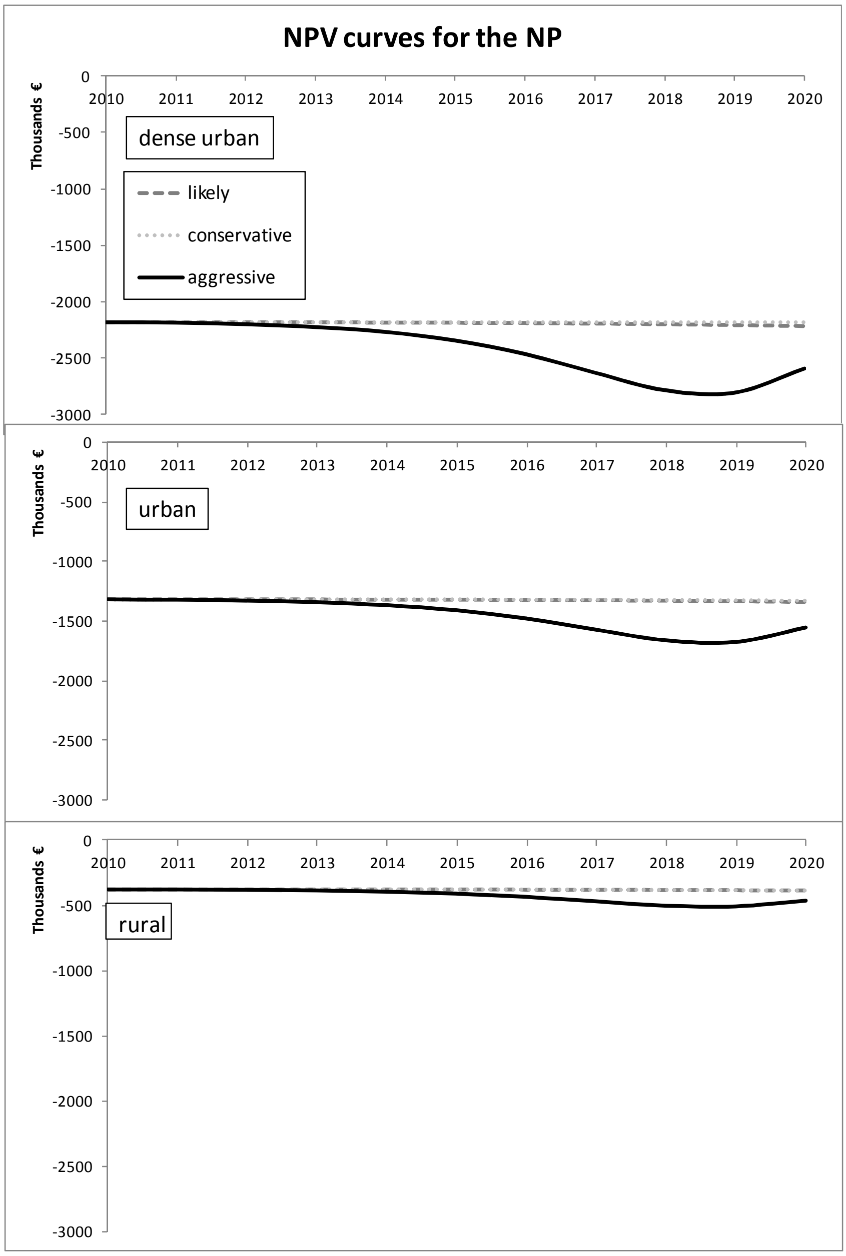


Figure 41: NPV curves for the NP business case (likely and conservative curves are coinciding)

It is clear that €10 per customer per month will not suffice to cover the business case for the NP (with the forecasted adoption curves and planning horizon), but how much is needed then? Figure 42 provides the answer: in the aggressive adoption scenario at least around €21 per customer per month, in the likely adoption €75-90 and in the conservative even €90-110! It is thus clear that the business case for the NP in these economic conditions does not fly!

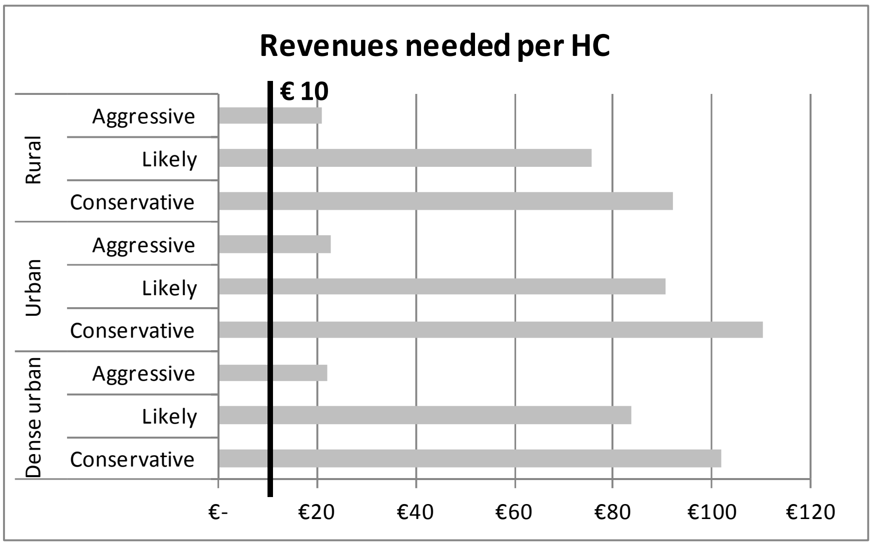


Figure 42: Needed revenues (per customer per month) to arrive at a positive business case for the NP after 10 years, including CPE cost

4.4.1.3 Possibilities to improve the business case for the NP

From the previous analysis, it has become clear that in the assumed conditions, the NP will never have a positive business case. Other paths should therefore be explored to verify what can be done to improve the business case. This paragraph will discuss several possibilities, like charging the customer an upfront fee to cover for the high CPE cost, prolonging the planning horizon, ensuring a higher adoption uptake by demand aggregation etc.

Recouping the CPE cost by charging an upfront fee

From Figure 38, it is clear that it is the high CPE cost that makes the business case so negative. This paragraph will therefore focus on finding other ways to recoup this high costs.

As seen from Figure 39, the CPE cost mainly consists of two parts: the in-house cabling on the one side, and the ONT including installation on the other. Both also incur some operational expenses for fault management and energy consumption (but those are only minor).

How to recoup the in-house cabling cost?

As described above, the in-house cabling is mainly done upfront, when a group of building owners or housing organizations decide to wire their buildings with fibre. This wiring can be done by the PIP, by the housing organization itself, or by the NP. It therefore can be the responsibility of the NP, but this is not necessary. Furthermore, this responsibility is only applicable for multi-dwelling units, since for single houses, the fibre will most likely end at the front door of the customer’s premises.

In this case, we assume that the in-house cabling is asked for by the housing organizations, and consequently paid by them. The housing organizations themselves can then recoup the costs by increasing the rent for the apartments with a couple of euro a month.

If we assume 50% of the people living in MDUs, the housing organizations there would have to increase their monthly rent with €3-€4.50 (for everyone, independent of their actual subscription to the FTTH network), depending on the area, which is a marginal increase when compared to the average monthly rentals for apartments across Europe.

How to recoup the cost for the ONT and its installation?

When a customer decides to subscribe, a socket and ONT should be installed in his home to ensure the end-to-end connectivity. When comparing to current VDSL or DOCSIS installations, operators frequently charge the customer's a one-off installation fee. It thus makes sense to investigate how much this fee would need to be in the case of FTTH ONT installation.

When taking into account that this upfront cost should cover for the ONT, its installation and the possible operational expenditures over a period of 10 years, an upfront charge of about €50 - €55 should be charged to each customer, which is reasonable and comparable to the upfront fees charged by DSL or DOCSIS operators nowadays. It furthermore is not too high, because this fee is charged in the same time period (year) in which the cost for it is made. If costs are only recouped in a later stage, the impact of discounting makes that a much higher fee should be paid then.

What is the impact of excluding CPE costs on the business case for the NP?

Following the results of the extra upfront charge and monthly rental increase, which can be assumed as reasonable, we decide now to leave them out when calculating the business case for the NP. The updated NPV curves, which now only include "true" NP and service provisioning costs, are shown in Figure 43 (for a monthly customer revenue of €10). It is clear that this evaluation definitely is better from an economic point of view, the business case is positive in every scenario.

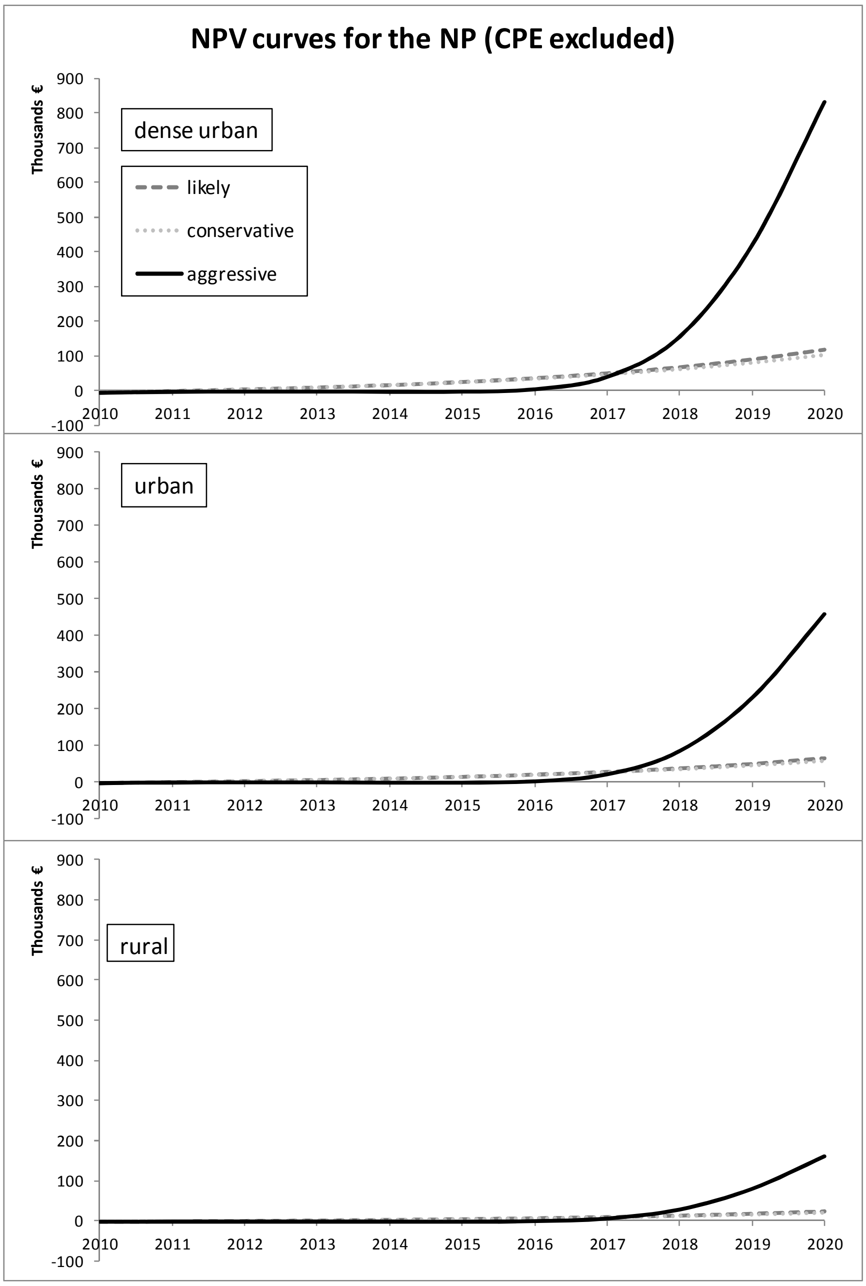


Figure 43: NPV curves for the NP business case (excluding the CPE costs, likely and conservative curves are coinciding)

Using estimated monthly revenue of €10 per customer, the results are positive, but how many revenues are now exactly needed? The answer is given in Figure 44: €5.75 - €7.50 per user per month, depending on the area and the adoption curve. Although the difference in between area types and uptakes are much smaller than for the PIP results, there is a trend in these dependencies on area type and adoption curve. Similar to the PIP, the cost for deploying active end-to-end connectivity in a dense urban area is cheaper than in a rural area, and thus the needed revenues there will be lower. When looking at the adoption curve on the other hand, we see a different trend: the higher the uptake, the higher the needed revenue. This can be explained by the impact of discounting: in case of the aggressive curve, customers are connected earlier on, so that, although the absolute cost is the same, the discounted cost is higher.

How come these charges are so much lower than the one presented in the business case for the NP including the CPE costs? An explanation can be found in the way the costs are recouped:

- The upfront in-house cabling is recouped by letting ALL households pay a higher rent if the MDU is fibred up, even if the household itself doesn't subscribe to the network (and thus decides not the take an internet subscription). Dividing the high in-house cabling cost by all residents leads to a very low extra fee (a couple of euro per month), in comparison to a very high fee for the few FTTH subscribers.
- The ONT cost is recouped at quasi the same moment as it is made, which filters out the impact of discounting (i.e. if fees are paid during a later period in time, they are less worth because the value of money decreases over time).

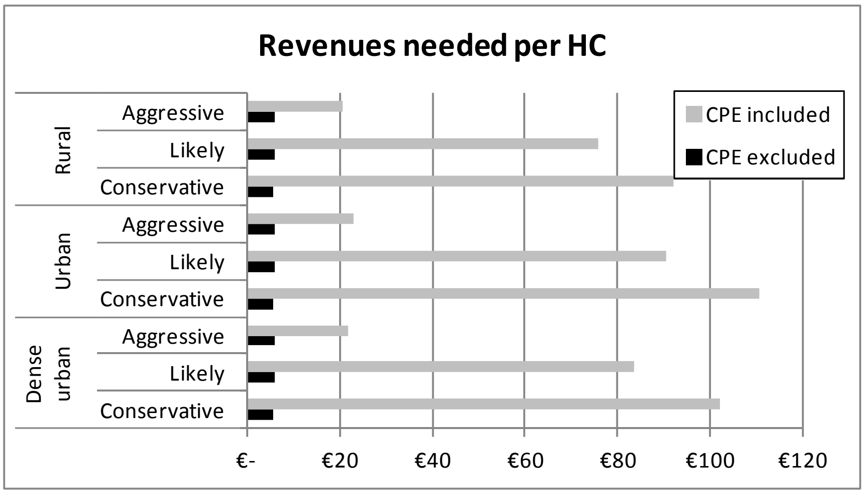


Figure 44: Needed revenues (per customer per month) to arrive at a positive business case for the NP after 10 years, for the case including CPE costs and excluding CPE costs

Demand aggregation to ensure take-up from the beginning

Although recouping the CPE costs in one or another way is the most likely option to improve the business case for the NP, we also investigate the impact of demand aggregation: what is the impact on the business case if there is an ensured take-up of 20% or 40% from the beginning of the project?

Figure 45 (example of the aggressive adoption curve) shows that there is clearly an improvement to the business case if there is a demand aggregation of 20% or 40%. In the case of 40%, the NPV is almost positive after 10 years for the dense urban and urban regions, and even absolutely positive for the rural regions. The difference in between regions can be explained by the fact that, for the rural region, there is less in-house cabling needed since there are not so many MDUs.

The revenues needed per customer per month shrink sharply to about €13 for the aggressive adoption curve with 20% demand aggregation, and even to around the assumed €10 per customer per month for 40% aggregation of demand from the start.

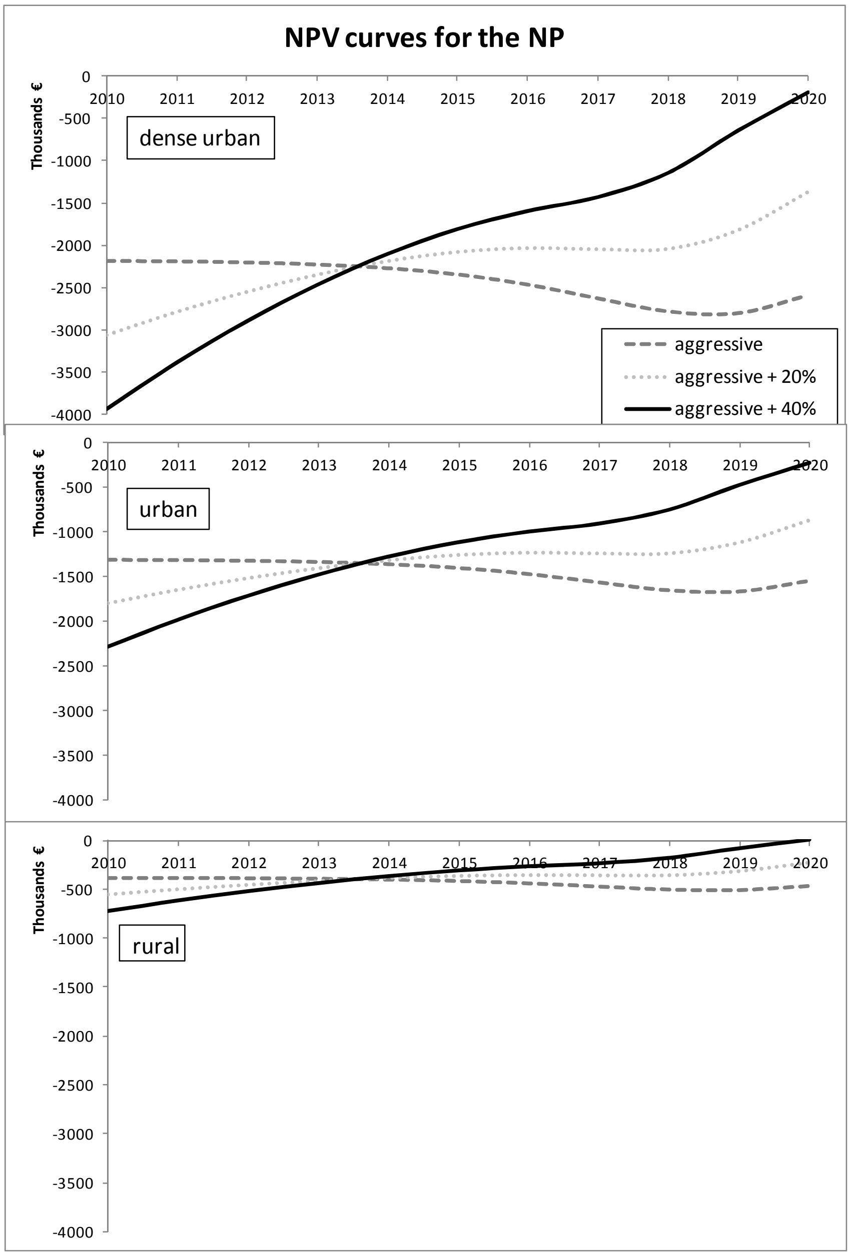


Figure 45: NPV curves for the NP business case (including CPE costs) for a demand aggregation of 0%, 20% and 40% and an estimated revenue of €10 per user per month

4.4.2 GPON 1:32

The second architecture under study is GPON, an optical network which has a dedicated fibre between the customer and a passive, power splitter based aggregation point and a shared fibre from that point on. The analysis concentrates on a 1:32 power splitter resulting in an on average maximum bandwidth per customer about 80 Mbit/s. It should be noted that this is much lower than the 150-500 Mbit/s detailed in D2.1 [60], but sufficient for the calculation time frame of 10 years. Similar to AON, an overview about TCO for the NP, a calculation of NPV and needed revenues for different scenarios will be given.

4.4.2.1 TCO for NP

Similar to the AON architecture, the total cost of ownership includes three main parts: the actual network provider costs, the customer premises equipment and the cost for service provisioning with the same cost split as detailed for AON in section 5.3.1.1. The overall cost is shown in Figure 46 below. Overall, one can conclude that the cost is similar to the AON case, slightly lower or higher. When evaluating this cost in detail, it becomes clear that this cost is much lower than the PIP cost (see section 4.3.3). It is more influenced by the customer take up, there as dimensioning rules for GPON systems are some kind of worst case scenario with technology investment in the beginning and a more OpEx driven approach in the end. Here, AON deployments scale better with customer demand. So in reality, costs will be lower for GPON based on an improved deployment strategy (see further in section 4.4.3).

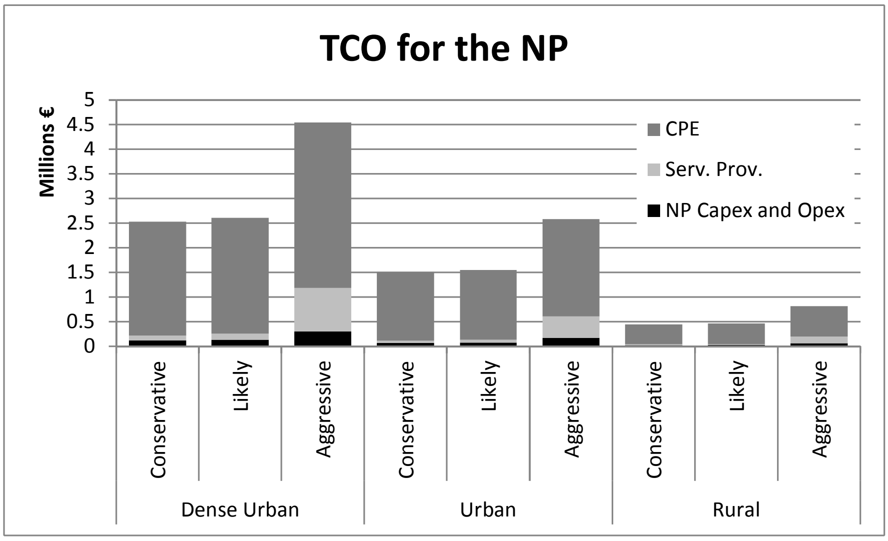


Figure 46: TCO for NP based on GPON 1:32, all cost included (discounted with 10% after 10 years and cumulated)

The split in between the different cost groups is similar to the AON case: the CPE costs are the most dominant costs (and are required partly in the beginning of the deployment, followed by service provisioning costs and the relative low costs for the network provider itself. As a proof of concept, the CPE costs are detailed below in Figure 47.

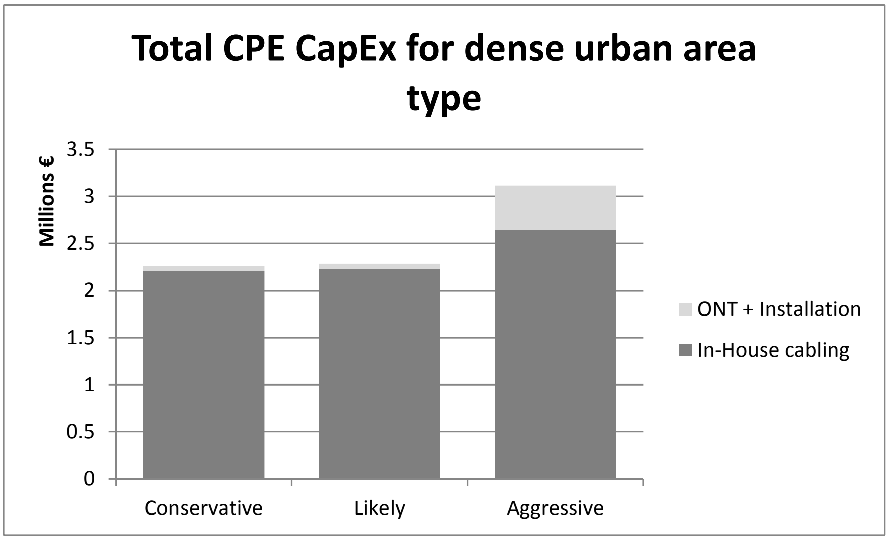


Figure 47: Split of CPE cost for the dense urban area (discounted with 10% after 10 years and cumulated)

The impact of the adoption curve on OpEx and CapEx of the NP as well as the service provisioning costs is presented in Figure 48. Please note that the cost for in-house cabling is excluded. The shape of the curve is to some extent like an S-curve and follows in principle the adoption curve. Again, it is exactly this time- or customer-dependency that differentiates the business model of the NP from PIP. Revenues and cost are associated to each other and there is a lower gap in risk and financing the whole business.

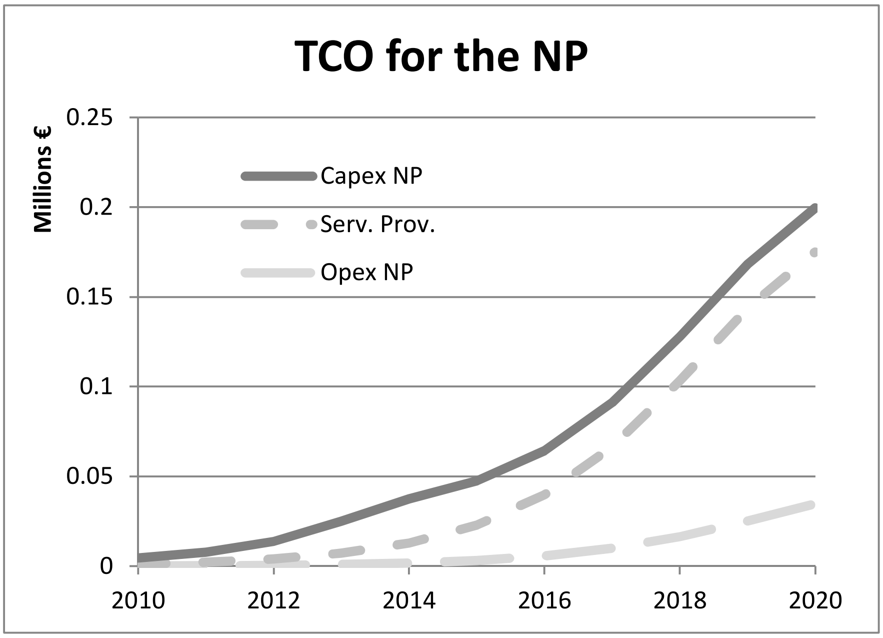


Figure 48: NP and service provisioning cost for dense urban area with aggressive adoption (discounted with 10% after 10 years and cumulated)

4.4.2.2 Evaluating the business case for the NP

Keeping the cost analysis as described above in mind, this paragraph will investigate the business case for the NP, i.e. will compare the costs with the expected revenues.

When using estimated monthly customer revenue of €15, Figure 49 shows that the business case for the NP is not economically viable. The difference to the graphs in of the AON section is that the revenue is increased to €15 instead of €10. The €10 level would be similar to the business cases based on AON, just with a slightly lower negative level. But the €15 estimation for the aggressive case shows already that there is a potential to bridge the gap to a positive business case. Again, the effect of the long run and slow improvement of the business case (starting in year seven or eight) can be explained when returning to the cost breakdown described in the previous paragraph: the large investment pit in the beginning of the planning period is due to the in-house cabling cost that the NP makes upfront, while the extra costs incurred later in the planning period are due to the ONT costs and installation.

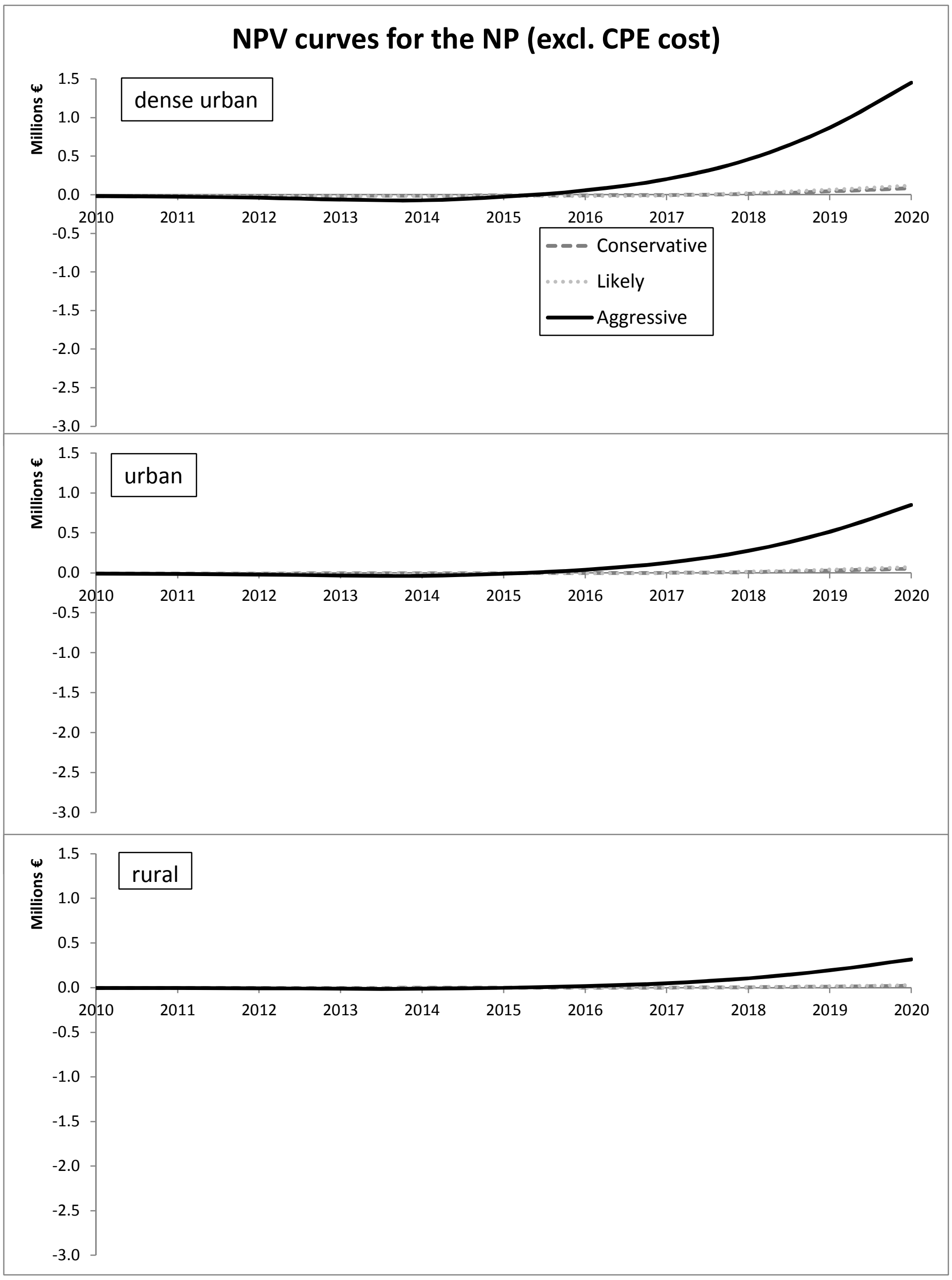


Figure 49: NPV curves for the NP business case based on GPON 1:32 (€15 monthly fee, likely and conservative curves are coinciding)

It was already clear that €10 is not sufficient for a positive business case due to the similar CapEx and OpEx of AON and GPON 1:32. In the previous section, the NPV calculation included a €15 fee per month and the aggressive adoption forecast is close to zero NPV (meaning 10% return on invest). The detailed required monthly fee could be found in Figure 50. The aggressive curve leads to needed revenues in the order of €15.70 to €17.30, whereas all other are in the order of €62-90. This could be explained by the required network equipment dimensioning rules and the upfront investment for the CPE.

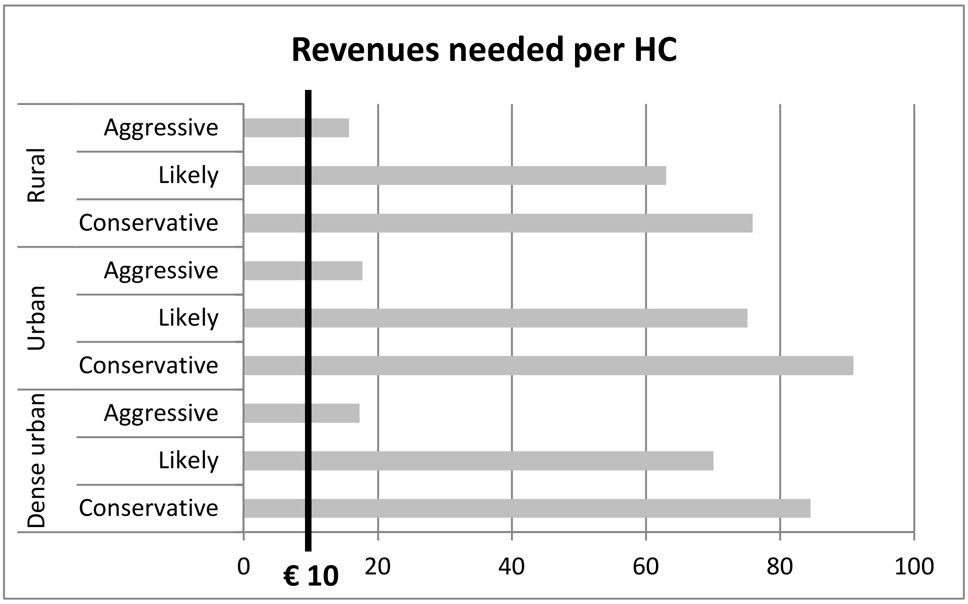


Figure 50: Required revenues for a positive NPV business case after 10 years (10% discount rate and constant monthly rate per customer)

4.4.2.3 Possibilities to improve the business case for the NP

From the previous analysis, it has become clear that in the assumed conditions, the NP has a lot of uncertainties for a positive business case. Other paths should therefore be explored to verify what can be done to improve the business case. Similar to the AON analysis, these are

- Prolonging the planning horizon
- Recouping the CPE cost by charging an upfront fee
    - For in-building network
    - For ONT
- Higher adoption uptake by demand aggregation

The first point seems to be difficult. Besides in-house cabling, the majority of investment is into technology with a high degree of upfront into the network sided equipment in the first three years. This means that the technology will have to work for a time frame of 7-10 years which is a relative long time frame and it seems unreasonable to assume that no replacement is required in the next five, ten or even twenty years. Second, even ten years are a relative long time frame for an investment of a privately owned company, whose services typically have contractual durations of two years.

The second bullet is split into two parts, as already detailed in 4.4.1. The argumentation would be the same for GPON. Overall, that would reduce the required monthly fee for the NP significantly, as shown in

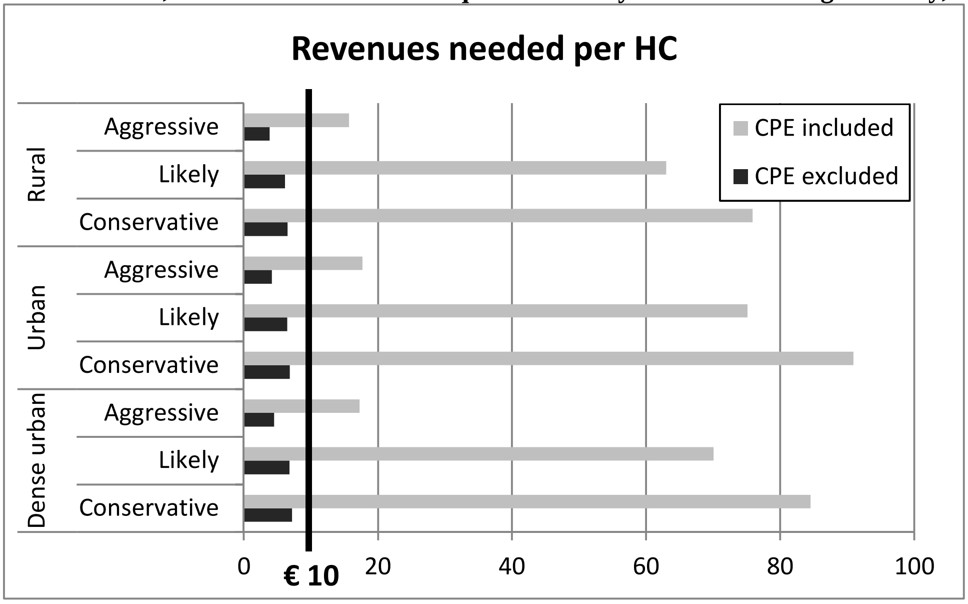


Figure 51. The resulting monthly fees are in the order of €3.80 to €7.20.

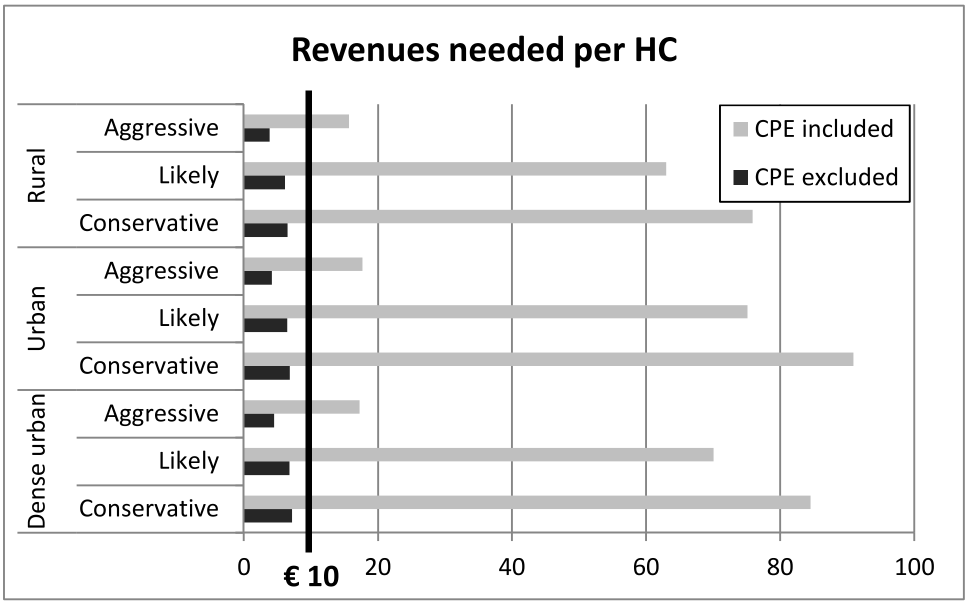


Figure 51: Required revenues for a positive NPV business case after 10 years (10% discount rate and constant monthly rate per customer)

The third aspect on demand aggregation was covered in the AON case, too. For completeness, the modified NPV curves are shown in Figure 52 below. Obviously, the enhanced income improves the business case, so that any aggressive adoption is reaching break even before 2015, the likely adoption forecast in 2019 and even the conservative adoption forecast provides a very positive trend and reaches a break even in the end of the time frame under investigation (not shown in Figure 52).

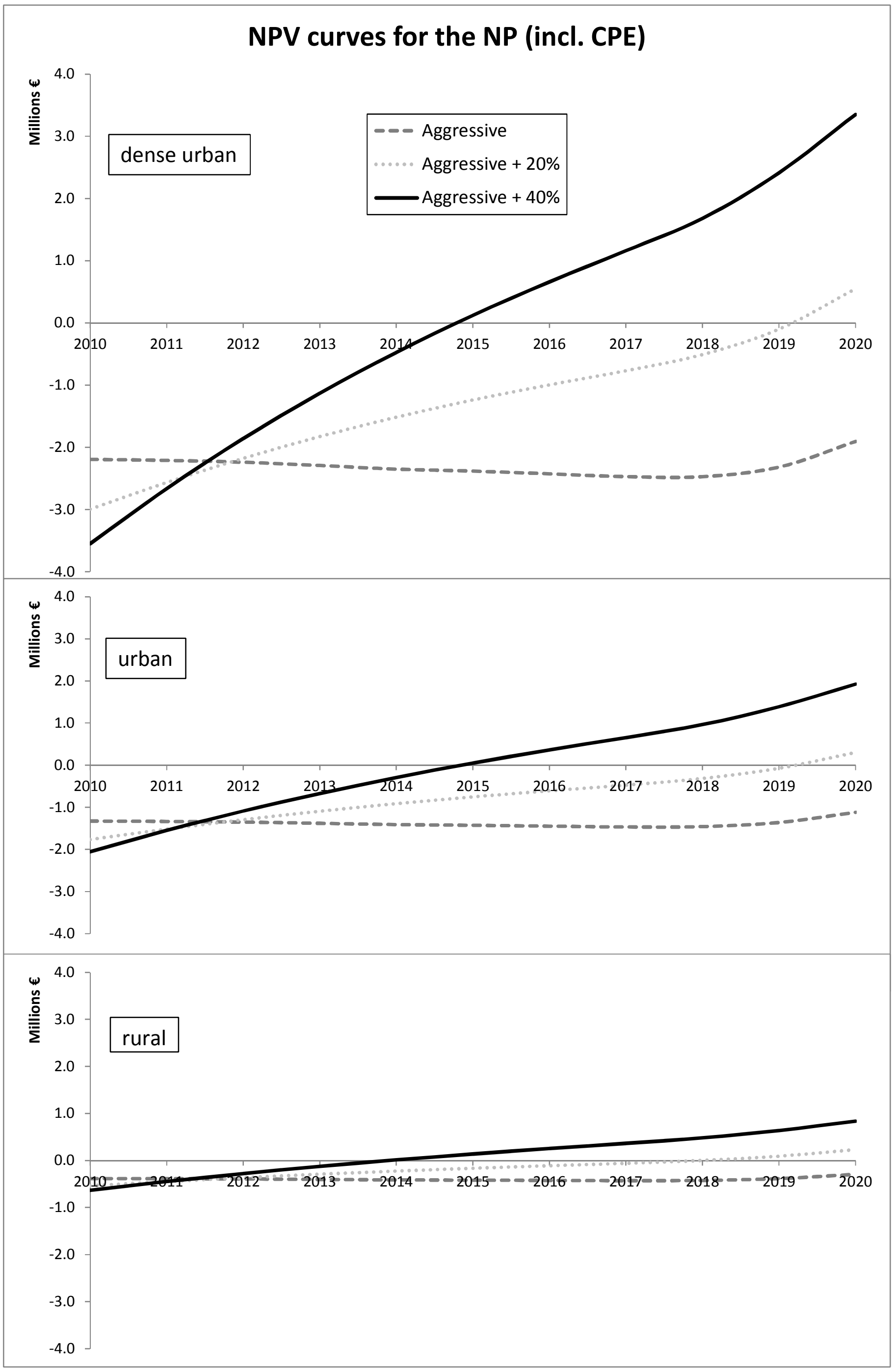


Figure 52: NPV curves for the NP business case based on GPON 1:32 and demand aggregation with 20% and 40% in 2010 (€10 monthly fee, 10% discount and cumulated)

4.4.3 Impact of demand aggregation with cherry picking on the business case for both NGOA technologies

The previous two sections detailed the business case for the AON and GPON 1:32 deployments in a time frame of 10 years (2010-2020). However, the outcome of this investigation was not always too positive. We will therefore in this section investigate other ways to improve the business case, namely by using the demand aggregation discussed before in conjunction with cherry picked rollout, and compare the impact of this suggestion for a selection of different technologies studied in OASE.

The geographic model, as described in WP5 [58], defines the service area of the NGOA under study, including the subscriber count. As demand increases, defined by the adoption curves identified within WP6 and detailed in D6.2 [54], these potential subscribers connect to the network. The tonic tool assumes that this demand is uniform; there is equal possibility of any particular client connecting to the network.

Unfortunately this is not realistic. It is likely that certain areas will be sources of higher demand than others, based on the socio-economic status of their inhabitants. Given this understanding, it is possible to build on the work on demand aggregation above by showing how an operator might take advantage of high demand by cherry picking such areas.

This may provide significant cost savings, as well as provide a differentiating factor between the architectures. Architectures with higher fan-out, for example, may suffer more under such a scheme as the benefits of smaller deployments cannot be realised because of excessively high equipment dimensioning needs.

In order to evaluate the expected benefits, the following scenarios were defined. Firstly, we define a "uniform" scenario where there is an equal chance of subscribers arising from anywhere in the network. Customers are connected to the network as soon as they demand. This closely models the assumptions of tonic, and can be seen in Figure 53 below.

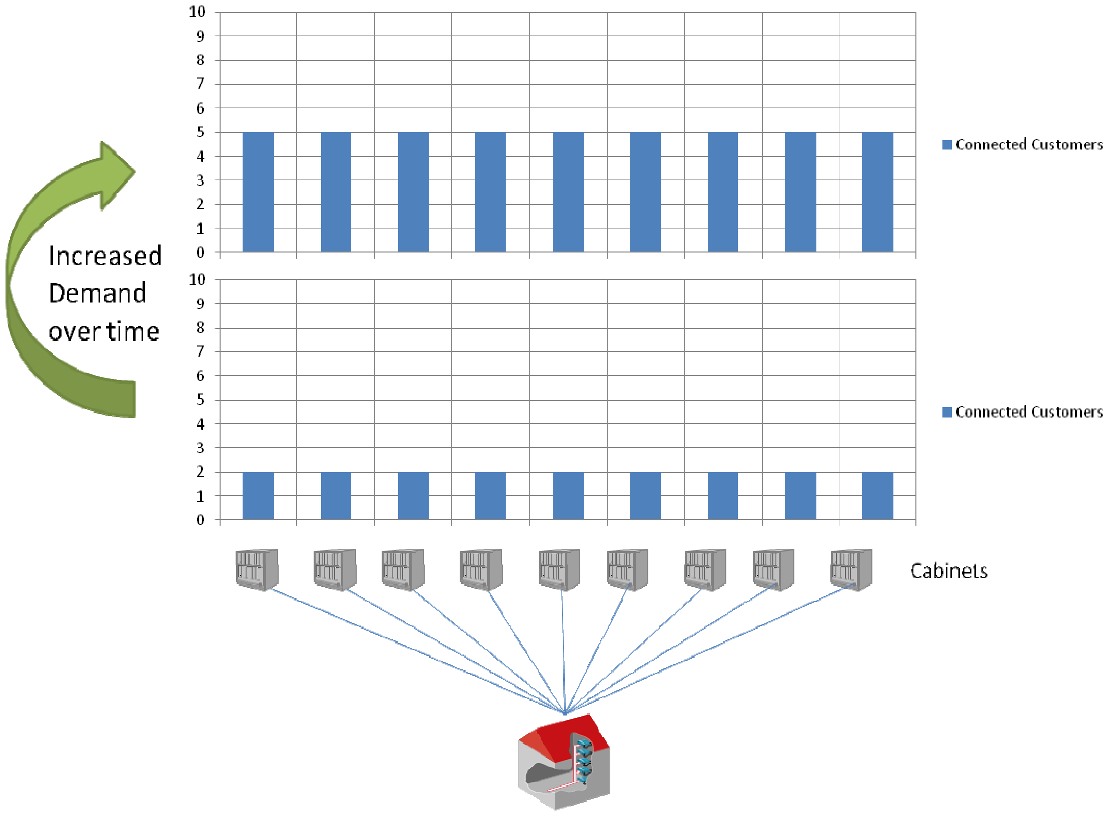


Figure 53: The evolution of customer connections over time for a uniform scenario with no demand aggregation.

Secondly, we define a "uniform scenario with demand aggregation" scenario. In this instance, there is a uniform chance of demand arising in any part of the network. However, rather than being instantly connected to the network, subscriber demand is recorded and the customer is placed on a waiting list. Once this waiting list passes a threshold, the customers on the waiting list are connected and future connections are instantaneous. We define the threshold at 32.4% as this is similar to the threshold utilised by Reggefiber and an easy scenario to implement in the simulator, and consider the area as all customers connected to a particular cabinet. This can be seen in Figure 54 below.

Figure 54: The evolution of customer connections over time for a uniform scenario with demand aggregation

Finally, we define a "triangular with demand aggregation" scenario. This follows the same mechanic as the "uniform with demand aggregation scenario", but instead of customer demand being uniform we assume that it is triangularly distributed over the entirety of potential subscribers. This leads to high and low demand areas, where the high demand areas will be provisioned first. This should lead to a more-organic rollout that better matches the real-world case. This can be seen in Figure 55 below.

Figure 55: The evolution of customer connections over time for a triangular scenario with demand aggregation

All these scenarios were defined using a dense urban environment, with no node consolidation, and utilising the "likely" demand curve and the medium bandwidth evolution curve.

All aggregation scenarios may lead to a delay in rollout due to the lag incurred while waiting for demand to aggregate. In order to investigate the deployment over its natural ten year life, it is therefore necessary to show results that extend beyond the 2030 timeframe where deployment begins after 2020.

In order to investigate how this might affect the choice of network technology, especially where those technologies differ by fan-out, we investigate three distinct examples: P2P NG AON, 32 wavelength WS WDM PON and 80 wavelength Hybrid PON employing 1:16 optical splitters.

4.4.3.1 Analysis of geographic demand distribution

Firstly, we will analyse the potential benefit of cherry picking utilising only a single network technology. For this scenario, WS WDM PON was chosen as it represents an interesting middle ground between the low fan-out (NG AON, 1:1) and high fan-out (Hybrid PON 1:1280) technologies.

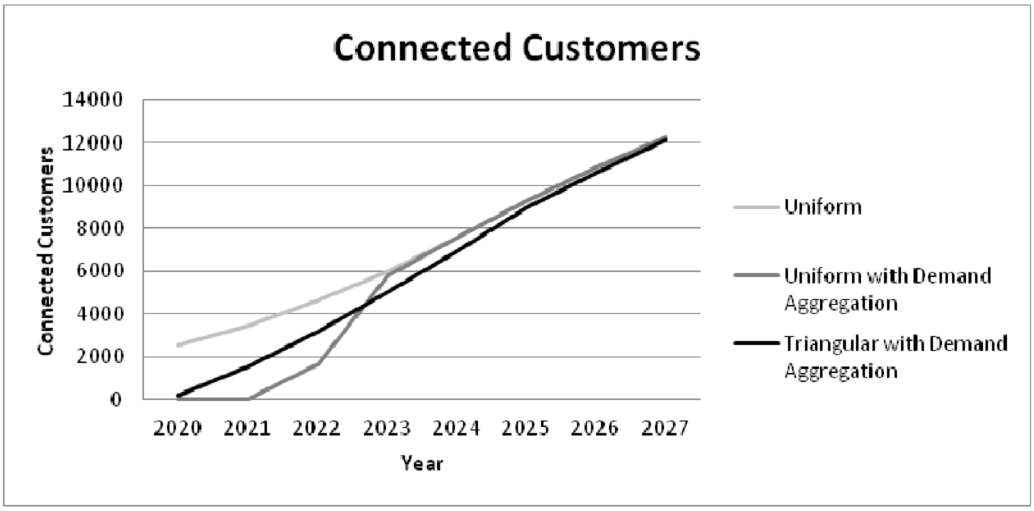


Figure 56: Connected customers for WS WDM PON in the three scenarios

Figure 56 above shows the uptake in the three demand scenarios. The uniform scenario perfectly mirrors the demand curve; customers are connected as soon as there is demand. The "uniform with demand aggregation" curve shows the delay incurred while waiting for demand to pass thresholds in the cabinet areas. This delays the start of rollout by a year, and contributes to slow rollout until year 2023. The "triangular with demand aggregation" scenario tends towards the demand curve over time as cabinets become "NGOA enabled" and their uptake profile comes to mirror their demand profile.

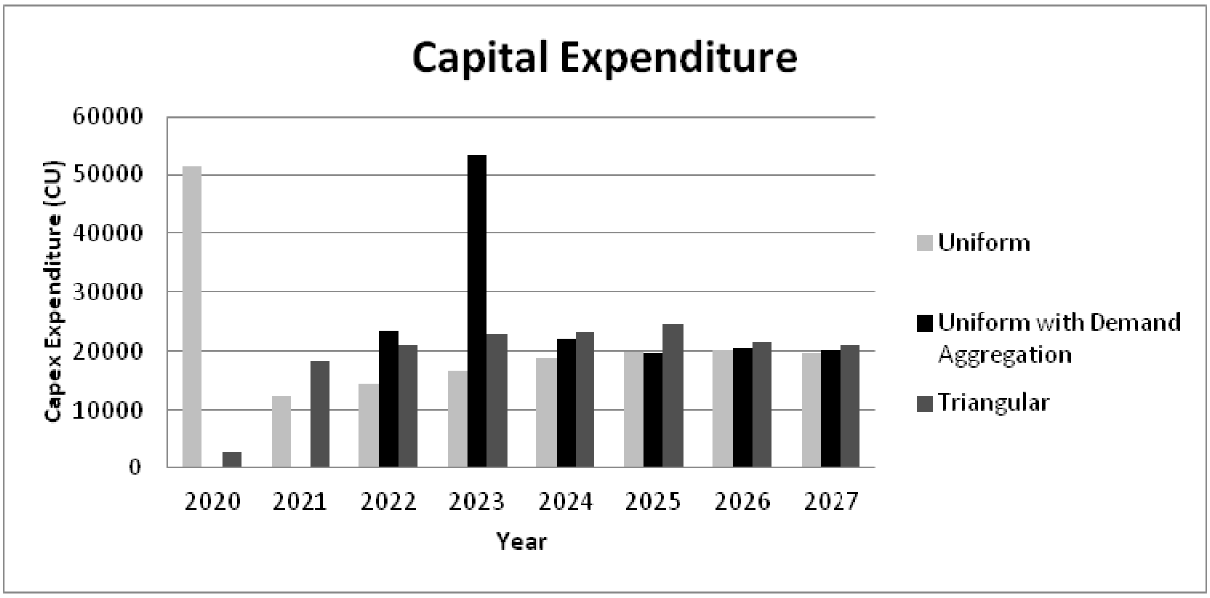


Figure 57: Capital expenditure for WS WDM PON in the three scenarios

Figure 57 above shows the capital expenditure incurred in each of the three scenarios. The uniform scenario shows the characteristic high up-front cost that is necessary to provide service to a small number of customers who are not topologically localised. This is problematic, as the equipment is extremely under-utilized, it consumes energy and contributes to failure costs while having low income attached through customer subscription costs. Adding demand aggregation reduces this profile somewhat, but is nonetheless associated with a large increase in cost in 2023. This is natural; without demand being varied by topology location, demand aggregation merely delays the rollout and does little to limit the initial cost spike. The triangular scenario, however, is much more natural. There is no high spike in costs with the associated under-utilisation of equipment.

In order to investigate this effect more closely, we calculate the service charge necessary to support the NP by solving for 0 NPV as has been done in previous studies. For the specific case of uniform demand with aggregation, we consider a 10 year timeframe from 2022 until 2032. The other scenarios utilise the standard 2020-2030 timeframe. This does somewhat complicate the comparison of the results, as the "uniform with demand aggregation" utilises the higher-value years in 2031 and 2032, where subscriber count (and therefore income) is high. These results can be seen in Table 15 below.

Table 15: Benefits of deployment scenarios for WS WDM PON

	Uniform	Uniform with Demand Aggregation	Triangular with Demand Aggregation
Necessary Revenue (€)	12.21	10.57	11.61
Percentage reduction compared to Uniform		13.4%	4.9%

The results show a modest reduction in the necessary customer charge when examining the triangular scenario. The uniform scenario employing demand aggregation does show higher benefits, but this comes with a cost of later deployment time.

4.4.3.2 Technology analysis

Comparing the benefits of demand aggregation across technologies poses problems. Because of the different absolute costs of the network scenarios, it is important to analyse the relative cost savings that are possible. Therefore, the percentage reduction introduced in Table 15 will be employed in this analysis. The percentage benefit (over the uniform scenario) when utilising uniform and triangular demand aggregation for NG AON, WS WDM PON and Hybrid PON can be seen in Table 16 below

Table 16: Technology response to demand aggregation and cherry picking

	Uniform with Demand Aggregation	Triangular with Demand Aggregation
NG AON	4.9%	-5.1%
WS WDM PON	13.4%	4.9%
Hybrid PON	8.7%	-0.6%

These results are fascinating, if they seem unusual at first. First of all, it is important to note that, for all network architectures, there is a benefit in the usage of demand aggregation in the uniform scenario. This benefit is more pronounced for WS WDM PON, where the fan-out (32) corresponds well to the aggregation threshold, which (in a dense urban scenario) corresponds to 50 connections per cabinet. The results of Hybrid PON are less pronounced because each remote node can support 1280 clients. There is, therefore, correspondingly less potential for optimisation with hybrid PON. NG AON shows the fewest benefits of uniform aggregation; its natural support for low connection counts means that the main benefit is delaying rollout to take advantage of the high subscription count in 2031 and 2032.

The results of the triangular distribution analysis are more interesting. Here, we can see a fascinating artefact: NG AON becomes less cost effective when utilising triangular demand with aggregation. This is due to the reduction in the uptake profile (as can be seen by the number of connected customers in Figure 56. As mentioned earlier, P2P NG AON does not suffer at low penetration – it is extremely simple to scale and does not require the high initial investment of the PON solutions as discussed earlier which necessitates demand aggregation. Therefore, employing an aggregated rollout strategy only serves to reduce the demand - until demand reaches 30% no-one in an area is connected and this demand is unrealised. This scenario is, therefore, not one that would ever be utilised in real life for this network architecture.

Hybrid PON too becomes slightly more expensive in the triangular scenario. This highlights the importance of fan-out and how it relates to the aggregation threshold. In the model employed here, utilising per-cabinet decisions, the high-fan-out of the Hybrid PON means that, in some instances, a PON capable of supporting 1280 customers needs to be provisioned to support just 50. Utilising a larger aggregation area, where the area size more-closely matches the fan-out of the equipment, may result in similar savings to the WS WDM PON. However, this may lead to an increase in the “cooling of demand” effect shown in Figure 56.

4.4.3.3 Conclusion

Cherry picking areas of particularly high demand, while waiting for demand in other areas to reach a critical level, can provide a significant benefit, provided that the areas are carefully chosen to match the technology employed. However, demand aggregation only makes sense where there is a significant upfront investment required to provide service for a small number of subscribers when uptake is low. If there is little upfront investment and costs scale nicely with increased subscription, as is the case with NG AON in the results reported in D5.3 [61], then cherry picking areas is unnecessary and harms the business case.

This has interesting implications for open access scenarios. In a P2P architecture, while a PON operator may need to wait until there is sufficient demand in an area before deployment, a NG AON operator may begin deployment immediately and capture valuable market share and brand recognition, while denying the PON operator the subscribers that they need in order to justify a deployment. In a P2MP architecture demand aggregation has advantages and disadvantages. Choosing the right fan-out for the network architecture is extremely important. We have shown that technologies with smaller fan-outs can be utilised to target smaller high-demand areas and therefore benefit more than high fan-out technologies. This could mean that an NP utilising technologies with smaller fan-out could be first-to-market, claim market share and deny the demand needed to reach threshold to the high fan-out technology operators.

The ability to enter a market early and gain a foothold is a particular advantage of the smaller fan-out technologies in these scenarios.

4.4.4 Conclusion on the NP business case

The section 4.4 gives an overview on the business case for the NP and some influencing factors. Similar to section 4.3, the analysis is split into P2P/AON and P2MP/GPON1:32. In addition, three NGOA technologies are covered with the evolution of AON to NG AON, the HPON and WS WDM PON.

The two main scenarios under investigation, AON and GPON 1:32, show high sensitivity on the cost for CPE, which includes installation of in-building infrastructure beside the cost for ONT. Including the cost for CPE, the required monthly fee for a positive business case of the NP is about €15 to €115, with a 10-20% advantage for GPON 1:32 compared to AON. If the cost is excluded the required monthly fee falls to €3- €8, with a rather low advantage for GPON 1:32 (it is in the same relative magnitude, but negligible in absolute terms).

In general, common knowledge about the required monthly revenues was confirmed. The higher the uptake, the superior is the business case and thus the lower the required monthly fee. But it should be noted that without any improvements or cost split, the only viable penetration curve is the aggressive one leading to a twice as high monthly revenue as the desired target of €10. The impact of the area type is rather low; the delta between the three area types is in the order of 10% only.

There are three general improvements for the business cases. First, the CPE costs have a huge impact on the business case and there exists a possibility to find alternative financing options, which could improve significantly the business case, as outlined in the previous paragraph. Second, one could increase the monthly fee, but it seems unlikely that it is possible to charge such high fees in certain scenarios: the likely and conservative adoption curves require monthly fees between €63 and €115 for the connectivity only. The aggressive curve is in the order of €15-€22, which seems to be reasonable in some scenarios but well beyond the desirable level of €10. The third option it the aggregation of demand. Due to the high upfront costs of the in-house, the business case starts with a huge burden and several million € below the ground line. In the all-in NP business case the result is disappointing; the business cases will not fly. Using demand aggregation improves the business case a lot, even with a monthly fee of €10. With 20% of customers aggregated upfront, the AON cases are tending to a positive direction, but do require 40% for reaching nearly breakeven (most probably 2-3 months after observation time frame). The GPON 1:32 cases are more promising, while even

20% demand aggregation in the beginning results in a break even between 2018 and 2019. While accumulating already 40% at the beginning of the roll-out, the breakeven is reached at latest six years after the start (2015) and has a good performance until the observation time frame of 2020.

Beside the traditional FTTH technologies, the analysis for three different future technology options was performed: NG AON, WS WDM PON and Hybrid PON. Assuming a migration in 2020, other assumptions for the penetration were required. Therefore three different scenarios were developed, a uniform, a uniform with demand aggregation and a triangular with demand aggregation. It could be concluded that the WS WDM PON with uniform demand aggregation provides the best results with a required monthly fee about €10.57, 13% lower than the uniform distribution. This is based on the high sharing factor and the same explanation could be applied for the second best option, Hybrid PON, and NG AON: both architectures have lower fan-out or sharing factors and do not scale in cost as well as the WS WDM PON. For lower demand, it could be assumed that the NG AON scales better and there are break evens with Hybrid PON and WS WDM PON at higher levels of demand.

To conclude, the business case for the NP is a complicated one. If the most dominant cost, the in-house infrastructure, could be shifted to another player, the business is positive in both architectures with slight cost advantages for GPON 1:32 over AON. With demand aggregation, the business cases could be improved a lot, reaching a break even including the in-house costs with a level of 40% penetration at the beginning of the project. For the NGOA technologies, there is a reasonable business case in the order of the desired €10 per month, assuming a high take-up, which seems to be reasonable in the future.

4.5 Allowing competition in the network: impact of open access possibilities on the business case

The evolution from vertically integrated towards more open business models allows multiple operators to compete on the same level of the network, be it on the service or the network level. General market theory has proven that competition enhances intra-firm efficiency and productivity, and leads in most cases to lower price charges towards the end-customer. On the other hand, providing the opportunity for competition entails extra costs for setting up cooperation interfaces between the different actors involved. The kind and type of costs that are needed have already been described in section 2.4.1. In this section, we will evaluate the extra equipment and infrastructure costs needed for providing open access through different models, and investigate the impact the new business models can have on customer's behaviour.

We will investigate and compare the cost for open access on fibre and wavelength layer, for the shortlist of architectures as defined in section 2.3. To allow a fair comparison of the three options, we will evaluate them for the same parameters:

Table 17: Parameters used for the open access evaluations

Parameter	Choice	Explanation
Planning horizon	2020-2030	A 10-year planning horizon for the passive fibre case suffices, because of the scaling with the adoption curve.
	2020-2040	For the wavelength OA, we use a 20-year time period to be able to fully reflect the impact of the higher adoption curves.
Network	Greenfield	We assume a full Greenfield deployment

deployment	in 2020	for both passive and active infrastructure in 2020, as Greenfield cancels out all possible cost savings that could have been done for one architecture but not for the other.
Node consolidation	None (7500 scenario)	Most relevant in comparison to the other studies within WP6.
Adoption curve	Likely	The cost for open access is an upfront cost, independent of the expected number of users. Comparing multiple adoption curves thus brings no added value. Do note that starting in 2020 means that we start with a certain level of demand aggregation.
Area	Dense urban	From the cases studied, the more populated the area, the higher the chance that competition on NP layer will arise.

Bitstream open access will be evaluated separately, as this type entails competition on SP layer (instead of competition on NP layer), and doesn't need extra equipment or infrastructure to be installed.

4.5.1 Evaluating open access on the fibre layer

Deploying a P2P fibre network is a fibre rich scenario, meaning that every customer has its own dedicated fibre all the way up to the Central Access Node (CAN). This P2P network topology allows for multiple network technologies to be implemented on top, and in this first section, we will make abstraction of the network technology that is implemented on top. However, where needed, the AON technology will be used exemplarily, because it is the most likely technology to deploy on top of P2P, which will be compared to the reference case of AON with only 1 NP (so no open access).

We will first calculate the extra absolute cost for adding open access to the physical infrastructure, to later see what the impact of this extra cost is on the needed revenues per customer. Furthermore, the impact of churn will be studied, by looking into how much it would cost to switch a customer from one NP to the other.

4.5.1.1 Extra cost needed to provide open access

First, we will analyse the extra cost needed to provide the possibility of open access. This extra cost will most likely be carried by the PIP (or another neutral third party). The cost can be separated into two parts: an upfront investment for the installation of the extra ODF, and recurring costs to patch the new customers (for more info on the technical details, we refer to section 2.4.1.2 or to the results of WP3).

When assuming that customers don't change NPs over time (thus thereby calculating the best case scenario in terms of added costs), the extra cost needed, cumulative and discounted, sums to a little over €1 million, where about €890,000 covers the ODF and its installation, the rest is needed for the extra physical patching (assuming a dense urban scenario and the likely adoption curve).

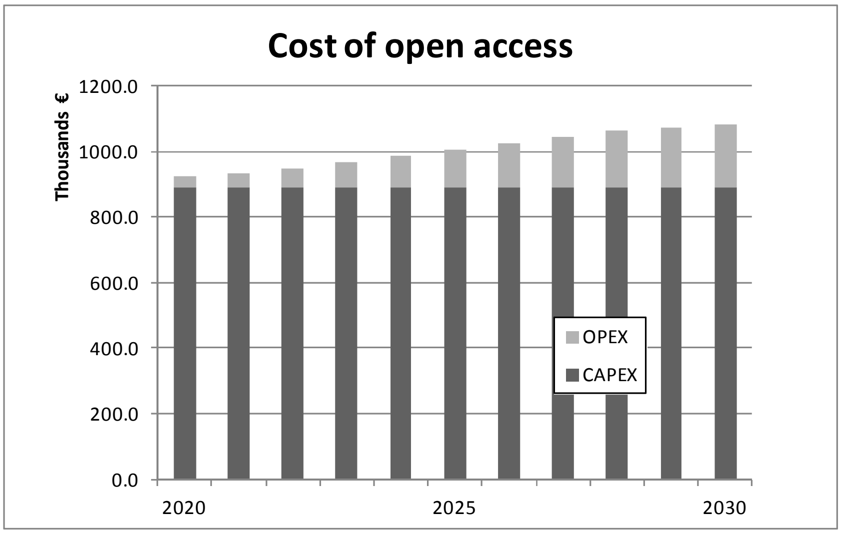


Figure 58: Cumulative and discounted (5% rate) cost of open access for the dense urban area and likely adoption curve (for AON)

When comparing this additional open access cost to the total cost for deploying the physical infrastructure, we see that including the possibility of open access, adds 12% to the total PIP cost.

4.5.1.2 Impact on the NP business case

The additional open access costs are all located on the PIP layer, so in theory, there is no direct impact of open access on the cost for the NP. In practice, the business case for the NP will of course be impacted if he operates on an open physical infrastructure. The following paragraphs describe these impacts in more detail.

Lower market share per NP

Open access on the fibre layer allows competition on NP level, which implies that the total market will be shared instead of fully allocated to one NP. In most cases, a lower market share would also lead to a worse business case, unless the NP opts for the AON technology. The total cost in this case (when the in-building infrastructure is excluded) scales nicely with the adoption curve, and therefore, the total market share will not impact the NPV for the NP. The relation between adoption curve and the total NP cost is represented graphically in Figure 59.

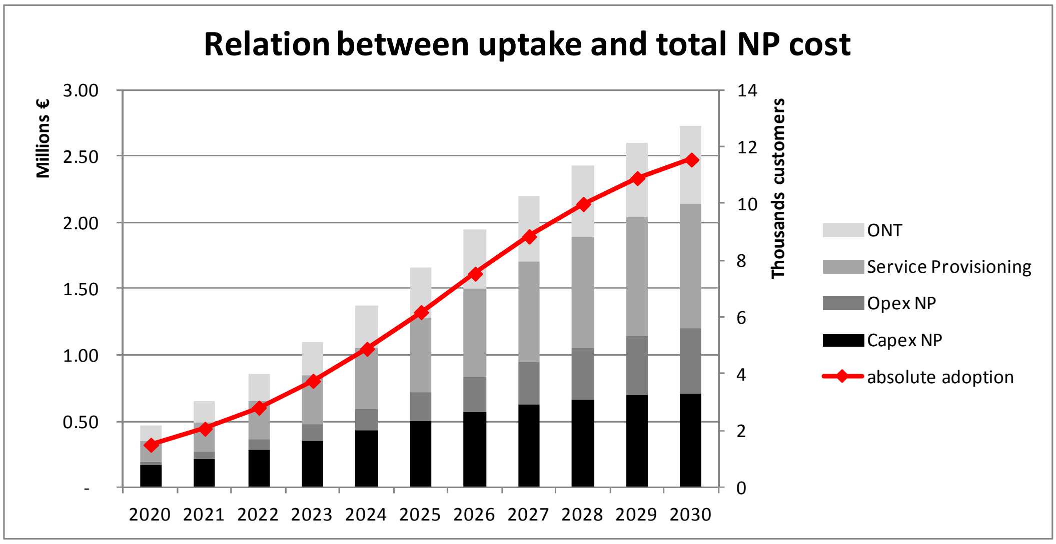


Figure 59: Relation between the adoption curve and the total NP cost for AON (dense urban area, likely adoption curve, cumulative and discounted with 10%)

If the NPs would not opt for the AON technology, the costs would not scale so nicely (because of the shared fibres and thus shared equipment in a PON implementation). Such a graph can be seen in Figure 60 below.

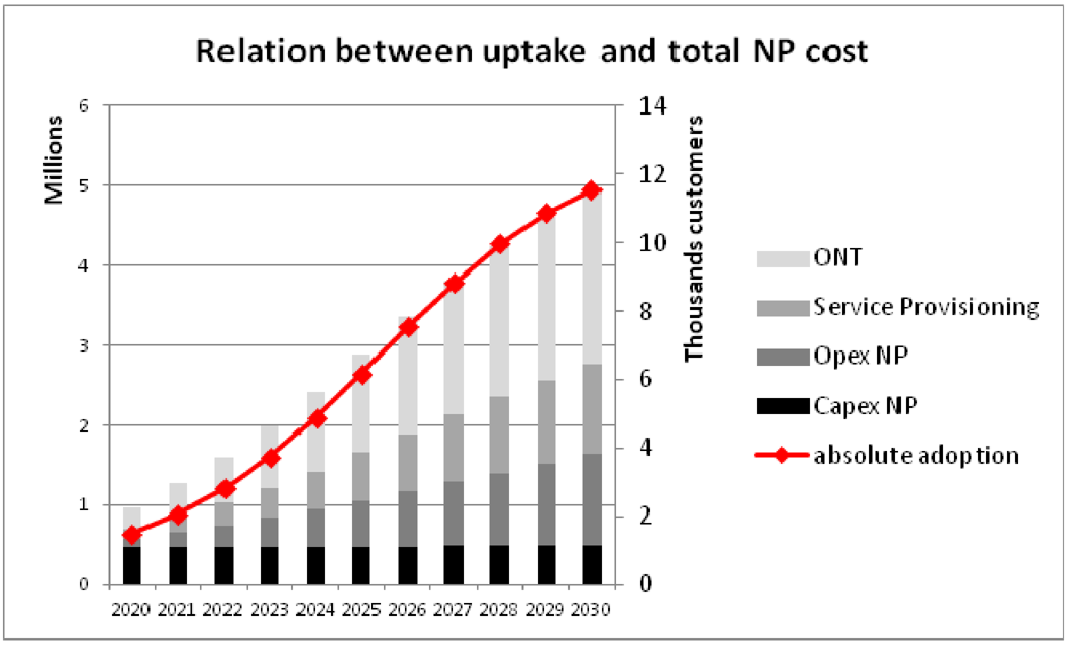


Figure 60: Adoption curve and total NP Cost for a Hybrid PON (dense urban area, likely adoption curve, cumulative and discounted with 10%)

<u>**Impact of switching customers**</u>

On top of the physical patching at the PIP side, there will be an added cost per switching customer, the 'current NP has to logically disconnect, while the 'future NP' has to logically connect this customer. Both physical and logical patching costs depend on time.

Secondly, there is the possible cost of replacement of the ONT at the customer's side. When the 'current' and 'future' NP don't operate the same network technology, the ONT would most probably have to be replaced, which entails a much larger cost. If the customer wants to change, the cost for this potentially new ONT (ranging from about €50 to €150, dependent on the technology), could be recouped through an initial installation fee.

4.5.1.3 Cost of switching customers: churn modelling

Taking into account all calculations from the previous sections, the cost per switching customer could now be calculated. This cost includes:

- Physical patching at the cross-connect ODF (responsibility of the PIP)
- Logical patching:
  - disconnection of the customer at the 'current NP'
  - connection of the customer at the 'future NP'
- possible replacement of the ONT (an AON ONT is taken here exemplarily)

The total cost would sum to about €135-€165, depending on the year of switching (see also Figure 61, input from section 2.4.1.2).

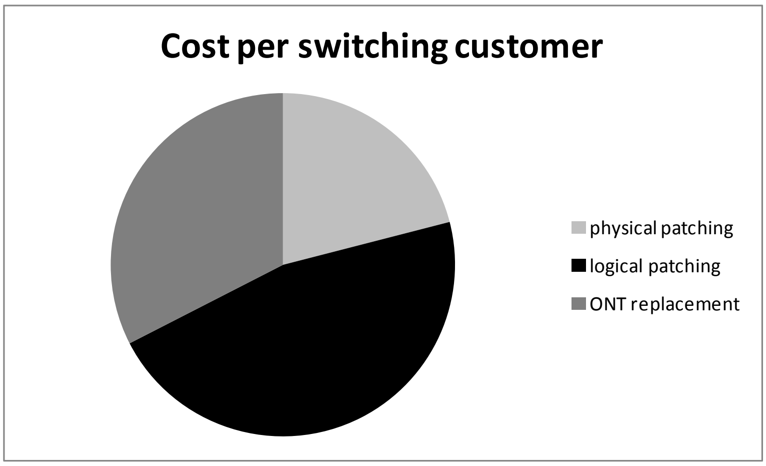


Figure 61: Cost breakdown of the cost for switching a customer

Looking deeper, let us assess the burden that this places on a network provider. If we assume a scenario where two network providers have equal market share at any given time, and a churn rate of either 10% or 20% (defining the fraction of their customer base that will choose to switch each year) then we can evaluate the costs associated. This analysis was performed utilising an AON network in a Dense Urban scenario without node consolidation and utilising the "likely" adoption curve. For comparison, we have also included the total costs of the NP (including equipment such as switches, failure management, energy costs etc.) but excluded the costs of the PIP. This is shown as undiscounted cost units in Figure 62 below.

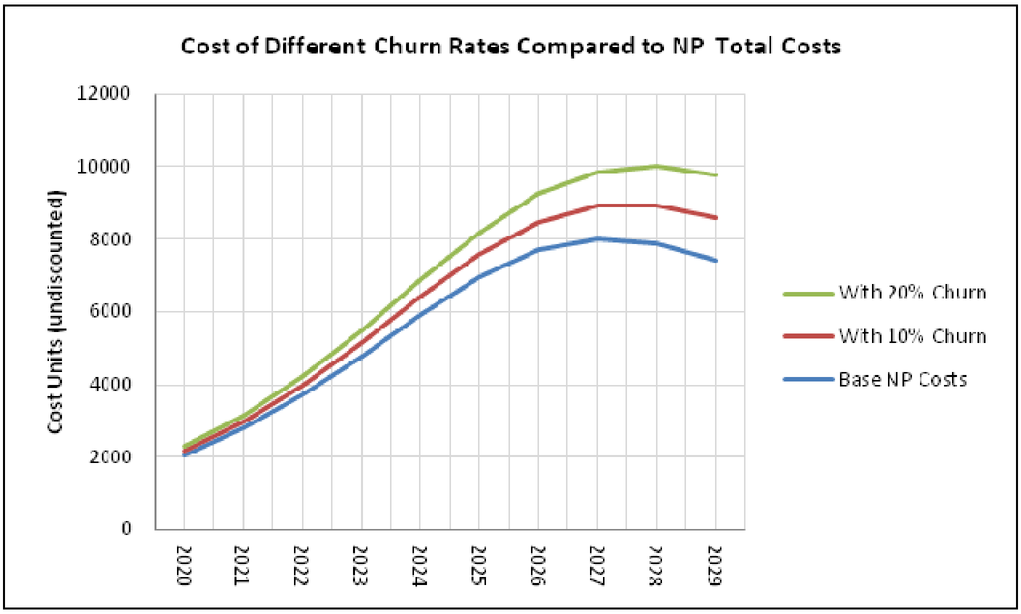


Figure 62: Cost of customer churn

It is clear that this cost, while an unpleasant addition for a network provider, is not excessively burdensome especially when considering that the PIP cost is not included here.

4.5.1.4 Impact on the needed revenue per customer

It can be discussed who will be responsible for the extra equipment and patching costs in this open access scenario, but in the end, the extra cost will need to be covered by the end-users.

Taking into account the upfront deployment of the cross-patching ODF and the physical patching, the PIP would need to charge €1.70 extra per customer per month.

For the NP, the additional cost is only there when a customer decides to switch. This cost was calculated before and sums to about €150.

4.5.2 Evaluating open access on wavelength layer: WR WDM PON and HPON

Within section 2.4.1.3, three schemes were identified which allow open access on two different architectures. These are the feeder fibre HPON scheme (which we refer to as HPON in the following section as it is the only scheme), the wavelength selective switch WR WDM PON variant (WR+WSS), and the feeder fibre WR WDM PON variant (WR+FF). Also provided within that section were the cost increases that might be expected to arise from designing a network that supports open access following from the schemes.

In this section we will analyse this further, looking in detail at each scheme and analysing how it affects the total cost and the amount that the PIP must charge per customer connection.

4.5.2.1 Extra cost to provide Open Access

The three schemes vary significantly in the cost overhead for providing open access on the wavelength layer. The most significant cost increase is associated with the Wavelength Routed variant utilising Wavelength Selective Switches. These devices are expensive, they consume power and they have a relatively high failure rate. It is thus likely that their usage will increase the cost dramatically.

In order to assess this, we analysed the total cost, without considering any discount factor, for the twenty years of operation of the PIP in accordance with the scenario outline presented above in the introduction of section 5.4. These results can be seen in Table 18 below.

Table 18: Increase in TCO necessary to provide Open Access

	Single NP	Open access	Delta (%)
HPON	€ 8,519,398.82	€ 8,523,898.82	0.053%
WR+WSS	€ 8,523,166.54	€ 16,835,356.84	97.525%
WR+FF	€ 8,523,166.54	€ 8,605,586.54	0.967%

As expected, the WSS variant is extremely expensive, contributing to an effective doubling of the TCO of the PIP. This is due to both high up-front costs of the WSS as well as the energy and failure costs. To evaluate this further, and to take into account the effect of discounting, we performed an NPV analysis and analysed the cost that the PIP must charge the connected customers in order to reach 0 NPV. The result of this study can be seen in Table 19 below.

Table 19: Increase in charge necessary to provide Open Access

	Single NP	Open access	Delta (%)
HPON	€ 6.66	€ 6.66	0.054%
WR+WSS	€ 6.65	€ 11.46	72.205%
WR+FF	€ 6.65	€ 6.72	0.988%

It is clear that providing open access is possible using both architectures utilising at least one scheme, and furthermore that the cost increase in order to do so is negligible. In the case of HPON this is achieved by leveraging the high fan-out to enable a small amount of upgraded equipment to reach a large number of users. In the case of WR + FF this is achieved by utilising economies of scale in fibre provision in the LL3+4 segments; moving from a 4 fibre cable to a 12 fibre cable (and therefore tripling the fibre count) increases the cost per kilometre by only a third.

4.5.2.2 Impact on the NP business case

Unfortunately, the above may lead the reader to the conclusion that open access on the wavelength layer for these architectures is a valid solution. Unfortunately, this is not the case where homogeneity must be conserved.

The fibre open access discussed in the previous section allows for excellent utilisation of equipment. For example, adding a customer connection in such a scheme is as simple as connecting one port on the ODF to one free switch port. By ensuring that additional cards are purchased only when required, a high utilisation of ports may be achieved. Furthermore, these cards are able to provide service for any customer anywhere on the network.

This is not possible with the architectures above. In order to see why, let us investigate the case of the wavelength routed PON above. At saturation, 80 customers are connected to a single line card through an AWG as detailed in Figure 11, giving excellent utilisation of equipment and therefore sharing of the cost. However, the cost is invariant with the number of users, and the capacity may only be provided to the 80 customers directly connected to the AWG; spare capacity cannot be utilised elsewhere in a simple manner. Due to these restrictions, in order to provide for the first customer on a different cabinet, another entire 80 channel line card has to be purchased and only utilised at $1/80^{th}$ of its capacity.

If we imagine that the customers are equally divided by preference for two network operators, then this would result in 40 customers connecting to one NP and 40 connecting to the other. Such a scenario would require two line cards each supported by half the number of users, meaning that the customer charge would have to increase. Other costs, such as the cost associated with providing customers with CPE would, however, decrease linearly. In order to investigate how significant the diseconomy of scale associated with open access is, we investigate a situation where demand is spread equally across two NPs. This is the “best case” scenario for open access; another ratio would lead to a better business case for one provider and a worse for the other. This result is then compared against a “single NP” scenario where there is no open access (although in the interest of fairness, both scenarios utilise the OA PIP cost in order to focus on the diseconomies of scale associated with the NP). These results, presented as the customer charge necessary to reach 0 NPV, can be seen in Table 20 below.

Table 20: Customer charge (per month) for different OA scenarios

	Single NP	Two NPs	Delta (%)
HPON	€ 12.77	€ 16.59	29.864%
WR+FF	€ 14.40	€ 19.11	32.725%

It is clear from these results that the diseconomies of scale associated with offering open access are responsible for a significant increase in necessary customer charge that, while dependent upon the technology, increases cost by around a third. This diseconomy would be amplified as the number of operators increases.

4.5.2.3 Churn Modelling

It is unlikely that users will make a single choice of NP once and then stick with it for the remainder of the network’s life. When offered the choice, some portion of users will likely wish to switch service (for a variety of reasons such as dissatisfaction, better offerings from other providers or lower cost, for example) at some point over the investigated time period.

In order to model this we assume a certain fixed proportion (the churn rate) of customers make this switch each year. For the architectures investigated here there are no costs for switching (for example, there is no manual patching at PCP5 which is needed for some other

OA variants presented in WP3 that were not selected for analysis). Users can even keep their CPE; for both variants it simply needs to be tuned to a different wavelength.

However, if we broaden our analysis to include a heterogeneous NP scenario then users who switch will need to have their CPE (especially ONT) replaced. In this specific instance it is worth analysing the effect on cost if we assume that CPE must be purchased and there is a 0% reuse rate. Given that the WR variant provides the greatest potential for heterogeneity, we will investigate the impact on a NP utilising WR WDM PON in a heterogeneous OA scenario with four churn rates: 0% (no churn), 5%, 10% and 15%. The results of this analysis, presented as the customer charge necessary to reach 0 NPV, are presented in Table 21 below

Table 21: Churn modelling in a heterogeneous scenario

	0%	5%	10%	15%
WR+FF	€ 19.11	€ 19.61	€ 20.11	€ 20.61

There is a small but measurable increase in the associated cost in this instance which would favour homogeneity at the network provider level.

4.5.3 Open access on bitstream layer

Open access on bit-stream layer is a potential mechanism for any architecture, area type and business model detailed in section 2.1.1.

In general, it can be assumed that only one PIP will be present in an area, so the NP will rely on a local monopoly for physical infrastructure and act as a local monopoly for logical connectivity, too. This is reasonable based on the analysis in section 4.4, where the business case is difficult for one NP per area already. Potentially, the NP will operate in other areas, too, but this is only relevant in consolidation scenarios or for certain cost types like overhead, marketing or transaction costs as such.

The main activity of the NP business is the operation of a connectivity network on top of the infrastructure between the distribution point at core, regional or local level (PCP5, 6, 7 or another peering point at the core) and the customer, represented by an ONT. This represents a two-sided market with several consequences for cost and revenue part.

The impact on the business case cost is two-fold as detailed in section 2.4.1.4. First the NP could choose an optimal technology (e.g. GPON) and therefore optimizes the roll-out of the PIP (e.g. P2MP), too. Second, an interface for service providers will be required allowing the physical transport, configuration of devices and a general business part allowing negotiation of contracts, distribution of information, billing, etc. Overall, one could assume that serious scaling effects exists, if a player reuses the model for NP operation and cost might reduce significantly for the business related parts, the IT parts, but not for the pure technical part. Overall, one can assume that the transaction cost part is the same for all technologies and architectures under investigation in OASE.

Under the previously detailed assumption that only one PIP / NP will be operating an area in parallel / monopole situation, churn has other characteristics on cost compared to other open access solutions. The activities for order management etc. will be the same, but the activities required for technical implementation will be highly automated, so the cost is more or less zero. The detailed cost of churn is not quantifiable, but in D5.3 total results per area for the likely adoption are documented. For dense urban area it is about 40k CU, for urban 19k CU and for rural about 6k CU. That results in cost per customer round about 3CU or 150€. Assuming a 50% part for churn, the overall contribution to the required monthly fee is in the order of 0.30€ undiscounted and most probably discounted not the significant part, but should be taken into account in an analysis.

The impact on the revenue side of the business case depends on the scaling effects the operator is able to achieve. In principle, the NP has a monopole situation, being the only one providing the connectivity. In addition, the NP is in a similar demand aggregating position like the PIP: achieving fastest, highest adoption possible. Another important factor is the ability to sell the virtual pipes to service providers, which will mainly depend on competition with other technologies and attractiveness of the area. Depending on the ability to achieve high adoption and market shares between other technologies and reaching cost levels, a sustainable business should be possible. This is shown in the analysis of the different adoption curves throughout section 4.4, where the difference between the aggressive, likely and conservative is analysed.

To be more concrete, several interviews have been performed in order to get a meaningful level of cost and an overall business case assessment. As specified in section 2.4.3.2, the typical transaction costs are in the order of 8%-15% of turnover. On the other side, the concentration on an open business model could increase the performance of the player to reach a positive business case and therefore an increase of adoption / penetration.

4.5.4 Conclusion

Within this chapter we have studied a number of different approaches to open access. The fibre open access layer clearly provides the greatest degree of flexibility and should result in the largest possible market competition thanks to the ease of deployment of multiple network providers that may opt for heterogeneous network technology. This allows for true product differentiation between network providers. However, it is not without its problems as the fibre-rich deployment contributes to an increased CapEx cost and the need for manual patching of customers contributes to a significant increase in OpEx. In general, end-customers would have to pay about €1.70 more per month to be connected to an open access network, while switching will cost them about €150.

While open access on the wavelength layer is possible, it is fraught with technical (as reported in WP3 + WP5 results) and economic issues. Fundamentally, OA can be enabled for both the studied architectures for a marginal increase in cost (below 1% if choosing the right option). However, due to the diseconomies of scale associated with the use of PON architectures by network providers there is a significant disincentive to utilise such a scheme. Paradoxically, increased choice availability results in increased cost to the consumer, leading to an optimum (cost) solution of a monopoly.

Finally, we have discussed the possibility for bitstream level open access which should be possible with all system variants, and have identified some additional cost overheads associated with providing access at this level. In contrast, there are some benefits (for example, optimising deployment, reducing duplicated equipment, lower service provisioning costs while no physical patching required), too. Based on the monopole nature, it can be assumed that the costs are offset by the higher customer numbers and the limited churn within the fibre infrastructure.

5. Competitive analysis

At the beginning of this activity it has been decided to evaluate the competition within the targeted market gaming field in a two-step approach. First a qualitative analysis should be introduced to create a better understanding of the FTTH market players and especially their interrelationships and objectives. Therefore, the MACTOR methodology was chosen to establish a structured way of gathering the opinions of stakeholders involved. MACTOR stands for Matrix of Alliances and Conflicts: Tactics, Objectives and Recommendations [4].

After creating this better understanding of the FTTH market, a quantitative analysis was performed. It is clear that game theory is a powerful tool in predicting the outcome of competitive interaction on the business cases of the different (existing and emerging) market players in the broadband market.

5.1 Qualitative Multi-Actor Analysis - MACTOR

From the case studies described in Annex A, it is clear that in the newly deployed telecommunication networks, multiple actors are active on different layers of the network. These actors comprise not only of pure telecommunication market players, like incumbents or former cable operators, but other parties, like Housing Corporations, Equipment Vendors, Regulators, etc. also play an important role. This section investigates the objectives of these market players and looks deeper into how they could interact or influence each other in their strategic decision making.

The identification of available strategic options in the value creation network is a key step when developing new products. When multiple actors and a variety of objectives within the ecosystem are involved, multi-issue actor model (MIAM) is the obvious choice to conduct the analysis. MIAM is applicable in situations where multiple actors are confronted with a situation whose future is difficult to foresee, e.g. the launch of a new product. Apart from the varying interests, perspectives and options that the actors have, MIAM recognizes that they might manipulate important factors of the focal system that will influence the future outcomes of the situation. The influences can go so far that individual actors or alliances of actors might threaten the existence of others through their actions [57].

5.1.1 Fibre-to-the-Home ecosystem analysed with MACTOR

In this section the FTTH ecosystem is modelled with the MACTOR approach. The MACTOR analysis explains the interplay of actors and is a first step towards game theoretical approaches. Possible alliances and conflicts among the actors can be identified and the power sources among the actors are explicated. Based on this and the light that is shed on the interests that the actors pursue, strategic options and recommendations concerning cooperation's and the competitive environment are formulated.

First, all relevant actor's that are potentially involved in the FTTH deployment are listed and described (section 5.1.1.1). Second, strategic issues and objectives of the FTTH market are identified (section 5.1.1.2).

5.1.1.1 Actors

All in all we came up with 13 different actors, which can be arranged in five groups:

- Device related
- Network related

- Large-scale enterprises
- Service related
- Public

In the device related group the Network Device Manufacturer (NDM) and the CPE Vendors (CPEV) are the most prominent actors. Network Device Manufacturers are companies that provide hardware solutions to other companies and governments enabling them to deliver voice, data and video services. CPE Vendors are companies that produce and sell electronic devices to end users. Examples are mobile phones, handsets, PDAs, mp3 players, TVs, set-top boxes, home servers, etc., including residential gateways (RGWs).

The network related group involves Housing Company (HC), Private Municipal Infrastructure Provider (Private MIP), Public Municipal Infrastructure Provider (Public MIP) and Active Network Provider (ANP)[4]. Housing Companies can construct, manage and exploit optical FTTH networks restricted to the in-house area. They often act in public interest. Private and Public MIP construct, manage and exploit optical FTTH networks (or to the building, where they may interface with housing companies) within cities. They intend to provide every dwelling with a connection. Private MIPs act in shareholder interest whereas Public MIPs are driven by the public interest. Active Network Providers are sometimes referred to as Communication Operators. They operate a network with own active equipment without application services. They mostly depend on Municipal Network Providers.

The next group includes the large-scale enterprises in the market. Examples are incumbents such as Telecommunication Operators (Telco) and Cable Operators (CO) or other international companies such as Technology Giants (TG). Telecommunication Operators operate the networks necessary for data, voice and IP-based video transportation. This actor includes the incumbents in telecommunications as well as mobile network operators (MNO). Both are mostly vertically integrated companies spanning several roles in the ecosystem. Cable Operators maintain and operate cable networks as basis for Cable TV. Rather recently Cable Operators started to offer Internet access, too. The activities of Technology Giants span several levels and are ever muting. Despite the vague definition, their big economic impact unifies all of them, as does their potential to act as mediator, their large financial assets and their significant market power (SMP).

Service related actors are the Internet Service Providers (ISP) and Service Providers (SP). ISPs offer access to the Internet for their customers. They maintain the customer data and provide AAA functionality (Authentication, Authorization, and Accounting). However, these companies do not necessarily operate their own network. Service Providers can take two different roles: Content Service Provider (CSPs) produce, own, aggregate and resell content and often have own service platforms. In contrast, Application Service Providers (ASP) develop and offer internet services.

The last group represents public organizations such as Public Authorities (PA) and Regulators (Reg). Public Authorities have a funding, supporting and legislative role that directly impacts regulation. Regulators can enforce their will in form of regulations, state & federal laws, EU laws, etc. Technical policies are not meant here.

5.1.1.2 Strategic Issues and Objectives

We identified eight strategic issues with altogether 21 objectives as shown in Table 22.

[4] The Municipal Infrastructure and Network Providers (MINPs) who construct optical fiber networks within cities and operate these networks with own active equipment are not considered in this MACTOR analysis as it is a combination of Private MIP, Public MIP and ANP.

Table 22: Strategic issues and objectives

Strategic Issue	*Operational Objective*		
Technology	A1	▪	Technology preference: Prefer fibre network instead of other technological solutions (coax, copper, wireless)
	A2	▪	Long term commitment for fibre networks
FTTH deployment	B1	▪	High FTTH network coverage
	B2	▪	Fast roll out of fibre networks
Collaboration	C1	▪	Build cooperation for fibre roll out (cooperation = collaborate to achieve common goals and interest, with or without contract)
	C2	▪	"Coopetition[5]": Cooperation & Competition, i.e. cooperation in less attractive areas & competition in highly attractive areas (geographical & risk dependent), collaborative efforts for funding in least attractive areas
Costs	D1	▪	Minimize production costs for fibre networks (hardware, infrastructure)
	D2	▪	Minimize operational costs
	D3	▪	Minimize transaction costs (e.g. contract related costs incl. initiation, negotiation and execution costs)
	D4	▪	Cost sharing according to risk, mainly infrastructure related costs because of high investments, also contract design in terms of traffic patterns (flat vs. volume based)
Rules & Standards	E1	▪	Standardization: Aim for standardized fibre equipment (active and passive including interfaces)
	E2	▪	Define long-term, stable and reliable terms and conditions for construction and operation of fibre network
Services	F1	▪	Offer new services, e.g. broadband telecommunication services, smart metering, health care services, etc.
	F2	▪	Provision of wholesale products on the infrastructure and operational levels
	F3	▪	QoS/QoE: Implementation of Quality of Service &

[5] "Coopetition" refers to the term cooperative competition. It describes market situations where actors cooperate in some parts of their businesses but compete with each other for the overall market [10].

		Quality of Experience within the network
Net neutrality	G1	▪ No traffic discrimination: Ensure net neutrality instead of traffic discrimination
	G2	▪ Product differentiation: Allow product differentiation on infrastructure & access level
	G3	▪ Open access networks: Enable open access networks by separating players according to infrastructure, operation and service layer
Public & social factors	H1	▪ Minimize negative social effects accepting possible cost increases, e.g. avoid road works, ensure sustainability, maintain townscape
	H2	▪ Act in shareholder interest and not necessarily in public interest
	H3	▪ Increase area attractiveness: Increase attractiveness of selected & geographically limited areas

5.1.2 Interaction within the FTTH ecosystem

While we have described the FTTH ecosystem in the former section 5.1.1, we will present our main results – the interaction of actors within the ecosystem – in this section. First, the position and attitude of the actors on each objective is shown (section 5.1.2.1). Second, the balances of power in the market are analyzed, i.e. the actors' influences on other actors (section 5.1.2.2). Last, both results are combined and potential alliances and pending conflicts are discussed (section 5.1.2.3).

5.1.2.1 Actors' position on the objectives

Summing up the results of our analysis the 13 identified relevant actors have a positive attitude towards the deployment of FTTH (see section 5.1.1.1). It is currently the preferred technology for a network expansion and high network coverage shall be obtained fast. Simultaneously, standards and fixed long-term conditions are favourable for all actors. Cooperation and coopetition regarding FTTH deployment are interesting for most actors but some resistances remain, especially from cable operators as they use a proprietary system which raises the complexity for collaboration. New services, wholesale products and implemented quality of service mechanisms are promising for most of the actors. Net neutrality and open access networks shall be ensured, albeit it is not in the interest of telecommunication and cable operators. However, both become acceptable for telecommunication and cable operators in case product differentiation on the infrastructure and access level remains allowed. Our study also shows that negative social effects, e.g. noise disturbances due to road work, will not be prevented at any cost. This can be ascribed to the fact that most actors are bound to shareholder interests and not the public interest.

Summing up the evaluation of the position of each actor according to the opinion of the questionnaire respondents we notice that the differences between all actors are rather small and occur in minor details only. All 13 actors have a positive attitude towards 8 of 21 objectives. The predominantly positive attitude is also valid for the other objectives. Differences can be observed particularly in objectives about collaboration, net neutrality and public and social factors. This is mostly due to the different position of Telco's and cable operators in these areas.

Figure 63 shows the absolute number of actors which have a positive ("Pro"), neutral ("Neutral") or negative attitude ("Contra") towards each objective for all 21 objectives. The strength of their attitude towards an objective is indicated by the number of blocks under "Intensity". More blocks imply a stronger positive (horizontally striped) or negative (vertically striped) attitude across all actors.

		Contra abs.	Intensity*	Neutral abs.	Intensity*	Pro abs.
Technology	Technology Preferences	1	▥	1	▤▤	11
	Long term Commitment	0		0	▤▤▤	13
FTTH deployment	High FTTH network coverage	0		1	▤▤	12
	Fast roll out	1	▥	1	▤▤	11
Collaboration	Cooperation for fiber roll out	2	▥	3	▤	8
	Coopetition	2	▥	2	▤	9
Costs	Minimize production costs	0		0	▤▤	13
	Minimize operation costs	0		0	▤▤	13
	Minimize transaction costs	0		0	▤▤	13
	Cost sharing	0		2	▤▤	11
Rules & Standards	Standardization	0		0	▤▤	13
	Define long-term terms and conditions	0		0	▤▤▤	13
Services	Offer new service	0		0	▤▤▤▤	13
	Provision of wholesale products	0		2	▤▤	11
	QoS/ QoE	0		1	▤▤▤	12
Net neutrality	No traffic discrimination	2	▥	1	▤▤	10
	Product differentiation	0		0	▤▤	13
	Open access networks	2	▥	1	▤▤	10
Public and social factors	Minimize negative social effects	1	▥	6	▤	6
	Act in shareholder interests	3	▥	1	▤▤	9
	Increase area attractiveness	0		3	▤	10

* Intensity of cumulated actor's position towards objectives

Figure 63: Actors' position on the objectives

5.1.2.2 Balance of power between the actors

This section covers the balance of power between the actors. The questionnaire revealed each actor's strength of direct influence on each other actor. The direct influence originates in customer-supplier relationships, general market power, or other dependencies. However, the direct influences do not reflect reality sufficiently. Indirect influences via third parties have significant impact as well. Often an actor can exert his influence on another actor to manipulate a third party in his interest, e.g. through buyer-supplier relationships where one actor depends on the other. Figure 64 is the result of our qualitative analysis that shows the relative differences of influences between the actors. It captures the direct as well as indirect influences on the x-axis. In other words the active role of an actor is displayed. The y-axis indicates the passive part of each actor, i.e. the strength of dependencies on other actors. Be aware that Figure 64 highlights the balance of power only in the FTTH market. Therefore, some actors that are generally perceived as being strong (for example the Technology Giants) do not have to show up as especially powerful in our analysis.

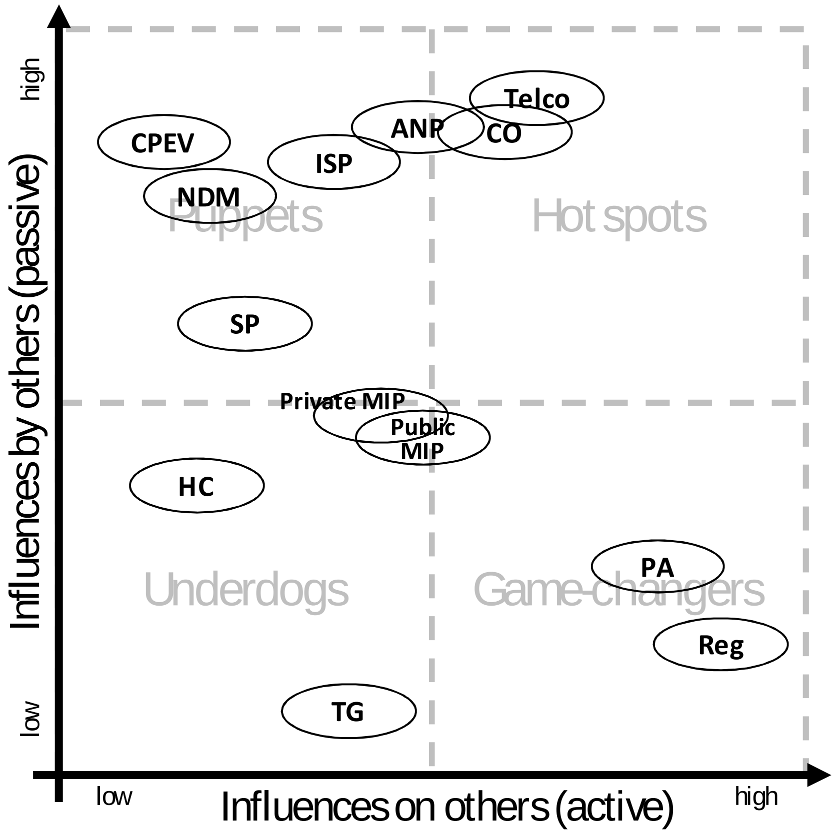


Figure 64: Balance of power between the actors

The market actors can now be split up in four groups:

- "Hot spots" – influences on others: high, influences by others: high
- "Puppets" – influences on others: low, influences by others: high
- "Game-changers" – influences on others: high, influences by others: low
- "Underdogs" – influences on others: low, influences by others: low.

The actors (Telco's and Cable Operators) within the "Hot spots" group have a high conflict potential. They have strong influences on other actors and at the same time both are strongly influenced by other actors. Due to their power within the market the whole market will be affected in case of divergences between these two.

In the upper left group, the "Puppets", two types of actors are represented: 1) vendors (CPE Vendors, Network Device Manufacturers) and 2) service-related actors (Service Providers, Internet Service Providers). Vendors have classical supplier functions: low active influence and a strong passive role. The main reason for this are the vast number of companies that exist, e.g. Huawei, Alcatel-Lucent, Ericsson, etc. as NDMs; Samsung, LG, Sony, etc. as CPE Vendors. The service related actors show up as relatively passive in our analysis although they are often perceived as being very strong. At first sight this seems to indicate errors in our analysis. However, the reason for the differences is our focus on the FTTH market only and not the whole ICT ecosystem.

The Active Network Providers are in-between the first two groups. Their active influence on others is present but not very distinctive. At the same time influences by others are rather high. An explanation for this position in the grid can be found in the regional limits of their operation: they often operate local networks. Thus, they have only limited influences in the whole ecosystem but depend on suppliers and large network operators. Active Network

Providers are caught in the middle of the value chain due to their dependencies on the lower infrastructure on the one side and on higher services on the other side.

The group “Game-changers” where actors are relatively independent with only little influences by others is made out of public authorities and regulators. Public Authorities, e.g. municipalities, have strong influences on other actors as they can set the conditions for deployment of city networks. Regulators constitute the overall rules for the ecosystem, authorized by law. The influences on Public Authorities are stronger than influences on regulators. This has two reasons: 1) public authorities have to provide a good public infrastructure and therefore depend on the actors who build the infrastructure 2) public authorities are indirectly influenced by voters. The strong position of both actors can be seen as a crosscheck for our methodology as this position was expected in advance.

The Technology Giants showed up in the last group – “Underdogs”. Here, actors have only limited influences on others but are also not strongly influenced by others. We believe that this position can be lead back to the less active role of Technology Giants in the FTTH market yet. However, they are very powerful in other markets where they compete with some of the same actors, e.g. Telco’s and SPs in the service market. Supplementary, they draw additional power through their ability to create market trends and new services, thus generating demand for bandwidth and FTTH networks eventually. Ultimately, technology giants may play an important role in the future and should not be underestimated or neglected when looking at the FTTH ecosystem.

Similar considerations are valid for housing companies. At the moment their influence is relatively low. However, in the future they can be expected to have an important role when the mass market FTTH deployment begins. They can ensure a high starting penetration by committing to equip a large number of residential objects with FTTH connections. After the initial deployment phase their power is expected to decrease to a lower level again due to their comparably small size.

Private and Public Municipal Infrastructure Providers will also be important in the early phases of FTTH roll-out. This trend can already be observed in some parts of Europe, e.g. in Sweden and the Netherlands. Their future role and importance is uncertain as of today. Accordingly, they can currently be found in the middle of the chart and do not belong to a specific group, yet.

5.1.2.3 Potential alliances and pending conflicts

Based on the actors’ position on the strategic issues harmony and hostility between them are revealed. Taking into account the distribution of power in the market as well, potential alliances and pending conflicts can be identified. In Figure 65 we show four potential co-operations and one potential conflict that are likely to arise:

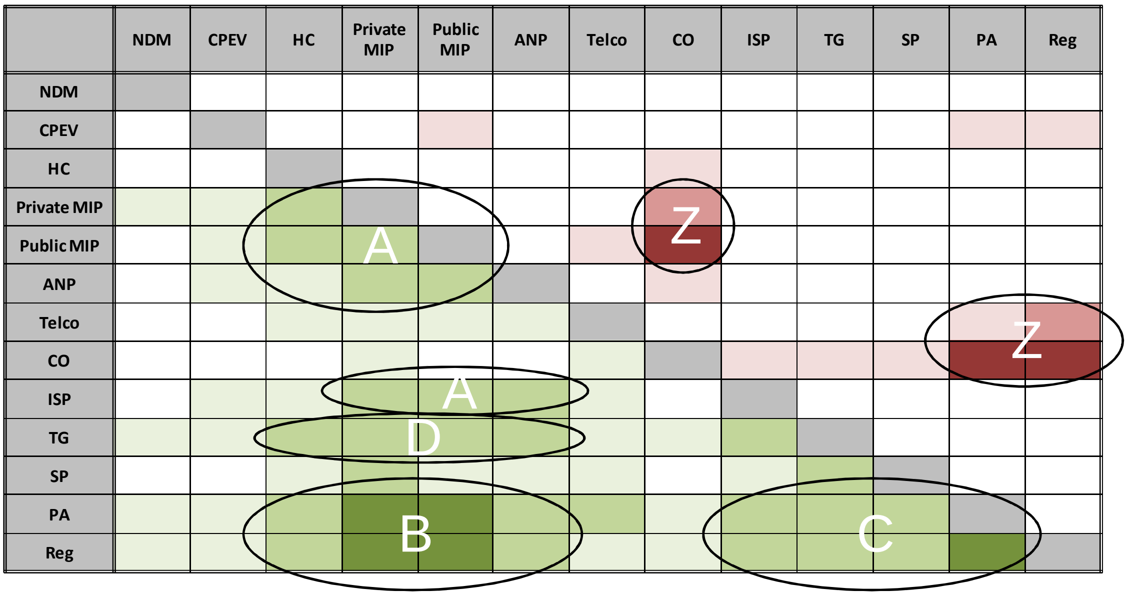


Figure 65: Potential alliances and pending conflicts

For clarification and readability reasons, we gave each alliance and the conflict a name to refer to (see Table 23).

Table 23: Potential alliances and pending conflicts

Potential alliances	***Pending conflicts***
A) City networks B) Publicly supported city networks C) Publicly supported services D) Lighthouse projects	Z) Publicly supported city networks vs. incumbents

In alliance city networks could be built collaboratively by different actors: Housing Companies, Municipality Infrastructure Providers, Active Network Providers and Internet Service Providers. The networks they could deploy and operate would be locally concentrated. Nevertheless, they could become strong competition for incumbents like Telco's and cable operators as this alliance could adapt the network deployment to specific local requirements and would have direct access to the end-user. Successful examples for such city networks exist for example in Sweden (City of Stockholm) [72].

Another possible alliance (B) arises if Public Authorities and Regulators would support the city networks. The core cooperation and initiative in this case would be between Municipal Infrastructure Providers and Public Authorities to build a city network. This cooperation could even be extended by Housing Companies and Active Network Providers as they are necessary to provide full-fledged city networks. The actors of this cooperation share at least one common goal: reducing market power of few big organizations. This would be in public interest. Nevertheless Private Municipality Infrastructure Providers might be also interested to be involved. They are often bound to Public Authorities and municipalities to get licenses to build city networks. Regulators can only be involved in a "round table" (in contrast to an alliance) since they are neutral by law.

Alliance C, publicly supported services, would have a more indirect cooperative character as it is not based on contracts but on same interests. Nevertheless, it would be an interesting type of cooperation because some key objectives, e.g. net neutrality, service offerings, etc. are involved. Public Authorities and Regulators are interested in a large variety of services offered by many service providers. This is why they are interested in supporting smaller organizations and networks to facilitate competition. Additionally, Technology Giants, Service Providers and Internet Service Providers could take the initiative and request Regulators to enforce net neutrality to overcome market power of incumbents.

The last possible alliance D – Lighthouse projects – is already visible today. Technology Giants approach city network consortia to realize lighthouse projects. Google, for example, started an experimental FTTH project in the US in 2010 to test new services before entering the mass market [36].

Besides these promising alliances and cooperation one conflict (Z) is pending: publicly supported city networks versus incumbents. This conflict swells between Telco's and Cable Operators on the one side and Municipal Infrastructure Providers, Public Authorities and Regulators on the other side. Eventually, it is a consequence of co-operations similar to alliance type A and B – city networks – as these are a counterpart of Telco's and Cable Operator's own ambitions. They both aim at enhancing their own network in cities and seek to avoid new competition which would certainly arise through city networks.

5.1.3 Qualitative Multi-Actor Analysis Conclusions

Overall, the actors show a mostly positive attitude towards the deployment of FTTH. Convergences across all objectives outweigh divergences between the actors by far. During our analysis, city networks emerge as the most promising co-operation. They would be built collaboratively by Housing Companies, Municipality Infrastructure Providers (both private and public), Active Network Providers and Internet Service Providers. It is likely that they would be supported by Public Authorities and Regulators because both aim for a higher level of rivalry and a multitude of choices for customers. Moreover, city networks could serve as counterbalance to incumbents such as telecommunication and cable operators. Thus, these city network alliances are likely to face fierce competition because incumbents will defend their strong position in the market. Exactly this conflict was revealed as the most severe one in our analysis. Incumbents will aim to enhance their own networks in the most profitable dense urban areas and will defend their core business field of infrastructure provision by all means.

5.2 Game theoretic analysis

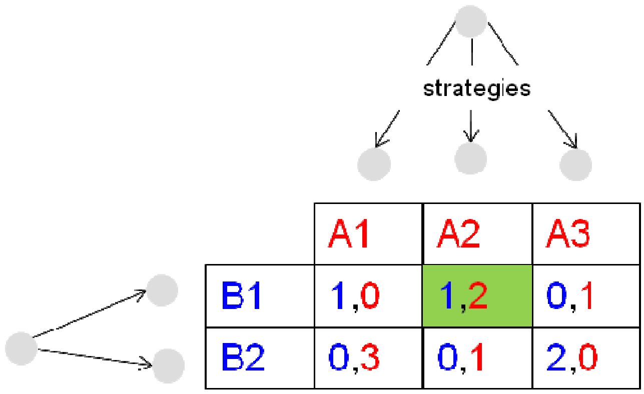
5.2.1 Game theory basics

Game theory is "aimed at modelling situations in which decision makers have to make specific actions that have mutual, possibly conflicting, consequences" [28].

In game theory, all players have sufficiently good knowledge of each other's possible strategies and payoffs. These assumptions allow representing the game by means of a payoff matrix. This matrix has a payoff (e.g. NPV) for all players for each possible combination of strategies. This is called the strategic form of the game and allows finding an equilibrium in the game (Figure 66). An equilibrium is a set of strategies (one for each player) at which players are not inclined to change their strategy. Different equilibrium concepts have been proposed in the field of game theory. The most commonly known equilibrium is the Nash equilibrium (NE), which is defined as a situation in which no player can gain by unilaterally changing its strategy. In a pure NE, each player will use a pure strategy, whereas in a mixed

NE, the players can play mixes (probabilistic combinations) of strategies [28]. It is often assumed that a game with fully rational players (using this equilibrium as criterion) is expected to result in one of the NEs being chosen.

Typically static games (the game has one stage in which the players interact) can also be reduced or solved by removing strictly dominated strategies. These dominated strategies have a strictly lower payoff than another (dominant) strategy for all possible counterstrategies. No fully rational player would play a strictly dominated strategy but would instead play the dominant strategy. As such this strategy can be removed for the considered player. By iteratively using this approach for the different players, the matrix of the game can be simplified and can in some case be solved to a unique strategic choice for each player. In these cases, this strictly dominant strategy set is the only NE of the game. Applied to the example case in Figure 66, it is clear that strategy A3 is dominated by A2. With this strategy removed, the strategy B2 is no longer interesting, since he gains a larger payoff in all cases for strategy B1. Now only the strategic combinations (B1, A1) and (B1, A2) remain, and player A will always choose A2.



	A1	A2	A3
B1	1,0	1,2	0,1
B2	0,3	0,1	2,0

Figure 66: Strategic form of a game and Nash equilibrium

Pareto optimality is based on the Pareto improvement concept. Given an initial set of strategies, a change to a different allocation making at least one player better off without making another actor worse off is called a Pareto improvement. When no Pareto improvements can be made from a given strategy set, the set is Pareto optimal or efficient. An economic system that is not Pareto efficient implies that changing the strategy set would make some players better off without reducing the payoff for the other individuals. From an efficiency point of view, it is clear that non-Pareto optimal points should be avoided. When looking at the example given in Figure 67, strategy set (B1, A1) is not Pareto optimal, since player A can improve its payoff from 0 to 2 without reducing the payoff off Player B if it chooses action A2. Extra analysis shows that the Pareto optimal points are in this small example (B2, A1), (B1, A2) and (B2, A3). Another way to identify Pareto optimal points is using the Pareto frontier concept. The Pareto frontier is the set op Pareto optimal solutions and can be graphically presented (Figure 67).

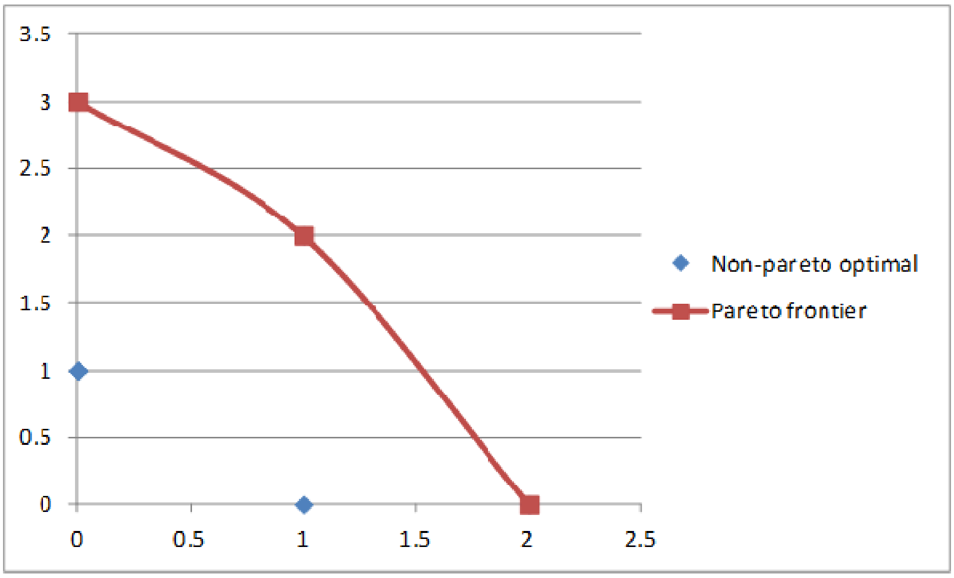


Figure 67: Pareto optimal strategy sets for the example game

5.2.2 Game theory in telecom

Game theory has already been widely used in telecom research. However, the main application of this theory is in wireless network research, more specifically networking games for flow and congestion control, network routing, load balancing and quality of service (QoS) provisioning. We refer to [2] for a complete literature overview of these networking games.

However, techno-economic telecom research can also greatly benefit from the concepts of game theory. Investment projects in new fixed and wireless networks never occur from a monopolistic perspective. Typically, for both the fixed and mobile market, customers have the possibility to choose between different vendors, operators and service providers. So when launching a new product, network or service, the actor has to take into account the effect of its decision on the competitive equilibrium in the market. Techno-economic oriented game theory offers important methods and concepts to assess this competitive interplay in the economic assessment. To use the concepts of game theory, it is important to model the impact of the competition between all players on their respective business cases. Most likely, the chosen strategies will have an impact on the division of the market between all players.

Competition modelling by means of game theory between different operators is a more recent field. Typically, a mathematical model is built to analyse the game and the resulting equilibriums. For example, [93] studied the competition equilibrium in the Chinese triple-play market. Another example is [73], where the optimal pricing strategy for new telecom services in developing countries is assessed using mathematical game theory models.

However, while such mathematical models can proof useful for general reflections on competitive interplay, they lack the possibility to model competition between different players with an underlying developed techno-economic model. Such research has already been used in several techno-economic publications. In [16], the viability of a municipal FTTH network rollout was assessed. It introduced a first mover advantage to divide the potential market between the cable operator and the FTTH network. Being the first to offer services to consumers resulted in a faster adoption and larger initial market share. This allows for an analysis of the business case of the FTTH deployment under more realistic assumptions, especially since the viability of such a deployment largely depends on the take rate and as such the competition with other operators. If the FTTH network is rolled out in regions where existing communication infrastructures, like copper and/or cable, are present, this could drastically impact the economic assessment. Applied to the specific case of a municipality rolling out an FTTH network where an existing cable operator upgrades its network to DOCSIS 3.0, game theory offers insight in the most profitable rollout scenarios under competition. Since an FTTH rollout suffers from high upfront installation costs, it is advantageous to start with a slower rollout compared to the cable operator and focus first on the largest industrial sites. In residential areas, FTTH should focus on the densest regions, since this reduces the digging costs per connection. On the other hand, the cable operator has less digging constraints and focuses on the larger residential areas.

In another case, using game theory to model the competition between different wireless operators, price competition was introduced to divide the market between the different operators [75]. Based on this market division, the viability of different business models offering wireless access was studied. A municipal WiFi network was found to be economically interesting, even in competition with several mobile operators offering 3G femtocell access. However, when other players looked at rolling out commercial WiFi networks, a public-private partnership (PPP) between these players is designated.

5.2.3 Competition aspects in the NGOA context

It is clear that game theory is a powerful tool in predicting the outcome of competitive interaction on the business cases of the different (existing and emerging) market players in the broadband market. In the following section, the distortive impact of the rollout of a physical P2P fibre infrastructure by a public MIP will be indicated. The newly installed infrastructure will compete for market share with the existing players. Two levels of competition can be distinguished. First, infrastructure competition on the wholesale market can be observed. Existing ANPs will have an alternative for their current legacy copper wholesale provider, and can choose between the copper and fibre infrastructure. An ANP moving towards the public MIP will have an impact on the profitability of the MIP, but also of the copper Telco. Secondly, the retail market will be impacted as well by the rollout of a fibre infrastructure. Consumers will have new offers to choose from, again impacting the bottom line of all players in the market.

Before conducting the game theoretic analysis of infrastructure competition, a short overview of the different players, their objective function and possible strategies will be given.

5.2.3.1 Players and strategies

In the introduction, the three players in the infrastructure game were already described briefly. Here, we will look at the distortive effect the rollout of a fibre infrastructure by a public MIP will have on the existing market. As such, the public MIP is the first player in the game.

As public MIP, there are still different possible strategies open. A very basic decision this player has to make is the one between an open or closed network. Choosing for a closed network, where the public MIP takes up both the role of infrastructure provider and ANP creates a more closed environment. An open infrastructure allows additional ANPs on top of the infrastructure, creating extra competition. Obviously, both strategies have advantages and disadvantages. In the closed environment, the public MIP claims more revenues from the fibre ANP market, as he is the only one offering such services. While these revenues might be reduced in an open environment, such an infrastructure may increase the total fibre market, improving the profitability of the fibre infrastructure.

The rollout of a public MIP will impact two kinds of players. First, the existing Telco’s and CO’s, who have their own infrastructure, will definitely observe an impact of fibre on their market share on the retail market. A certain amount of customers will move towards the fibre infrastructure, depending on the price and quality of the fibre offers, but also on the price sensitivity of these customers. In order to safeguard their profitability, these players also have different possible strategies. The first one is the simplest strategy, namely staying on their existing infrastructure. Although they risk losing customers to new entrants, they can avoid investments. A second strategy is extending their current offer on their legacy infrastructure with a fibre offer. Either they decide to roll out their own fibre infrastructure, making them independent of the public MIP, as private MIP. Or they decide to become an ANP on top of the municipal infrastructure. While the first strategy will result in high investment costs, they will be independent of the MIP. It should be noted that the move towards the fibre network of the Telco does not mean the copper infrastructure is unused in these scenarios. The Telco offers a fibre service, next to his existing copper offers. As such, he risks cannibalisation of his copper service.

The second player impacted by the emergence of a new infrastructure is the group of existing ANPs. While they are currently bound to the Telco's for their broadband offers, they will now have a choice between different infrastructures. They can either choose to stay on the legacy copper network, or migrate towards the municipal fibre. Again, the decision will impact their market share and as a result their profitability.

As such, the broadband market will be divided between different offers. First, the public MIP will obviously capture a part of the market through its offer. Additionally, the existing Telco legacy and CO legacy will notice the impact of this introduction on their offer. The same rationale goes for the ANP legacy. If the Telco or ANPs decide to migrate towards fibre, these offers will also capture a market share.

When strategies of one player have an impact on other players (e.g. with a closed municipal infrastructure, Telco's and ANPs cannot migrate towards this infrastructure), game theory is very well suited. Here, the resulting game will look like Figure 68. In order to conduct the game theoretic analysis, the objective functions of the different players need to be modelled, to estimate their payoff in the different strategic combinations. In this game, the goal of all players will be to maximize their net present value.

		Public MIP			
		CLOSED	OPEN		
Telco	STAY			COPPER	ANPs
				FIBER	
	MIGRATE			COPPER	
				FIBER	
	OWN			COPPER	
				FIBER	

Figure 68: Strategic combination in infrastructure competition

5.2.3.2 Pay-off function per player

As a payoff function, the NPV of each player in the specific strategic combination is used. As such, cost and revenue models are built for each player. These models are based on a bottom-up approach. The different models are discussed in more detail below.

We chose not to analyse the existing OASE reference areas, but implement the game theoretic model on an exemplary case of an FTTH deployment in the city of Ghent, Belgium. This city consists of roughly 135.000 households, spread out over an area of 156 km^2. This area was the specific study case of the ICON TERRAIN project [79], where detailed GIS models were used to calculate the optimal deployment paths. Although we could not use the TONIC model (it doesn't allow for the needed automated repetitive calculations need for the game theoretic model), we did implement the German market shares from OASE in the analysis.

Public MIP

The goal of the infrastructure competition game is to evaluate the impact of fibre rollout by a public MIP on the existing market. Therefore, the first part of the payoff function of the public MIP is the NPV of the fibre infrastructure rollout. Based on GIS modelling, the total trenching, duct and fibre length was calculated. Together with the amount of homes passed, a full deployment cost model can be built. To cover the entire area with the FTTH network, trenching of 1.200 km, a duct length of 1.500 km and just over 5.000 km of fibre is required.

These lengths were used as an input for the equipment model, described in [84], and adjusted to calculate the cost and revenue structure for the public MIP.

Although the physical infrastructure provisioning is a major part of the costs for the public MIP, the costs of his ANP unit should also be taken into account. Both in case of an open and a closed network, the public MIP also provides ANP services. The related costs are now driven by the number of homes connected by the public ANP.

The only additional aspect still required is the revenue model. For both the PIP and ANP layer, this is based on a monthly revenue per home connected. Concerning the ANP layer, the revenue is based on the KPN charges in the Netherlands, at about €20.00 per month. For the MIP layer, the regulated fibre access charges for urban areas from the Netherlands were taken as well, at €12.14 per month per line.

To model the net present value, the yearly cash flows are discounted with an appropriate discount rate. In order to diversify between the long term investment in physical infrastructure and the more short term oriented investment from the ANP, the discount rate for the latter is placed higher (10% vs. 5%).

Telco

The payoff model for the Telco is very dependent on the chosen strategy. Three different parts can be observed in its model.

In case the Telco decides to stay on his existing legacy copper network, the payoff for this network needs to be taken into account. A simplified model was used, taking into account both wholesale and retail revenues. In the wholesale model, the costs and revenues the incumbent incurs since it offers access to ANPs are calculated. However, since these regulated wholesale access prices are based on an LRIC calculation, the revenues the incumbent gains from the ANPs should cover the costs.

For the retail model, the cost is based on the bitstream access prices, plus an additional cost for service provisioning. Additionally, a cost to connect a new customer is included. The revenue model is based on the monthly subscription price per customer. The used input parameters can be found in Table 24.

Table 24: Cost parameters for the Telco legacy network model (per customer)

Parameter	Value
Yearly LLU cost	€96.36
Yearly bitstream access cost	€83.40
Yearly cost for service provisioning	€144.60

However, in case the Telco chooses to migrate or deploy his own fibre network, extra costs and revenues need to be taken into account, in addition to the legacy network model. Note that it is assumed that the Telco continues to offer services through the existing network! When migrating to the public MIP, the additional costs and revenues for the Telco can be modelled through the ANP model introduced in the public MIP section, now driven by the number of customers the Telco attracts as ANP. In case of deploying its own fibre network, a special case is taken into account.

Different studies have showed that a joint rollout of infrastructure can decrease the total cost of the outside plant installation [5]. When two fibre infrastructures are rolled out, one by the Telco and the other one by the public MIP, such cost savings of 20% on the total trenching costs are taken into account for both actors.

ANP

The payoff model for the ANP is again strongly influenced by his strategy. Comparable to the Telco model, the ANP model is based on a simplified cost-benefit model, starting from the existing regulated access prices. Per customer, the ANP pays a monthly price to the Telco. Again, extra costs were taken into account for service provisioning and customer connection. For simplicity, the same costs as for the Telco were taken into account. The revenue model simply multiplies the number of customers with the yearly income.

However, in case of migration to the fibre network, the payoff from being active on this infrastructure need to be taken into account as well. Again, it is assumed that the ANP does not stop directly with offering services through the legacy network, and still reaps some revenues from its old business model. The cost-benefit model is again based on the ANP model, already described in the public MIP section.

5.2.3.3 Market model

It is clear that the amount of customers in every year is the main driver for the total cost and revenue structure in each year for all players. Therefore, a market module implementation was used to estimate the take-up of all offers. Using cross-elasticity and initial market shares, the evolution of the market share of all offers was estimated. We refer to Annex B for an overview of this model.

The market model calculates the market share of all players active on the market, based on their offer. Consumers choose an offer from the available set, but it is taken into account that these customers are rational, and thus price and/or quality sensitive. As such, they always have a preference for the cheapest or best quality offer. In order to model this price sensitivity, a cross-elasticity measure is used, indicating how sensitive consumers are to broadband prices or quality. Previous research indicated a low price sensitivity for broadband of -0.0476 [64] for a €1 difference. This means that when an offer is €1 cheaper compared to another offer, it grasps 5% more of the market. It should also be noted that the market model also takes into account the effect of timing on changes in the market shares. Not all customers change instantly when a price or quality gap is introduced. This is modelled through an ‘available to churn’ concept. Every time period, there is only a portion of the market that can switch between different offers. These are customers whose contract ended, or who are actively looking for a better offer. In this case, 20% of the total market can switch offers each period. However, the most expensive offer will not lose 20%, since some customers will still decide to stay with this operator.

Additional parameters and the initial market shares of the players can be found in Table 25 and Table 26, based on the revenue scenarios from D6.2 [54] and Chapter 3 from the current deliverable. Although the market model allows implementing a growing or shrinking market, this was left out in this analysis. It is assumed that broadband is a saturated market. The introduction of new offers will not increase the total market size. The price competition is played on the retail prices found in Table 27.

In Figure 69 and Figure 70, the evolution of the market in two of the strategic combinations is shown. In Figure 69, the evolution of the market is modelled when the fibre infrastructure is closed, forcing existing players to stay on their legacy infrastructure. It is clear that this results in a strong growth of the uptake of the public MIP to over 15%. The results of players migrating to the open fibre infrastructure can be found in Figure 70. Here, the evolution of the market under strategic combination [MIGRATE – OPEN - FIBRE] is shown. The market shares of the copper and cable Telco's show a clear drop, due to the introduction of a fibre offer. Additionally, the market share of the copper ANPs also decreases. There is only a marginal difference between the market shares of the fibre offers, due to the low price sensitivity for broadband.

Table 25: Current broadband market shares in the case study (relative to the market size from Table 26)

Offer	Initial market share
Cable	18.19%
Telco	45.45%
ANP copper	36.36%

Table 26: Parameters of the market model [54]

Parameter	Value
Market size 2011	66.0%
Market size 2030	81.1%
Cross elasticity	-0.0476
Available to churn	20%

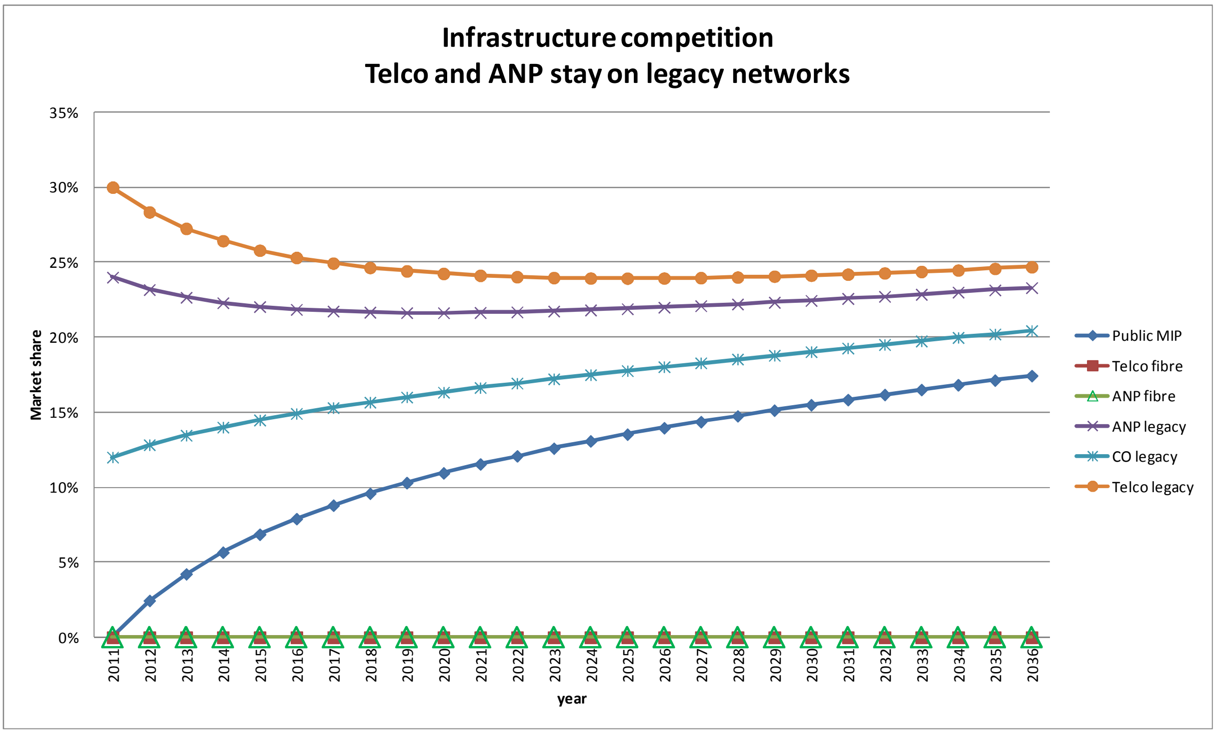


Figure 69: Market share evolution under infrastructure competition

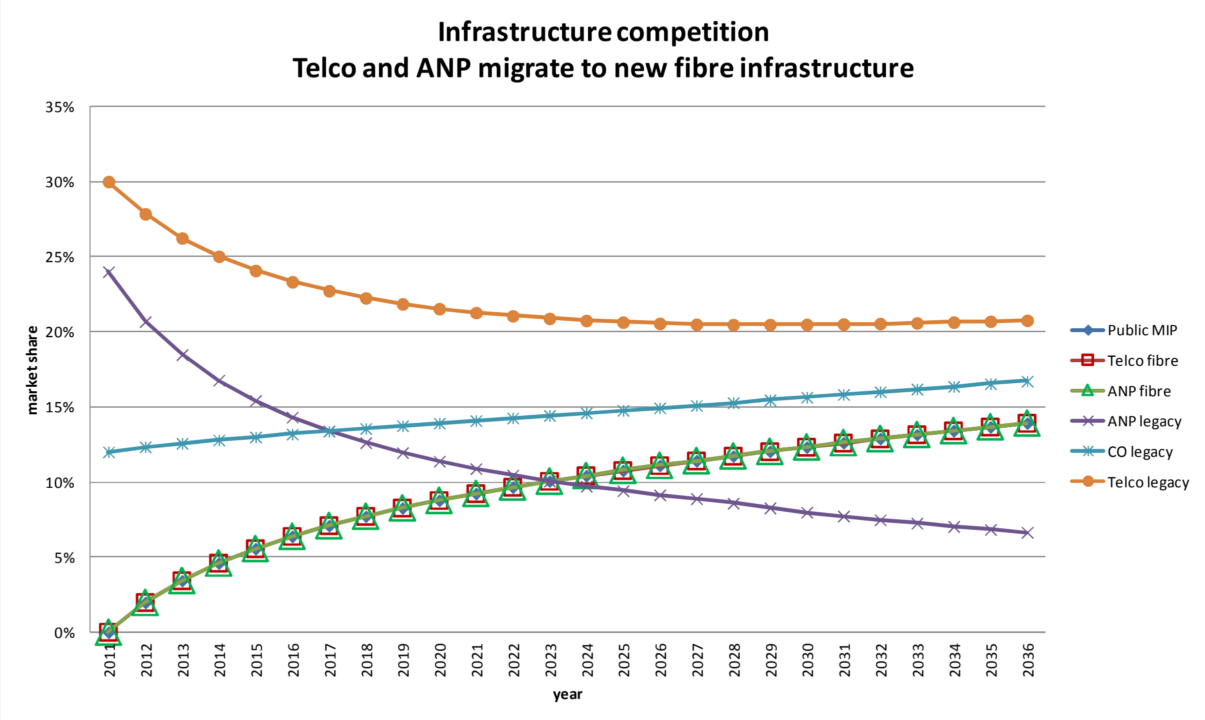


Figure 70 Market share evolution under infrastructure competition

5.2.4 Actual evaluation results

5.2.4.1 Price competition

The main question that rises from the figure above is about the profitability of an FTTH deployment by a MIP. In Figure 70, it can be seen that the uptake for the fibre offers combined only reaches 42% after 25 years. Compared to the uptake scenarios from WP6, it is to be expected that fibre rollout will not be a viable project. The negative outcome is also reflected in the payoff for the public MIP in Figure 71. When two fibre infrastructures compete, the uptake on each fibre network will be even lower than this 42%. This uptake is insufficient to result in a positive business case, even when cost savings in the rollout phase are taken into account.

The graphical representation of the game can be found in Figure 71. The results show the NPV for each player after 25 years in millions €. It is immediately clear that under the given circumstances, an FTTH rollout is unprofitable in case the public MIP chooses for a closed network. Even with an open access network and all operators moving towards this network, the business case for the MIP is still negative [MIGRATE – OPEN - FIBER]. However, this is clearly the best case for the public MIP. When looking at the rollout of two fibre infrastructures, it is clear that this is uninteresting for both infrastructure owners [OWN – OPEN – FIBER].

Table 27 Monthly retail prices for broadband access [54]

Retail offer	Monthly subscription
Telco DSL	€30.00
ANP DSL	€30.00
Cable	€33.00
Public MIP fibre	€40.00

Incumbent fibre	€41.00
ANP fibre	€40.00

		Public MIP							
		CLOSED			OPEN				
Telco	STAY	5.65	-33.00	5.00	5.65	-40.00	5.00	COPPER	ANPs
		-∞	-∞	-∞	5.57	-15.00	4.95	FIBRE	
	MIGRATE	-∞	-∞	-∞	6.92	-25.00	4.50	COPPER	
		-∞	-∞	-∞	6.83	-5.40	4.50	FIBRE	
	OWN	-31.00	-29.00	4.50	-31.00	-36.00	4.50	COPPER	
		-11.00	-29.00	4.50	-31.00	-16.00	4.50	FIBRE	

Figure 71: Results from infrastructure competition under different strategies (Telco – public MIP – ANP) (in million €)

When analyzing the game in more detail, the following conclusions can be drawn. The first Nash equilibrium, where no player can unilaterally change his strategy to improve his payoff is [STAY – CLOSED – COPPER]. In case the municipality chooses for a closed network, the incumbent can only choose between two strategies, namely deploying his own network, or compete through the legacy copper network. However, the latter strategy clearly dominates the fibre deployment option. Also, in this case the ANPs can only choose to continue buying access from the incumbent. Although this is clearly negative for the business case of the municipal fibre network, it is one of the prevailing competitive equilibriums.

The second Nash equilibrium is [MIGRATE – OPEN – COPPER]. In case of an open access network, the Telco will definitely migrate to the more profitable municipal fibre network. However, the best business case for the ANP remains the legacy network case. The COPPER case is slightly higher than the FIBER case, but cannot be observed in Figure 71 due to rounding of the numbers. While this second competitive equilibrium could also result from the free competition between the different players, it is also the Pareto optimal strategic combination. In this point, no player can change his strategy to improve his payoff, without hurting another player. It may be clear that in order to reach this Pareto optimal point, the municipal policy maker can influence the strategic choices of the competition. By choosing for an open access network, the physical network will attract the Telco. Although this point is Pareto optimal, the public MIP does not attract enough customers to come to a viable business case. His case could be considerably improved if also the ANPs would migrate to the fibre infrastructure.

5.2.4.2 Price and quality impact – measuring willingness to pay

In the previous analysis, it was assumed that the customers were indifferent for the differences in quality between the different broadband offers, and only based their choice on the retail price for their offer. However, fibre based broadband access offers a significant increase in download and upload speed. This way, new services can be offered to users, and result in a higher willingness to pay for fibre broadband.

Here, this was taken into account by dividing the retail prices by the download speed they offer. The used speeds can be found in Table 28.

Table 28: Perceived broadband quality measured by download speed

Offer	Speed (in Mbps)
Price Incumbent Copper	20
Price ANP Copper	20

Price Cable	30
Price Incumbent Fibre	60
Price Public MIP	60
Price ANP Fibre	60

When taking such a quality measure into account, it is to be expected that the uptake of fibre based services will be significantly higher. As a result, the business cases for the different fibre cases (MIP and ANP) in the game will improve compared to the strategies where the operators continue to use the legacy copper network. The resulting game can be found in Figure 72.

Due to the higher willingness to pay for fibre, the prevailing equilibriums change. [STAY – CLOSED - COPPER] remains an NE, but if the municipality opt for an open access network, the increased take-up of fibre services due to the willingness to pay, shift the dominant strategy of the ANP to migration to fibre. As a result, the second NE is [MIGRATE – OPEN - FIBRE]. In this point, which is also Pareto optimal, the payoff for the Public MIP is also maximized. However, their case remains negative, although it is improved compared to the case without willingness to pay. The resulting market division for this strategic combination can be found in Figure 73. The difference with the previous case is only marginal. A second Pareto optimal strategy set can be identified, namely [MIGRATE – OPEN - COPPER]. Although no player can improve his payoff without reducing that of another player, the Public MIP and the ANPs would prefer the first Pareto optimal solution.

		Public MIP							
		CLOSED			OPEN				
Telco	STAY	5.60	-32.00	4.95	5.60	-39.00	4.95	COPPER	ANPs
		-∞	-∞	-∞	5.55	-15.00	4.97	FIBRE	
	MIGRATE	-∞	-∞	-∞	6.92	-23.00	4.45	COPPER	
		-∞	-∞	-∞	6.82	-5.10	4.50	FIBRE	
	OWN	-30.00	-28.00	4.45	-30.00	-35.00	4.45	COPPER	
		-11.00	-29.00	4.50	-31.00	-16.00	4.50	FIBRE	

Figure 72: Infrastructure competition with willingness to pay

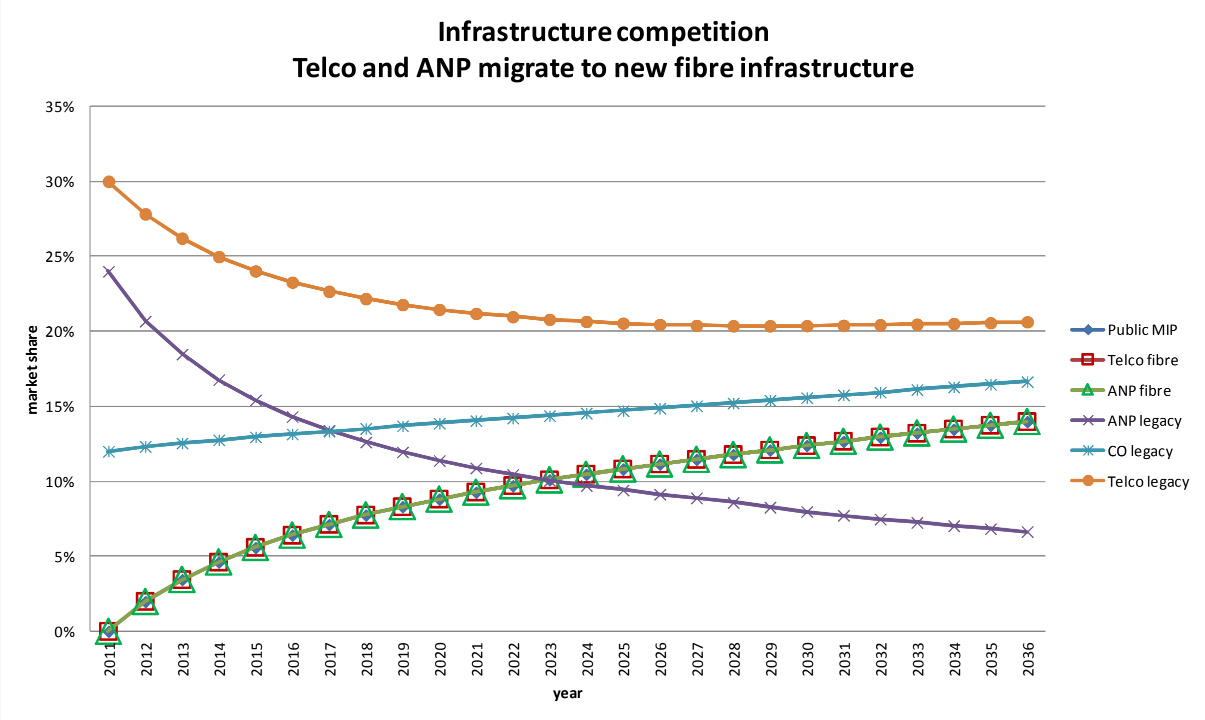


Figure 73: Market evolution with WTP

It is clear that in both scenarios, with and without willingness to pay, the business case of the infrastructure provider is negative in all cases. However, in the initial assumptions, especially concerning the market, a rigid market was modelled. Only one fifth of the customers can switch each year to another provider, and the price and quality difference between different offers has almost no impact on the distribution of the free customers between offers (low cross-elasticity).

5.2.4.3 Market distortion due to fibre rollout

Assuming that the introduction of a new infrastructure would have a large disturbing effect on the market, these assumptions (cross-elasticity, churning customers) can be challenged. Increased churn would result in a faster take-up on the fibre network, and a stronger decrease of the market shares of the existing players. Both churn and cross elasticity have been doubled for the following analysis. This will of course have an impact on the evolution of the future market shares. The evolution of the market shares can be found in Figure 74. Comparing these with the results from Figure 73, the uptake on fibre is faster and reaches a higher market share in 2030.

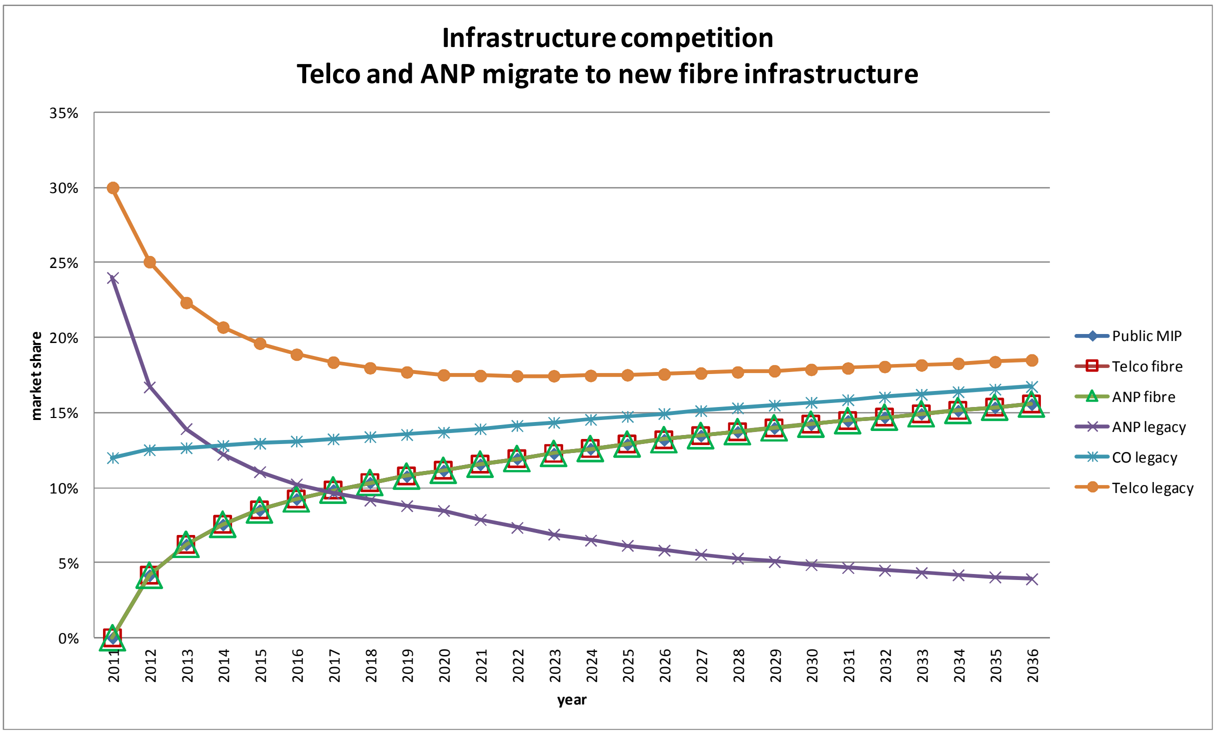


Figure 74: Market share evolution with WTP and market distortion

As a result, the business cases of the different operators in the infrastructure competition game will also be impacted (Figure 75). Due to the increased price sensitivity and volatility of the customers, the business case for the public MIP improves significantly in all strategic combinations. Compared to the previous analysis, without higher churn and price-quality sensitivity, the same equilibriums occur. But unlike above, the public MIP now has a positive business case in the Nash and Pareto combination [MIGRATE – OPEN - FIBER]. Therefore, it is of key importance that fibre adoption is stimulated on all ANPs, e.g. through marketing campaigns. Prevailing of new, innovative services can also push the fibre uptake.

		Public MIP							
		CLOSED			OPEN				
Telco	STAY	4.84	-23.00	4.50	4.84	-30.00	4.50	COPPER	ANPs
		-∞	-∞	-∞	4.75	-0.91	4.86	FIBRE	
	MIGRATE	-∞	-∞	-∞	6.77	-9.90	3.82	COPPER	
		-∞	-∞	-∞	6.54	12.20	4.21	FIBRE	
	OWN	-24.00	-21.50	3.82	-24.00	-28.20	3.82	COPPER	
		-0.25	-23.40	4.50	-26.00	-4.30	4.21	FIBRE	

Figure 75: Infrastructure competition with WTP and market distortion effect

5.2.5 Conclusions from the game theoretic analysis

Rolling out a fibre infrastructure as municipality will happen in the existing competitive broadband market. As a result, the new fibre based offers will have to compete for market share with existing legacy copper networks and cable networks. Additionally, when multiple NPs are allowed on top of the physical infrastructure, intra-platform competition will most likely also impact the business case of the fibre infrastructure.

By modelling a realistic market environment, the previous section indicated how market shares of different offers change under the influence of price and quality preferences by end consumers. In addition, the strategies from existing and new actors on the market will also influence the market division. Using a game theoretic analysis, this section modelled the dynamic interaction between different operators and indicated the prevailing competitive equilibriums.

Three games were modelled, to check the outcomes for differences in willingness to pay for higher broadband speeds and market dynamics. The first two cases studied the impact of fibre rollout in the current market, leaving out the distortive effect this rollout might possibly have. In both cases, two equilibriums existed in this competitive environment. In the first equilibrium, the fibre infrastructure was a closed infrastructure, pushing existing operators to remain on the legacy networks. Additionally, the business case for the public MIP network was unviable. The second equilibrium, where the public MIP opted for an open access infrastructure, resulted in existing players migrating to this infrastructure. Now, the total fibre adoption rose from 17% to 42%, spread out over 3 offers, namely the public MIP, Telco fibre and ANP fibre. As a result, the fibre business case improved significantly. This equilibrium is a Nash equilibrium, and could be reached under competitive interaction. However, since the municipality not only focuses on profitability of the fibre network, but also on social welfare, it can push the market towards the more preferred Nash equilibrium. In fact, the equilibrium where all players migrate towards the fibre network is also Pareto optimal, and should thus be preferred. By opening up the physical infrastructure, the municipality can push the other actors towards the social optimal situation.

However, under these assumptions, even when the Telco and ANP migrate to the fibre network, the business case for the public MIP remains unviable. On the other hand, precise forecasting of how the market will react or evolve is as complicated as rocket science.

For instance, to model the distortive effect a fibre rollout can have on the retail market, the dynamics of this market were increased. Customers switch faster and are more price sensitive due to the increased competition. In this specific case, the same equilibriums were observed compared to the previous two games, but in the Pareto optimum, where all players migrate to the fibre network, the public MIP has a positive business case. It can be concluded that the viability of the public MIP business case will be highly dependent on the adoption. Stimulating measures, like marketing campaigns, but also the emergence of new services and applications could push the adoption to viable levels for all actors.

5.3 Conclusions from the competitive analysis

Within this chapter, we have evaluated the competitive setting between the different actors (Telcos, Housing Companies, Municipal Infrastructure Providers, Active Network Providers, Internet Service Providers, Public Authorities and Regulators) in the field of NGOA deployment, both in a qualitative and in a quantitative manner.

During our qualitative analysis, city networks emerged as the most promising co-operation. They would be built collaboratively by Housing Companies, Municipality Infrastructure Providers (both private and public), Active Network Providers and Internet Service Providers. It is likely that they would be supported by Public Authorities and Regulators because both aim for a higher level of rivalry and a multitude of choices for customers. Moreover, city networks could serve as counterbalance to incumbents such as telecommunication and cable operators, who would have conflicting objectives compared to the municipal player.

Using a game theoretic analysis, this section also modelled, now in a quantitative manner, the dynamic interaction between different operators and indicated the prevailing competitive equilibriums. We indicated different equilibrium situations between the Municipal Network Provider and the Telcos. We focused on the case of a fibre infrastructure deployed by a municipal infrastructure provider (which was indicated as most promising by the qualitative analysis). Although a closed infrastructure could also be an equilibrium situation (where the telco and other NPs are forced to stay on the legacy network), an open infrastructure clearly leads to a more preferable equilibrium situation with a better business case for the MIP (which remains difficult though). Since the municipality not only focuses on profitability of the fibre network, but also on social welfare, it can even push the market towards the more preferred equilibrium.

5.4

6. The effect of uncertainty and strategic decision on profitability studies

6.1 Applications of real options theory in telecom network planning from literature

6.1.1 Real options basics

Real option theory is a more recent addition to the economic evaluation theory [19]. It allows implementing the value of managerial flexibility during the project lifetime in the economic assessment. An excellent definition of real options is given in [49]: "*Real options is a systematic approach and integrated solution using financial theory, economic analysis, management science, decisions sciences, statistics and econometric modelling in applying options theory in valuing real physical assets as opposed to financial assets, in a dynamic and uncertain business environment where decisions are flexible in the context of strategic capital investment decision-making, valuing investment opportunities and project capital expenditures.*" As this definition states, the real option theory is based on the option concept as used in financial markets. A financial option is defined as the right to buy or sell an asset for a predefined price during or at the end of an agreed period. Transferring the financial option concept towards business investment decisions is quite straightforward. A real option is the right to invest or disinvest in business activities. For an introduction to the foundations of real option theory (ROT), we refer to [93].

A real option analysis (ROA) always starts from the standard NPV analysis taught to all business school students. In fact, the standard discounted cash flow (DCF) approach is a special case of the real option analysis, evaluating the project as if no flexibility is present. It is therefore vital to start any ROA with a correct standard NPV valuation. The total value of a project is expressed by the following formula.

$$\text{Project value} = \text{NPV} + \text{Flexibility value}$$

Three different solution methods have been proposed to calculate the value of real options in investment projects. We will give a short description of each of them in the following sections.

6.1.1.1 Black and Scholes model

Since real options are derived from financial options, it is logical that the calculation methods for financial options were transferred to real option valuation. The mathematical Black and Scholes model is one of the most used option valuation models in the financial sector [6]. It was developed in 1971 to evaluate the value of a European option. This indicates the first underlying assumption of the model, namely the option can only be exercised at the end of the time period. Most of the parameters of the mathematical model are straightforward but others cannot be directly transferred to investment projects.

6.1.1.2 Binomial tree model

The binomial tree model is a discrete time model. A binomial tree model is applicable to simple processes. The main assumption is that the uncertain input can only take discrete values. This allows modelling the problem by a tree structure. The main assumption results in both the greatest advantage and disadvantage of the model. An uncertain parameter only taking discrete values largely simplifies the analysis, but realistic cases are generally subject to continuous uncertainty. Detailed examples using the binomial tree method can be found in [47].

6.1.1.3 Monte Carlo simulation

The Monte Carlo simulation is the last calculation method we will discuss. While the two previous models allow for a simple option value calculation, they both have their own drawbacks. Their underlying assumptions do not always match reality. A Monte Carlo simulation solves these problems but results in a more complicated calculation method. Sawilowsky defines the Monte Carlo simulation as a repeated sampling to determine the properties of a phenomenon [69]. Since the Monte Carlo Analysis allows for the most detailed option valuation, it is this technique that will be used in the real option analysis in this work package.

To perform a Monte Carlo analysis, spreadsheet based solutions exist. In general, these consist of extending a standard NPV analysis with the existing options. Since an option comes down to maximizing payoff, this is quite straightforward. After indicating all uncertain input parameters with an appropriate probability distribution, the Monte Carlo simulation can be conducted. Choosing these probability distributions for the input parameters is the most delicate task in the Monte Carlo simulation. For every simulation, the input parameter is randomly sampled from the defined probability distribution and the best project path is selected. The NPV is calculated for thousands to hundreds of thousands of possible combinations of input parameters within the predefined distribution boundaries. As indicated, the model automatically selects the best option in each scenario. The result from a Monte Carlo analysis is a probability distribution of the expected payoff. From this distribution, an extended NPV can be derived, together with the option value for the studied case.

6.1.2 Option valuation in realistic cases

In this section, the methodology commonly used to perform real option analyses is discussed [19], [47]. However, before the ROA can be conducted, the business case must be assessed on three conditions.

- First, there needs to be uncertainty in the project. During the standard NPV evaluation, some assumptions on future costs and revenues have been made.Some assumptions come with a certain degree of uncertainty. Future customer uptake, the future price of raw materials and components can only be estimated. When this is the case, the project meets the first condition.
- Secondly, the project offers some kind of flexibility. This flexibility can easily be recognized if one of the options in the 7S framework (see further down in section 6.1.3 and Figure 77) is present in the case.
- The last condition concerns the timing aspect. A real option analysis can only be performed if the investment decision covers a two (or more) phased project. An initial decision is made at the start of the project, but extra decisions can be made during later stages of the project. For example, the network operator can, after the first part of the network has been deployed, still decide in later stages what his next steps will be. Will he do nothing or extend the network to other regions?

After the case has been assessed, based on these three conditions, a clear methodology needs to be followed to perform the ROA. In this paper, we use the methodology proposed in [19], [47]. It is clear that the second and third steps of the methodology are closely linked with the preconditions. In essence, the second step comes down to identifying the uncertain input parameters that can influence the result of the project. The third step links back to the second and third condition listed above. When the management has no options to act against the changing parameters, a real option analysis is pointless. To identify the different options present in the studied case, the 7S framework can be used (see Section 6.1.3). The conditions and methodology are summarized in Figure 76.

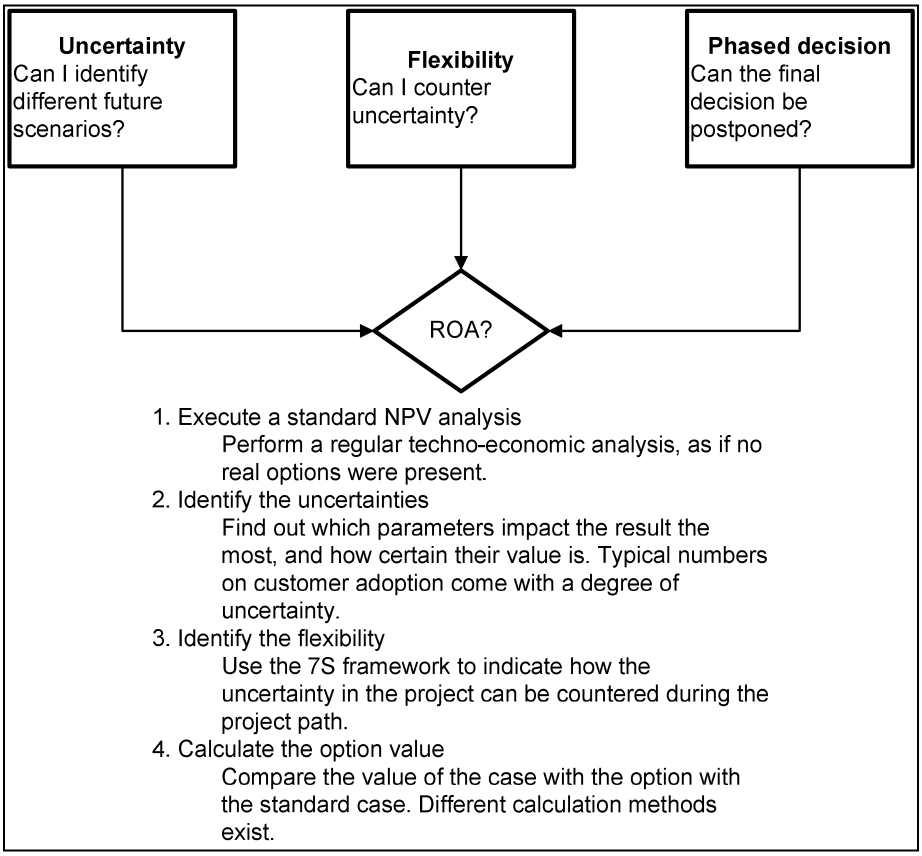


Figure 76: Conditions and methodology to perform a real option analysis

6.1.3 Option categories and telecom examples

In general, the different existing options can be subdivided in three distinct categories, namely growth, shrink and learning options. The most well-known real options categorisation is the 7S framework by Copeland and Keenan [20]. The different real options and telecom specific examples are shown in Figure 77.

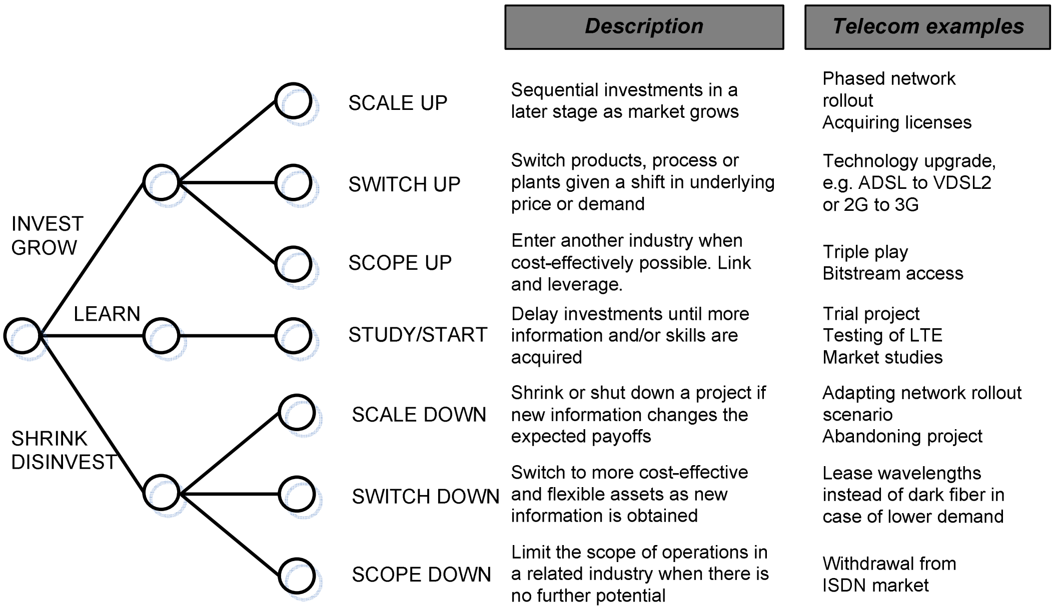


Figure 77: Overview of the 7S framework and telecom examples

As can be seen from Figure 77, real options can be applied to a wide range of telecom related investment projects. While study/start and scale options are the most common options studied in both fixed and wireless networks telecom research, switch up and down options are typically found in the rollout of wireless networks. Upgrading the technology from 2.5G to 3G is studied in [82] and [37], while [38] focussed on the extension of GPRS networks with WiFi integration. Research on scope up or down options is less widespread, but typical examples are the extension of the product portfolio towards triple play, or offering bit stream access [48].

A literature review can be found in Table 29. Real options have been applied to service oriented cases, e.g. [85] applied the scale up option to the case of the Belgian rail operator offering internet services on board. However, most of the existing literature applies real options to telecom infrastructure rollout [1], [39], [68] and [82]. This rollout is related to a large investment covering several years and thus allows for flexibility in the rollout path. The scale of such projects covers large areas, and both the rollout area and speed can be changed during the project to optimize the return on investment. Abandoning the project due to unsatisfactory results is a special case of a real option. A quantitative and simplified example to illustrate real options is the M-commerce project, describing an investment by a telecommunications firm [47]. This is a typical example of a scale up and scale down option. During the project, management has two options, either expanding the project scale by 60% if expectations are exceeded, or abandoning the project completely and reaping the salvage value. Another paper describing scale options in telecom networks is [39]. The feasibility of Mobile WiMAX as an alternative for fixed DSL and HFC networks is analysed, with the possibility of extending the scale of the project. Several rollout scenarios are studied, changing the rollout location from nationwide to only in urban areas and with the option to change rollout speed. Closely linked with this paper is the research of [68] who studied the rollout of a WiMAX network in Eindhoven, The Netherlands. In this case, the value of a study/start option is investigated. Before extending the network to a larger area, the technology is first tested on a very small scale. In the second phase, based on the results from the trial phase, the operator can decide to invest or abandon the project.

While study/start and scale options are the most common options studied in both fixed and wireless networks telecom research, switch up and down options are typically found in the rollout of wireless networks. Upgrading the technology from 2.5G to 3G is studied in [82] and [37], while [38] focussed on the extension of GPRS networks with WiFi integration.

Research on scope up or down options is less widespread, but typical examples are the extension of the product portfolio towards triple play, or offering bit stream access [48].

Table 29: Real options in telecom literature

Option	Flexibility	Reference	Uncertainty
Scale up/down	Rollout area	[1], [39], [47], [50], [77] and [82]	Adoption Costs Tariffs
	Speed up/slow down rollout	[1] and [39]	Adoption Costs Tariffs
	Abandon project	[47] and [85]	Adoption Costs Tariffs
Switch up/down	Technology	[37], [38] and [82]	Firm value Adoption Costs Regulation
Scope up/down	Product portfolio	[48]	
Study/ start	Trial project	[68]	Technological Performance
	Wait and see	[1], [9], [15], [30], [68] and [82]	Market Technology Regulation

In addition to the analysis of large infrastructure projects, a lot of research has been performed on the impact of regulation on investment decisions by network operators. Regulatory bodies imposed local loop unbundling (LLU) on the incumbent operators to improve competition. For new entrants, LLU has the advantage that they do not have to make large investments in network infrastructure before they can offer network services. However, fixing the price for network access is not straightforward. One should take into account that new entrants should also pay for the financial risk of the incumbent since he did invest in the network infrastructure. LLU in fact offers a study/start option to new entrants, while the incumbent gave up his option when he invested. In [85], this problem has been discussed in more detail.

Next to large investment projects and the regulatory impact on these investments, telecom licences are a last important field of research within real options and telecom. Licenses for wireless networks are known to be very expensive, so it is important to correctly evaluate the license investment. For example, in the UK, 35 billion dollars was paid for the 3G licenses. In [5], the authors try to estimate the value of these licenses based on a real option approach. Buying the 3G license resulted in acquiring a strong market position and a broad range of options, including scale up, switch up and down and temporarily halting the project. This research showed that with the correct valuation techniques, the value of the 3G license was close to the price paid for the acquisition. Spectrum management is closely linked with telecom licenses. Dynamic spectrum management, with a two stage assignment through the use of options was proposed in [22]. The option concept allowed calculating the penalty value and the overbooking ratio.

6.2 Flexibility options throughout the NGOA planning problem

6.2.1 Impact of providing open access

One of the important questions that needs to be addressed during the planning phase of the NGOA network, is whether the infrastructure provider will offer an open or a closed network. While this decision may be partially driven by regulatory and policy decisions, the impact of this choice on the business case cannot be neglected.

Indeed, offering an open access network comes with an upfront cost and an additional provisioning cost when a customer connects to the fibre network. Linking this back to the real option concepts above, the infrastructure provider buys the option to offer open access to the end users during the deployment phase. Later on, he can offer open access to other players and lift this option.

The effect of this option can already be observed in the game theoretic analysis in 5.2.4.1. In Figure 71, strategic combination [STAY – CLOSED – COPPER] indicates a situation where the public MIP did not buy the option for an open access network. Comparing this with [STAY – OPEN – COPPER], all underlying assumptions are the same, apart from the public MIP buying the option here. As a result, his business case decreases significantly, since he bought the option, but no other player migrates to its fibre network. Since the option is not lifted, due to strategic choices by the other market players, no extra revenues are gained. The same result can be seen between the combinations [OWN – CLOSED – COPPER] and [OWN – OPEN – COPPER]. Again, the option is not exercised, resulting in a significant deterioration of the payoff for the public MIP.

However, in cases when the option is lifted, a significant improvement of the public MIP business case can be observed. In the base scenario, shown in Figure 71, exercising the option, by offering the open access network, clearly pushed the other players towards a migration to the fibre network. A twofold reason for this behaviour can be given. First, when the option is not exercised, the public MIP reduces the possible strategies for the other players. Neither the Telco’s nor the ANPs can migrate to a closed network. Secondly, if the option is exercised, the uptake of the fibre network is increased (Figure 69 and Figure 70), increasing the viability of the PIP business case. This can be seen by comparing the COPPER and FIBRE strategies in case of an open network.

It can thus be concluded that in this case, the public MIP profits from buying the open access option in the planning phase. By effectively opening his network and exercising the option, the existing players migrate to his network and improve the viability of the public MIP’s business case.

6.2.2 Cost implications of providing open access

However, an important remark must be made. Up to now, the impact of transaction costs for the public MIP was not taken into account. These have been estimated between 10 and 20% of the yearly revenue for the MIP (see section 2.4.3.2), and can thus significantly impact the viability of the business case.

In case no transaction costs are present, the results from section 5.2.4 hold. In order to check for the impact of transaction cost, an extreme case was modelled, with a transaction cost of 20% for the public MIP. For every customer connecting to the physical infrastructure via the

Telco fibre or ANP fibre, the monthly revenue of the public MIP is reduced with 20%. The results of this analysis are shown in Figure 78 (in case of a dynamic market). First, it is important that the transaction costs only have an impact on the public MIP. The payoff for the other players remains the same. Indeed, since these costs are limited to the public MIP, and are not reflected in the retail prices, the market division does not change. Secondly, the prevailing equilibriums do not change under transaction cost uncertainty. In this sequential game, where the public MIP can make the first choice (open or closed network), it remains in his best interest to exercise the option of the open access network. Although his viability decreases significantly in [MIGRATE – OPEN – FIBRE] due to the transaction costs, it remains the most profitable strategic combination from his point of view.

		Public MIP							
		CLOSED			OPEN				
Telco	STAY	4.84	-23.00	4.50	4.84	-30.00	4.50	COPPER	ANPs
		-∞	-∞	-∞	4.75	-15.50	4.86	FIBRE	
	MIGRATE	-∞	-∞	-∞	6.77	-22.50	3.82	COPPER	
		-∞	-∞	-∞	6.54	-5.58	4.21	FIBRE	
	OWN	-24.00	-21.50	3.82	-24.00	-28.20	3.82	COPPER	
		-0.25	-23.40	4.50	-26.00	-16.70	4.21	FIBRE	

Figure 78 Impact of transaction costs on infrastructure competition

In Figure 75 and Figure 78, the two extreme cases for the game theoretic analysis are shown, but there is a large degree of uncertainty on the height of transaction costs for the public MIP. A scanning was performed between these extremes for the payoff of the public MIP in the strategic combination [MIGRATE – OPEN – FIBRE] (Figure 79). It is clear that the transaction costs have a significant impact on the viability of the public MIP business case. Once these costs rise to about 13.5% of the monthly revenue per customer, the public MIP business case turns negative (Figure 80). Again, the transaction costs have no impact on the prevailing Nash equilibrium and Pareto optimum. Due to the modelling of the transaction costs, the relation between the public MIP payoff and the transaction costs is linear.

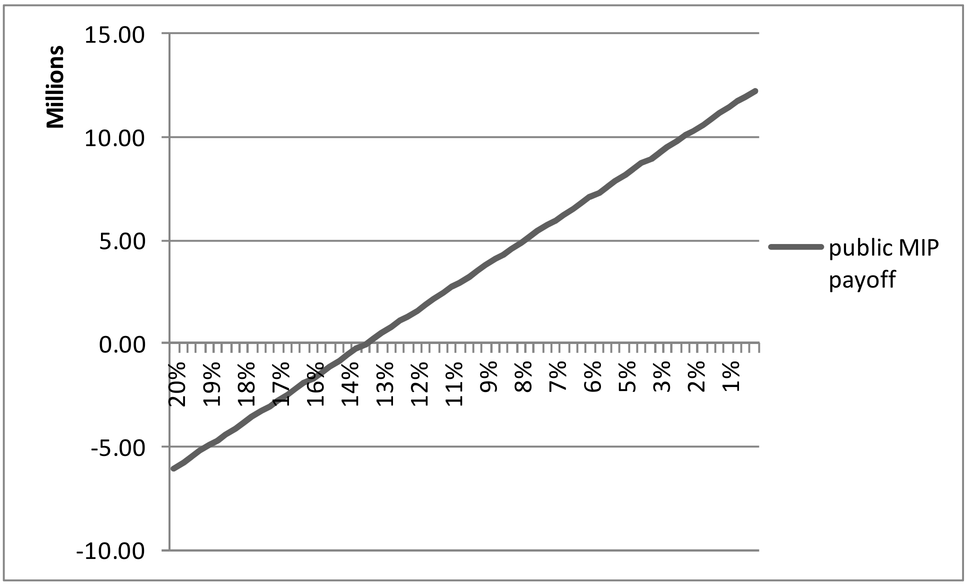


Figure 79: Impact of transaction costs on the public MIP business case

		Public MIP							
		CLOSED			OPEN				
Telco	STAY	4.84	-23.00	4.50	4.84	-30.00	4.50	COPPER	ANPs
		-∞	-∞	-∞	4.75	-10.70	4.86	FIBRE	
	MIGRATE	-∞	-∞	-∞	6.77	-18.40	3.82	COPPER	
		-∞	-∞	-∞	6.54	0.20	4.21	FIBRE	
	OWN	-24.00	-21.50	3.82	-24.00	-28.20	3.82	COPPER	
		-0.25	-23.40	4.50	-26.00	-12.20	4.21	FIBRE	

Figure 80: Infrastructure competition with 13.5% transaction cost

6.3 Conclusions

The initial choice between an open or closed network will have a significant impact on the viability of the public MIP. Not only will the open access solution result in a higher upfront investment and provisioning costs, transaction costs will also reduce the profitability of the MIP.

Here, both effects were studied. First, it was shown that deploying an open access network (buying the option) without exercising it, due to other players not migrating, already has a large negative effect on the viability. However, under competition, it is always more interesting to exercise the option, as existing players will choose to migrate to the network. The extra revenues due to the increased uptake on the fibre network clearly offset the upfront and provisioning cost.

Secondly, transaction costs are expected to play a major role. These can amount up to 20% of the yearly MIP revenues, and will as such affect the profitability of this player. While the prevailing competitive equilibriums remain, the MIP suffers from a negative payoff in all cases when transaction costs are above 15% of the yearly revenue.

7. Extending the business analysis to include indirect effects and therefore indirect revenues

In the traditional telecom operator perspective the investment decision is based on a simple cost/benefit calculation in which the benefit is the revenue that the operator gets from selling services over the network. This calculation becomes more complicated in the converging network scenario, in which several service types are increasingly provided over one and the same network, by competing service providers. Moreover, concentrating on the revenue from the end-users leaves out an important portion of benefits which are not necessarily internalised and represented by the end-user willingness to pay for specific services: we call these the uncaptured values and they should also be taken into account when considering costs and benefits of a deployment. It should be noted that these are benefits for society and the economy at large, independently on who funds the deployment. In other words, the benefits of a deployment may not accrue those funding the employment. This is particularly true in the case of telecom operator-funded fibre deployments, whose business case will be little affected by uncaptured values, while open access business models with participation from public actors will tend to more successfully internalise them.

As with any other infrastructure project, there exist both positive externalities (the uncaptured values mentioned above), and negative ones.

This section will describe two approaches of identifying and quantifying these uncaptured values: a top-down and a bottom-up analysis. Both approaches aim at getting a full overview of these benefits, and propose different calculation methodologies. We have also identified some potential negative effects. It should be noted that we only attempted to quantify the effects that seem to be substantially large.

7.1 Top-down analysis

In this analysis, the identification of the different effects starts from what can follow from the deployment of FTTH. These effects can be divided into direct, indirect and induced effects, whereas the category refers to the level of impact. In this section, we explain these three categories and link them to the various stakeholders. Furthermore, we identify the effects that can be quantified, and perform this quantification based on statistical regression methods.

7.1.1 Direct, indirect and induced effects

Direct effects of the construction of FTTH are significantly higher access capacity, access to a new future-proof infrastructure and direct economic value generated by the network build up, construction, fibre cables and active equipment. These values are available immediately at construction (and we can therefore expect that they are visible already after 1 year), leads in turn to view other **indirect effects,** such as:

- higher access capacity allows better service quality, which in turn may lead to increased use and development of new services: some of these services may depend on high bandwidth in itself, for example, some video-based services;
- higher capacity can enable new services, including services that work on other types of broadband connections which can nonetheless benefit from the higher bandwidth provided by FTTH because the total available bandwidth is not saturated by other services delivered at the same time (such a current example can be sensor networks with services video surveillance, smart grid systems, traffic and congestion charges, accident avoidance through the monitoring of buildings and social functional infrastructure[6]. Although many of these services can be individually operated over copper infrastructure, the aggregate bandwidth of the growing number and the increase in data-intensive services are best supported by fibre connection).
- FTTH represents a future-proof infrastructure that provides higher bandwidth and lower signal loss compared with radio and micro wavelength, therefore leading to higher housing value;
- The installation of a new infrastructure offers the ability to more easily abandon traditional business models (in favour of more open access models) and to solve marketing problems in the presence of ownership, long-term agreements and established benefits[7].
- The disruption of current business models may create undesired economic effects on market actors, for instance the open access business model may lead to higher market efficiency, lower end-user prices and new revenue sources especially for new and alternative service providers, but may be so at least in part at the cost of reduced revenue streams for incumbent operators, and reduced labour demand (and hence employment).

The direct and indirect effects of FTTH in their turn have a positive impact in areas other than ICT: we call these **induced effects.** For example,

[6] Some such examples, we see already in the municipalities that invested and quantified them – see the case studies in Annex A

[7] To grasp this is largely a matter for regulators and the public sector [34].

- services like high-quality cloud computing, video-conferencing and tele-presence have a positive impact on productivity[8], e-learning (with benefits on education and competence development) and distance working, which in turn reduces traffic congestion, increases virtual labour mobility, and reduces the cost of doing business. Reliable and high-quality e-health services reduce the need for expensive hospitalisation and home visits; while e-government services increase efficiency and transparency in public administration, which in turn strengthens democracy, increases transparency and decreases corruption and the burden of bureaucracy;
- widespread use of advanced ICT services brought about by FTTH increases ICT maturity of the population, which creates both new potential customers of, and new human capital for the production of new services and products;
- This in turns leads to the creation of new ICT companies, which in turn increases the level of entrepreneurship, favouring the creation of more companies, or the improved management of existing ones;
- putting in place the correct business model induces other benefits back on the ICT sector: if network and service providers are freed from the heavy upfront investments required to deploy the passive infrastructure they can scale investments with the number of users served, and therefore achieve profitability in the short-medium term;
- This, together with the availability of end users with very high access speeds will allow the provision of bandwidth-hungry, but profitable services like HDTV, 3D TV, Video-on-Demand (VoD). Those profits will then propagate down the value chain to the network providers (NP) and the physical infrastructure provider (PIP).
- Better broadband quality may lead to changes in social behaviours, both positive (increased interaction with individuals far away, with personal and intercultural enrichment; attraction away from more passive entertainment habits like TV-watching, increased exposure to quality information and culture) and negative (decreased incentive to physical social interactions, risk of isolation, exposure to new and poorly understood cyber risks).

Figure 81 describes the complex interactions between factors that are affected by and have an impact on FTTH.

[8] Katz et al (2009) refers to a number of studies that demonstrate increased productivity in the service sector, and partly in the manufacturing sector in the context of increasing broadband penetration [44].

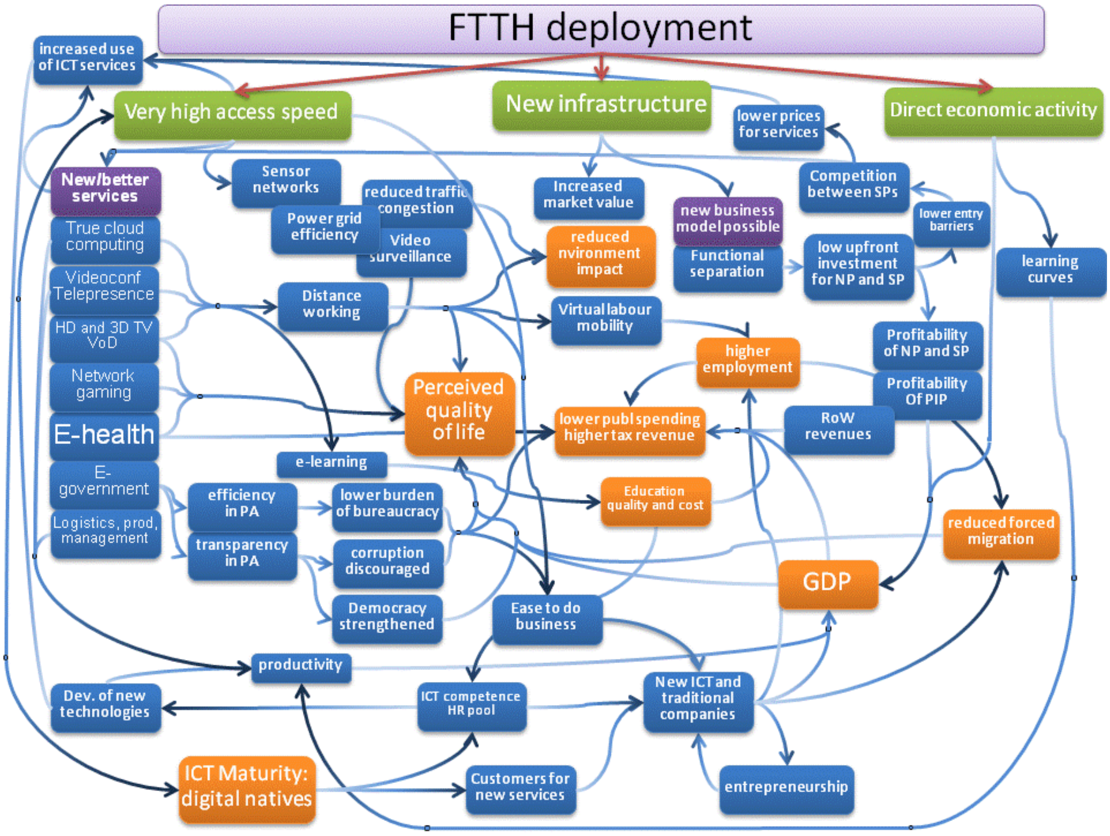


Figure 81: Direct, indirect, and induced effects of FTTH Deployment

7.1.2 Identification of currently quantifiable effects, calculation method and data sources

Figure 81 shows that the effects of fibre deployment are many and complex. We have chosen in this study to identify a number of effects that can be quantified. We then calculated the total return that they provide. The effects we have chosen are:

- The economic activity directly generated by the network deployment; this will also have both positive effects in terms of increased GDP, but also negative ones such as traffic disruption, pollution. Deployment. It should be noted that similar effects of economic activity would also take place when building any other type of infrastructure (a bridge or a road for instance)
- Savings of data and telecommunications costs[9] (mainly due to increased transmission efficiency as well as competition between providers [34]) for
  - Municipal administrations
  - Regional administrations
- Savings/added value to individuals *("perceived quality of life"* through higher speeds and better services, lower prices through competition between service providers); estimated through an agreement between tenants and landlords on the value for fibre connectivity

[9] To this corresponds a lost revenue for the incumbent operator, which is however difficult to currently quantify; the model is *LR=S – EG –NR*, where *LR* is the lost revenue, *EG* is the efficiency gain forced on the incumbent by more competitive market, and *NR* is the new revenues made for the incumbent possible by a better infrastructure and a market with increased ICT maturity..

- Higher employment that leads to increased GDP, calculated by means of statistical analysis of the situation in different municipalities (note that this will be the net sum of positive and negative effects on employment mentioned above)
- Population evolution, a measure of reduced forced migration (currently not quantified in monetary terms)

The effects that we have chosen to analyse occur in various forms and are therefore best estimated using different methods:

- The (short-term) increased GDP due to network construction is estimated using the input-output approach; while we currently lack tools to monetise the negative effects (mainly traffic disruption and pollution), although our estimation is that these are of a smaller order of magnitude and can be safely disregarded in a first approximation;
- the indirect savings have been calculated by extrapolation of examples from some local governments; while lost revenue for the incumbent is left not quantified, although anecdotal evidence suggest their magnitude is limited[10];
- the direct positive impact on value for end users has been estimated in the form of an agreed rent increase;
- the indirect employment effects are estimated by multivariable regression analysis;
- the impact of FTTH on population evolution was also calculated using multivariable regression analysis, but we refrained from quantifying the financial return, due to the lack of a robust method for this;
- we do not investigate social effects and leave their analysis to specialised studies.

The remainder of this analysis focuses on the deployment of FTTH in Sweden, more specifically in Stockholm and other Swedish municipalities (both urban and rural). We focus on Sweden, because it had the most extensive list of available data, and because Sweden is well advanced in the deployment of fibre.

Data for fibre penetration was collected by the Swedish telecom regulator's (PTS) online database [66] and from a survey conducted by Acreo. PTS data provides fibre penetration in each municipality for the years 2007, 2008 and 2009 in terms of percentage of population in the community who are able to adhere to the fibre network[11] and for the year 2010 in the form of connected customers. Acreo's survey collects data for a number of municipalities in terms of percentage of population in the community who are able to fibre, as well as with pre-fibre connector and active customers, for the year 2011. It also collects other relevant information such as IT policies, technical and business solutions, prices and services, and more. We have also collected demographic and socioeconomic data from Statistics Sweden's (SCB) annual report [70].

Another important source of information has been the OECD, and the FTTH Council Europe, as well as Acreo's network of contacts among key players in the fibre market, from the city network, to systems manufacturers, installers, research institutes, local authorities and operators. From these latter sources, we have collected data to estimate the investment required to build out FTTH to all of Sweden. We have used the research findings from the literature to estimate the direct economic activity the investment will result in.

[10] The incumbent telecom and cable operators in Sweden (TeliaSonera and Comhem respecitvely) are in great wealth and have seen a positive development during the past ten years, during which fibre has been deployed massively by municpalities and alternative operators in the country, and currently show margins above 30% [18], [78].

[11] PTS definition: interest in or within 353 meters of a fiber-connected property

7.1.3 Economic activity generated by FTTH deployment

The most direct effect of FTTH investment is the economic activity needed to build FTTH. This is displayed as soon as the build-up starts and disappears when the network is completed. Its effect is short lived, but may be large. The best way to make the calculation is to use the multiplier from the *Input-Output* Approach [87]. As a first approximation, we use the results of a study from 2010 on the German economy [45] where it is found that the investment will result in a GDP increase of 0.93 times the investment. This figure may differ slightly for fibre-only deployments and between countries, so it would therefore need to be recalculated for FTTH deployment in Sweden in a more comprehensive study. We decide nonetheless to use this figure as a first approximation, which would lead to an increase in GDP in Sweden of 52 billion SEK (or **€5.8 billion[12]**) the value of the economic activity generated by the total fibre investment to cover the whole country[13].

It is clear, as mentioned elsewhere, that this economic activity generated by FTTH deployment is a general effect that would occur from any infrastructure deployment.

7.1.4 Effects measured: Savings on local data and telecommunications costs

There are several examples, and all point to the fact that fibre allows a saving of around 30% of the total municipal data and telecommunication costs. This is partly due to increased efficiency (reduced equipment, energy consumption, and *footprint* per unit of transmitted information), partly due to the fact that the fibre network with high capacity allows for more competition[14].

Some examples to vouch this number: the *city of Stockholm* started in 1996 purchasing telephony from an open market. A prerequisite for the procurement of telephony in full competition (which was unique to public organizations in Europe at this time) and to drive down costs for was that the city had recently connected its operational sites and offices with its own fibre network. The city's external telephony cost at this time was 150 million SEK per year. The competition made available on its fibre-optic network, resulted in a savings of 30%, i.e. 45 million SEK [25]. However, this is a conservative estimate, and savings have probably grown larger than that over time, says Per-Olof Gustavsson, who at that time was active in the City of Stockholm's city council office.

In *Jönköping, Sweden*, where the fibre connection has been less extensive, the saving figure was around 10% to 15% [63]. If one compares the figures for fibre penetration (25% of workplaces had access to fibre in 2010) with the municipality of Stockholm (62%) one can see a nearly proportional relationship between fibre penetration and savings rate. We have no examples to quantify the savings brought about by 100% penetration, so we work with the Stockholm figure. If one extrapolates this figure from Stockholm to all municipalities in Sweden, FTTH would lead to savings of approximately 500 million SEK in annual municipal data and telecommunication costs for the entire country[15].

[12] using a long-term exchange rate of €/SEK=9.

[13] If we consider that current fibre penetration is not zero, both actual cost and benefits would have to be scaled down as we will argue in in Section 7.1.8; please refer also to [33] for a broader analysis.

[14] e.g. in Stockholm, there are about 90 different operators in the network

[15] If we consider that, according to PTS, about 30% of Swedish households already have access to FTTH, this figure would scale down to 350 million SEK annually as a return of the total FTTH fibre investment to cover the remaining part of the country.

Similar savings have been observed at regional administration as well. The Stockholm Regional Council (Stockholms läns landsting) reduced its data and telecommunications costs by 50%, equivalent to 60 million SEK thanks to the fibre network [25]. In *Norrbotten*, a fibre network has been installed, linking five hospitals, 33 clinics and 34 dental clinics, which reduced communication cost also by 50%, while providing a fifty times faster communication [26]. Service providers have been able to create solutions for digitised medical records, transmission of digital radiography, digital recipes, video conferencing and IP telephony. If we extrapolate the Stockholm's and Norrbotten's Regional Council savings to all of Sweden, FTTH would result in a saving of around 270 million SEK of annual data and telecommunications costs by the regional governments[16]. Summing this figure to the one extrapolated for the municipalities leads to a national saving of around 770 million SEK (or **€86 million**) **annually**.

7.1.5 Effects measured: Savings/added value for individuals

As we argued before, the individual benefits of FTTH vary in direct and indirect ways: high-quality services at lower prices, especially entertainment and communications, the ability to work remotely and more free choice of work and housing, improved individual health, reduced need for hospitalization, simpler and more transparent interaction with public services, etc. It is difficult to estimate the value of FTTH for end users in dollars and some of the effects may only show up later (indirect and induced effects). We can still estimate a conservative figure for the direct effects, in terms of willingness to pay, by observing that the Sweden's tenants' association (*Hyresgästföreningen*) has agreed with property owners' associations and housing companies to an increase in rent between 45 SEK and 47 SEK per month (equivalent to estimating the value of FTTH to an average 46 SEK per household per month) [55]. This would lead to a value of 2.3 billion SEK (or **€258 million**) **per year** if Sweden's 4.2 million homes connected to fibre-optic network[17].

7.1.6 Effects measured: Population evolution

A way to verify and quantify the benefits of fibre is to collect relevant data for a large number of municipalities with different fibre penetration, and relate fibre penetration to how some economic indicators have changed over time. Of course, the socio-economic development in a municipality depends on more than fibre investment. A relevant analysis of the effects of the fibre must be based on a model that takes into account as many relevant factors as possible. Such a model can be described as a function

$$Y = f\,(X_1, X_2, ..., X_N), \qquad (1)$$

where Y is the socio-economic indicator that one wishes to explain (the *dependent variable)*, and X_n are the various factors that have impact on the indicator.

When such a model has been developed, one can observe how well it reflects reality by measuring Y and $X_1, X_2, ..., X_N$ in a number of different municipalities. The difference between Y and $f\ (X_1, X_2, ..., X_N)$ gives the error, e, which depends partly on the model's limitations and partly to errors in the measurement of Y and $X_1, X_2, ..., X_N$ (measurement error). The smaller e is, the better the model.

[16] Calculated with a simple linear extrapolation, given Stockholm County's and Sweden's population being 2,073,952 and 9,446,812, respectively, in June 2011.

[17] If we consider that, according to PTS, about 30% of Swedish households already have access to FTTH, this figure would scale down to **1.6 billion SEK** annually as a return of the total FTTH fibre investment to cover the remaining part of the country.

We can expect that the evolution of population size has a tendency to continue in the trend it is in, unless something else happens, i.e.:

$$P(t) / P(t_0)= \{P (t_0) / P(t_0 - T)\}^K, \tag{2}$$

where K is a factor that tends to be equal to $(t - t_0)/T$. The trend may be affected by various factors, which may increase or decrease the attractiveness of the municipality, such as housing rent, improvement/deterioration of various services and infrastructure, economic situation in the region and more. We can model the effect of these changes as a contribution in terms of percentage increase/decrease in population, which translates into an exponential term in our equation for any such effect. Equation (2) therefore becomes

$$P(t) / P(t_0) = \{P(t_0) / P (t_0 - \mathrm{T})\}^K \exp \{\kappa_1 X_1 + \kappa_2 X_2 + ... + \kappa_N X_N\} \tag{3}$$

If we take the logarithm of both sides of the equation we obtain:

$$\Delta P(t) = \log P(t_0) + K \cdot \Delta P_T + \kappa_1 X_1 + \kappa_2 X_2 + \ldots + \kappa_N X_N, \tag{4}$$

where $\Delta P_T = \{P(t_0) - P(t_0 - \mathrm{T})\}/ P(t_0 - \mathrm{T})$ is the population change starting from time t_0 over the time period T, where we have used $\log(x) \cong x - 1$ for $x << 1$. Which ones, among all possible factors, we choose to include in the model is determined by a compromise between model accuracy and availability, reliability and accuracy of factor measurements. Statistical independence between factors is also an important parameter for the model to be applicable. In this study, the measurement data available to us, allow us to specify the model to[18]

$$\log P(t) = \log P(t_0) + K \cdot \Delta P_T (t_0) + \kappa_F F(t_0) + \kappa_s \Delta s(t) + \kappa_u u(t_0), \tag{5}$$

where $t = 2010$, $t_0 = 2007$, $T = 10$, so that $P(t)$ and $P(t_0)$ are the population of the municipality in the years 2010 and 2007, respectively, $\Delta P_T(t)$ is the relative population change between 1997 and 2007, $F(t–3)$ is the proportion of the population of the municipality provided for connection to fibre-optic network[19]. $\Delta s(t) = s(t) - s(t_0)$ is the change in tax set, and $u(t)$ is the share of foreign citizens in 2007 (with residence in Sweden for at least two years, according to SCB definition)[20]. That is, the model looks for a correlation between the situation in the municipalities in 2007 (namely population trend, fibre infrastructure, and demographics) and the change in the population three years later. We introduced the time shift for two reasons. One is that the effects of the changes are usually not instantaneous (except taxation changes[21]). The second is that it eliminates the problem of reverse causality (although not the possibility that a third factor is the cause of both fibre investment and change in population trend).

We can now use the model to quantify the impact of each effect. Equation (5) has the merit of being linear, which allows us to verify the model using linear multi-variable regression, which consists of estimating the unknown coefficients κ_n that minimize the error[22], ε. More

[18] Other factors that we considered are the cost of pre-training costs, costs of elderly and disabled population in the age group 20-64 years, proportion of population aged 65 years, and average income, but all showed either non-significant correlation with P(t), or high correlation with ΔPT, or both; measurements of educational attainment (which we judged as possibly relevant) was not available.

[19] PTS definition: interest in or within 353 meters of a fiber-connected property

[20] We observe that U(t) as well as Δs(t) and $F(t_0)$ are uncorrelated with $\Delta P_{10}(t)$ for t = 2010, t_0 = 2007

[21] That's why we look at the s(2010) – s (2007); we have actually run the analysis by taking into account taxation changes in previous years, but found much less strong correlation.

[22] That is, β_n is the estimate of the unknown factor κ_n.

specifically, for each municipality i, we measure $P(t)^{(i)}$, $P(t_0)^{(i)}$, $\Delta P_{10}^{(i)}$ $F(t_0)^{(i)} + \Delta s(t)^{(i)}$ and then measure the error as[23]:

$$\varepsilon^{(i)} = \log P(t)^{(i)} - \{ \log P(t_0)^{(i)} + K \cdot \Delta P_{10}^{(i)} + \kappa_F F(t_0)^{(i)} + \kappa_S \Delta s(t)^{(i)} + \kappa_u u(t_0)^{(i)}. \quad (6)$$

We can compute an error indicator as $\sigma_\varepsilon = \Sigma |\varepsilon^{(i)}|^2$ and then look for the smallest values of σ_ε by varying K, κ_F, κ_S, κ_u. The values β_K, β_F, β_s, β_u which minimise σ_ε define our estimate of the effects of K, κ_F, κ_S, κ_u.

When we run the calculations in the software environment *MATLAB* ®, using a linear regression toolbox, we get the following results:

$$\beta_K = 0.27 \pm 0.02$$
$$\beta_F = 0.025 \pm 0.008$$
$$\beta_s = -0.50 \pm 0.42$$
$$\beta_u = 0.18 \pm 0.13,$$

where we have also indicated the 95% confidence interval. We can see that much of the population evolution is explained, as expected, by the prior trend (and β_K is close to the value which we would expect, if the trend from 1997 to 2007 remained unchanged in the period 2007–2010, i.e. 3/10 = 0.3). We can then observe that FTTH has a positive effect: a 10% increase in the proportion of the population that have access to fibre, corresponds to a positive change in the population after three years of 0.25%. Not surprisingly, tax cuts also have a positive effect in the short period (3 years), though their significance is not strong, as shown by the large confidence interval. Finally, perhaps less expected, high proportion of foreign citizens has a positive effect on the population development (although also with a weak significance).

Let us now analyse the effect of fibre in more detail. Figure 82 shows a graph in which each municipality is represented by a point whose *x-coordinate* shows the municipality's fibre penetration (measured as a proportion of the population with a fibre connection) in 2007, and whose *y*-coordinate shows the adjusted change in its population between 2007 and 2010. The adjustment represents a "*cleansing*" of other factors, and a removal of the average[24]. The black line follows the model's forecast, with $\beta_F = 0.025$. Each municipality deviates from the forecast with a certain error, $\varepsilon^{(i)}$, which is explained by other factors that the model does not take into account.

It is important to recall that 95% margin of error 0.008 means that a municipality's population would have increased between 0.17% and 0.33% (i.e. [0025 ± 0008] × 10%) if it had 10% more fibre and if everything else had been exactly the same; and this statement is true with a 95% certainty. The fact that a particular municipality shows a population development that is greater or less than the model's prediction does not depend on the confidence interval, but because everything else that the model did not take into account (and that *was not* exactly the same in all municipalities), as well as measurement errors. The reader who is more familiar with multi-variable regression can see more details of the calculations in Table 30 below.

It should be noted that the changes population evolution is most likely due to reallocation between municipalities, hence extrapolating a fibre-driven positive population evolution to the whole country and conclude that Swedish population would be boasted by fibre would be

[23] We will have a specific error for each municipality, because, even except as regards to measurement error, each community is unique and will therefore be described better or worse by the model than other municipalities.

[24] In mathematical terms: $y^{(i)} = \log P(t)^{(i)} - \log P(t_0)^{(i)} - \beta_K [\Delta P_{10}^{(i)} - \langle \Delta P_{10} \rangle] - \beta_s [\Delta s(t)^{(i)} - \langle \Delta s(t) \rangle] - \beta_u [u(t_0)^{(i)} - \langle u(t_0) \rangle]$, where $\langle x \rangle = \Sigma_i N\, x(i)$ is the mean value of the factor x over the N = 290 municipalities; t = 2010, t_0 = 2007

wrong. Rather, what is most likely happening is that people living in municipalities with a good fibre infrastructure are more free to choose to live where they prefer (often their hometown) because they are able to work there, instead of being forced to move to larger urban areas. In other words the effect of fibre is that of stopping migration from rural to urban areas. This is generally seen as a positive fact for the socio-demographic and economic fabric of the country, although the slow-down in urbanisation per se may represent missed efficiency opportunities and has some positive as well negative effects on the environment which are hard to quantify.

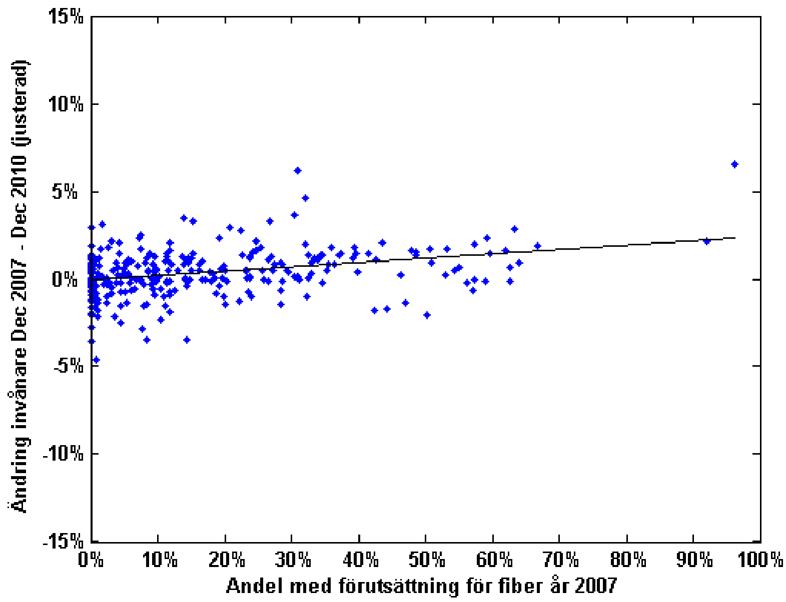


Figure 82: Effect of fibre installation in the municipal attractiveness: one can see that higher fibre penetration in 2007 (measured as a percentage of pre-condition for fibre according to PTS definition) point to a higher occupancy (or lower emigration from) the local authority (measured as percentage change in population, adjusted for other effects).

Table 30: Performance of Linear Multi-Variable Regression

```
----------------------------------------------------------------------
Number of observations: 290
R-square: 0.77335
Adj. R-square: 0.77017
Explained variable: log(pop_Dec_2010 ./ pop_Dec_2007)
----------------------------------------------------------------------------
beta coeff    | std. err  |  tstat   |      95% conf int       | parameter
----------------------------------------------------------------------------
    0.02548   | 0.0042499 |    5.9954 |  0.017116    0.033845  |  PTS_FN_2007
   -0.50148   |   0.21558 |   -2.3262 |  -0.92579   -0.077174  |   (s2010 - s2007
)
    0.27269   |    0.0105 |    25.971 |   0.25203     0.29336  |
Delta_pop_10_2007
    0.18092   |  0.066612 |     2.716 |  0.049817     0.31202  |
foreign_share_Jun_2007
 -0.0013712   | 0.0017409 |  -0.78766 | -0.0047977   0.0020552  |
ones(length(K01),1)
----------------------------------------------------------------------------
```

7.1.7 Effects measured: Employment

When it comes to employment, we make the assumption that a municipality with high employment is also an attractive place. This is a rough qualitative argument, but it will help when we try to separate the effect of FTTH from other factors. An indicator describing a municipality's attractiveness is its population change over the decade 1998–2007 (see previous section). One can thus expect that a municipality that has had a positive evolution for a decade has great potential to have a positive economy, which can lead to positive development of employment. This is currently only a working hypothesis that needs to be verified in the calculation. We can then identify a number of *new* factors, i.e. factors that appeared around 2007 (or a short period around it) as a potential due to the change in employment. Fibre is one such candidate, as discussed in Chapter 3 (although we expect most of its effects on employment to occur in a period longer than three years). Other factors that we can identify are immigration, tax changes from 2007 to 2010, education, and other infrastructure and services in the municipality. Therefore, we can construct a similar equation as we did for the population development

$$\Delta w\,(t) = K \cdot \Delta P_T + \kappa_1 X_1 + \kappa_2 X_2 + \ldots + \kappa_N X_N + \Delta_0, \qquad (7)$$

where we have now added a term, Δ_0, which accounts for the national change in employment due to general economic conditions, and that affects all municipalities.

Again, which ones among all possible factors we choose to include in the model is determined by a compromise between model accuracy and availability, reliability and accuracy of factor measurements, and statistical independence. Our model then becomes[25]

$$\Delta w\,(t) = K \cdot \Delta P_T\,(t_0) + \kappa_F F(t_0) + \kappa_u^{+}\, u^{+}(t_0) + \Delta_0, \qquad (8)$$

where $t = 2009$, $t_0 = 2007$, $T = 10$, so that $\Delta P_T(t)$ is the relative population change between 1998 and 2007, $F(t_0)$ is the proportion of the population of the municipality provided for connection to fibre-optic network[26], and $u_{+}(t)$ is an indicator of "*economic advantageous"* immigration, defined as:

$$u^{+}(t_0) \;= u\,(t_0) \cdot [\; i(t_0) > i_R\,]. \qquad (9)$$

The indicator is based on the observation that immigration can lead to positive and negative effects, depending on its nature. One can expect that asylum based immigration has a negative effect on employment in the short term, while the immigration of highly educated people has a positive effect. The statistics about the type of immigration is missing, so we used average income $i(t_0)$ for a municipality as a guide: we made the assumption that highly educated immigrants have higher purchasing power and will therefore settle in the area with higher average income (and typically higher housing prices). If a municipality has an average income exceeding a certain threshold i_R, the municipality is classified as *"rich"* and its share of foreign citizens[27] $u(t_0)$ is equal to the *"economic advantageous"* immigration $u^{+}(t_0)$. Otherwise, $u^{+}(t_0) = 0$. However, we could not find an indicator of *"economic disadvantageous"* immigration.

[25] Here also, we have tested the effect of pre-training costs, costs the elderly and disabled, population in the age group 20-64 years, proportion of population aged 65 years, and average income, but all showed either non-significant correlation with $P(t)$, or high correlation with ΔPT or both; neither changes in taxation nor taxation level in t_0 showed any correlation with $w(t)$ either; neither did immigration (as defined by SCB): however, there was significant correlation between $w(t)$ and $u^{+}(t_0)$; again, measurement of educational attainment (which we judged as possibly relevant) was not available.

[26] PTS definition: portion of population within 353 meters of a fiber-connected property

[27] Again, $u(t)$ as well as $\Delta s(t)$ and $F(t_0)$ are uncorrelated with $\Delta P_{10}(t)$ for $t = 2010$, $t_0 = 2007$

Again, we look for effects on employment after a certain time. SCB's latest data on employment, however, was November 2009, therefore, the time lag is 2.5 years. We expect stronger results with longer lags. Again, we are looking for β_K, β_F, β_u^+, β_0 which minimise the error variance σ_ε which estimates the effects K, κ_F, κ_u^+ and κ_0. *Matlab* ® calculations give us the following results:

$$\beta_K = 0.11 \pm 0.02$$
$$\beta_F = 0.011 \pm 0.010$$
$$\beta_u^+ = 0.51 \pm 0.44$$
$$\beta_0 = -0.017 \pm 0.002,$$

where we have also indicated the 95% confidence interval. We can see that some of the employment change is correlated to population change between 1998 and 2007, which supports our hypothesis that this is a good indicator of the municipality's attractiveness (and margin of error for β_K is relatively low). The economic cycle also has a significant but less powerful influence: all other factors being equal, employment declines by 1.7% (and in the years 2007 to 2009 actually showed a reduction in employment in Sweden).

We can then observe that fibre has a positive effect, although with less intensity and significance than on population development: a 10% increase in the proportion of the population that have access to FTTH, corresponding to a positive change in employment after two and a half years between 0% and 0.2%. Finally, high *”economically advantageous”* immigration has a positive effect on employment: 1% higher share of immigrants in the "rich" municipalities in 2007 represents a 0.5% higher employment.

Let us now analyse the effect of fibre in more detail. Figure 83 shows a graph in which each municipality is represented by a point whose *x-coordinate* shows the municipality’s fibre penetration (measured as a proportion of the population with the condition of fibre) in 2007, and whose *y*-coordinate shows the adjusted change in its employment between 2007 and 2010. The black line follows the model's forecast, with β_F = 0.0011. Details of the calculations are shown in Table 31 below. Fibre investment are expected to show positive effects on employment through indirect and induced effects, so it will be interesting to follow developments in order to verify if β_F increases significantly in the coming years.

As in the case of population evolution, what the regression analysis tells us is that there is a causal correlation between fibre penetration and short-medium-term employment: municipalities with higher fibre penetration tend to have better employment evolution than those with lower fibre penetration. In principle this could be given explained by two phenomena:

a) Fibre-rich municipalities attract jobs from neighbouring municipalities, or
b) Fibre-rich municipalities create new jobs that would otherwise not have existed.

In case (a), there is a mere job reallocation from fibre-poor to fibre-rich municipalities, so the total gain is zero. In case (b), new jobs are added and any fibre deployment leads to a job increase. In fact, one can imagine a further case:

c) Fibre-rich municipalities create new jobs within their territory, and to a lesser extent in neighbouring municipalities, due to spill-over effects[28].

In fact it is reasonable to assume that a mix of the three effects takes place. Anecdotal evidence suggests that case (a) has stronger impact than case (b)[29], while case (c) may have

[28] This effect could actually be measured in a more sophisticated regression analysis, using geo-tagging of the municipalities, which will be implemented in a further stage of the study.

importance in Southern Sweden, as well as in the metropolitan regions of Stockholm and Gothenburg, where physical distances between municipalities are smaller.

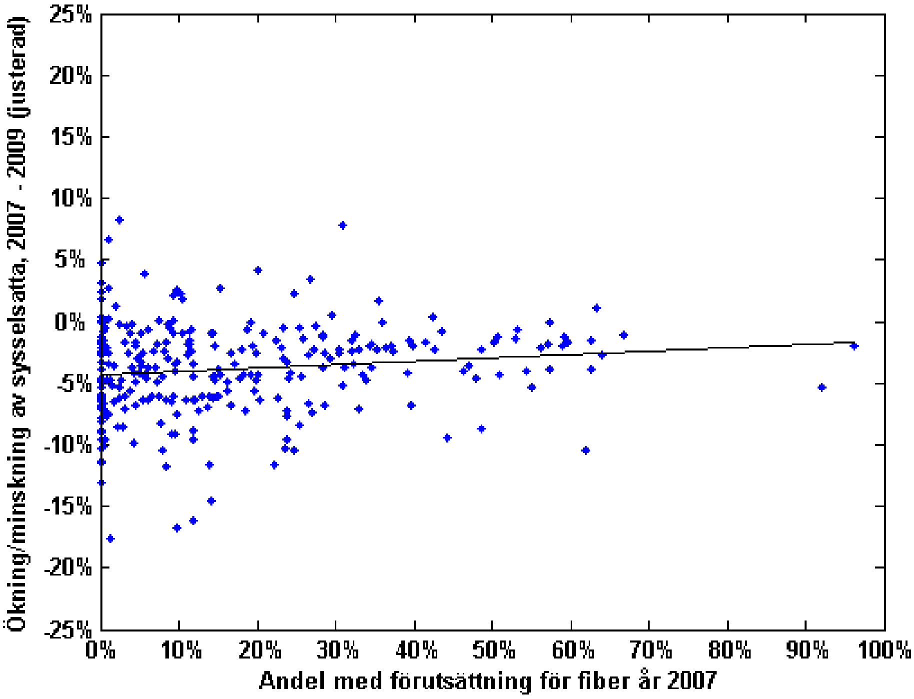


Figure 83: Effect of fibre installation in municipal jobs: one can see that higher fibre penetration in 2007 (measured as a percentage of pre-condition for fibre according to PTS definition) point to a better development of employment in the municipality (measured as percent change in employment rates in the municipality, adjusted for other effects).

Table 31: Results of Linear Multi-Variable Regression

```
----------------------------------------------------------------------
Number of observations: 290
R-square: 0.30812
Adj. R-square: 0.30087
Explained variable: (w_Nov_2009 - w_May_2007)
----------------------------------------------------------------------------
beta coeff    |  std. err  |   tstat   |      95% conf int       |  parameter
----------------------------------------------------------------------------
  0.010579  |  0.0049547  |   2.1351  |  0.00082698    0.020331  |  PTS_FN_2007
   0.10806  |   0.012329  |   8.7646  |    0.083794     0.13233  |  Delta_pop_10_2007
   0.50822  |    0.22574  |   2.2514  |     0.06393     0.95252  |  I_plus_Jun_2007
 -0.016827  |  0.0012631  |  -13.322  |   -0.019313   -0.014341  |
ones(length(K01),1)
----------------------------------------------------------------------------
```

[29] In the many interviews with key people involved in fibre deployments we heard many stories of local companies staying put or of new companies being created, but not much about companies leaving a municipality with low fibre penetration for a fibre-richer municipality.

7.1.8 Overall socio-economic returns

If we consider a rapid deployment scenario in which the FTTH network is built in four years, with a 40% investment in the first year and the remainder distributed over the year 2-4 with gradually decreasing intensity (see Figure 84), specifically the investment in year t = 1, 2, 3, 4 and 5 is

$$\begin{aligned} I(1) &= 0.4\,K, \\ I(2) &= 0.3\,K, \\ I(3) &= 0.2\,K, \\ I(4) &= 0.1\,K, \\ I(5) &= 0. \end{aligned} \tag{10}$$

We assume that the resulting fibre penetration of each year is proportional to the cumulative investment up to the year before, and we do not include operating costs. Similarly, we take no account of inflation, and discount rate, but make our calculations in real terms.

With these assumptions we can take the figure calculated above, and weigh them with fibre penetration reach at each year. Direct returns for year t are given as:

$$A_d\,(t) = 0.93\,I(t-1), \tag{11}$$

according to the calculation results that [44] has developed for direct return for investment in broadband infrastructure (where $I(t-1)$ is the investment in the previous year).

Indirect returns are counted as:

$$A_i\,(t) = (b_k + b_l + b_i\,N_h + 0.01\,y\,N_a)\,R_i(\mathrm{t})\,[1 - F(0)], \tag{12}$$

where b_k is the municipalities' total savings, b_l is the municipality total savings, b_i is the individuals' savings/added value per household, N_h is the number of households, y and N_a are Sweden's current average income and labour force). $F(0)$ is the current fibre penetration in Sweden (30% according to PTS), and $R_i(t-1)$ is the accumulated years before[30]. The total return in year t is simply:

$$A_{tot}\,(t) = A_d\,(t) + A_i\,(t). \tag{13}$$

The resulting returns as a function of time are presented in figures below. We can note that a total investment of about 39 billion SEK (or **€4.3 billion**) giving a cumulative return of about 59 billion SEK (or **€6.6 billion**) after five years. In other words, €1invested between now and about four years, brings back a minimum of €1.5 in five years. We expect that the returns to be greater than that, due to other effects that are difficult to quantify. We plan to tackle this in a more extensive study. Furthermore, it should be noted that a similar effect can be expected by another type of municipal investment.

We use the results generated above in Equations (10) – (13) to calculate the investment and return over time. The results are presented in graphs that show how the investment and return may look like in five years.

Figure 84 shows the investment and returns in a year. It can be seen that during the first year investment is highest, but decreases in the following years, according to the assumed investment plan of Equation (10). On the other hand, a significant return starts appearing as early as at year two, thanks to the direct economic activity generated by fibre deployment.

The return due to direct effects starts decreasing with time (Figure 85), while indirect and induced economic effects increase. Induced effects are likely to grow larger with time, but a more comprehensive study is needed to quantify this.

[30] In mathematical terms Σ0t I (t – 1)

In Figure 86 we see that the cumulative investment reaches *"breakeven"* in terms of societal impact of 3.5 years, and after five years the total return to 1.5 times the total investment.

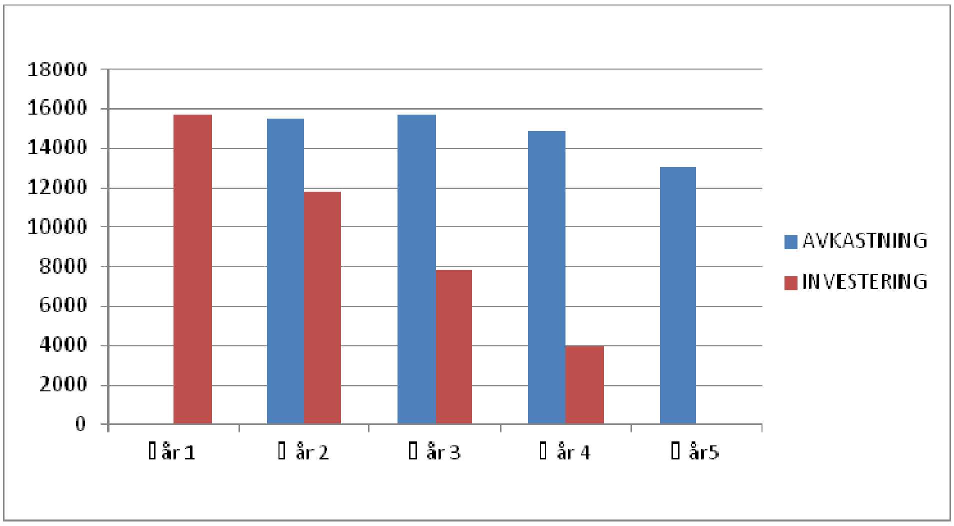


Figure 84: Investment (red) and socioeconomic returns (blue), in million SEK

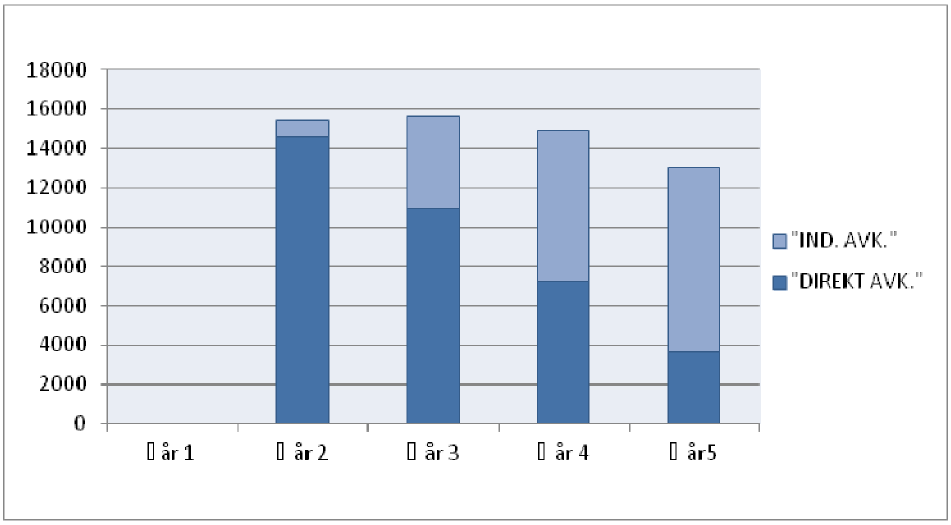


Figure 85: Direct and indirect socioeconomic yield (million SEK)

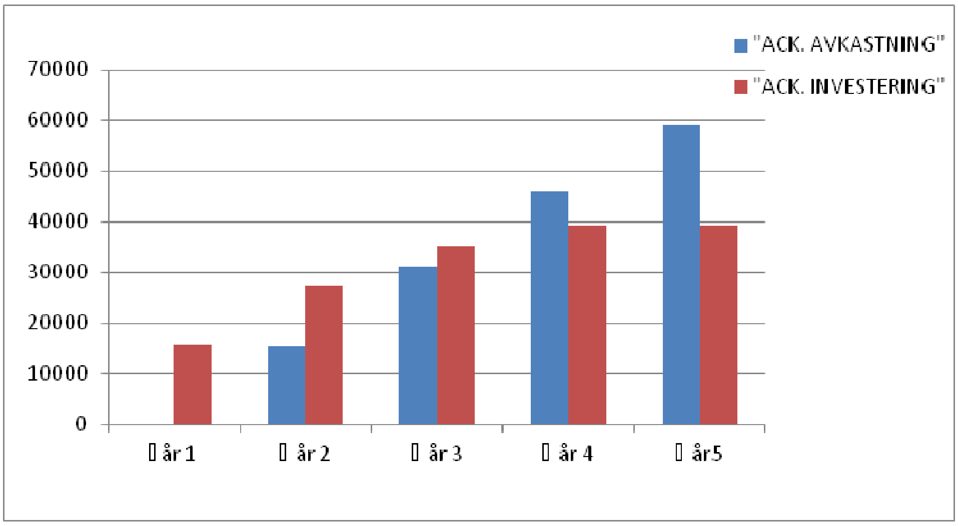


Figure 86: Cumulative Investment (red) and socioeconomic returns (blue), in million SEK

7.2 Bottom-up approach

A second methodology for identification and quantification of the uncaptured value or indirect benefits of broadband or more specifically FTTH, aims at listing all the specific services that will have an effect on the different stakeholders (or society at large) when being deployed in an environment where a good-quality broadband network is present. The identification of these services and their effects is based on a developing a tree structure, starting from the different sectors, going over services and sub-services, to end up at the concrete effects. The aim of this second approach is then to pick some specific effects that have the greatest impact and for which data is available, so that they can easily be quantified.

In order to identify as much indirect effects as possible, we chose to start from the various sectors that are influenced by the availability of good-quality broadband and identify specific services for each sector that use this availability to gain efficiency or reduce the costs of operation. The specific effects for these services are then identified, sometimes directly, sometimes through the use of sub-services.

7.2.1 Bottom-up methodology for identification and quantification of social benefits

This section will describe the model designed for evaluating the value of the indirect effects of a broadband and FTTH network using a bottom-up approach. This type of approach allows to more clearly link the monetary results to the individual effects, while a top-down method starts from aggregated macro-economic data. We selected this bottom-up methodology because of its transparency and because it enables us to predict the individual indirect effects of broadband deployment.

The methodology consists of two main parts: firstly, the important effects are identified by means of a tree structure (section 7.2.1.1) and secondly, the individual effects are modelled and quantified (section 7.2.1.2). The value for the entire sector or actor can then be calculated by summing the values of the related effects.

7.2.1.1 Identification approach: building a tree structure

The identification process takes the form of a tree structure, starting from the different sectors that can be influenced (e.g. eGovernment), to identifying specific services that are deployed (e.g. an e-counter deployed by the city or municipality), to finally arrive at the actual effects of these specific services (e.g. reduced number of visits to the administrative centre, leading to reduced travel and waiting time and costs, as well as reallocation of the administrative personnel's time). A generic example of this tree structure is given in Figure 87.

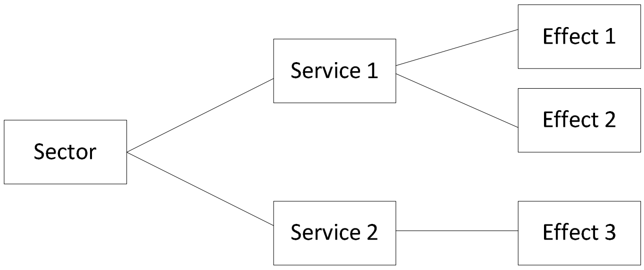


Figure 87: Generic example of identification tree

The individual effects are subsequently categorized along three axes: measurability, term and actor. A summary of the categorization axes, as well as their abbreviations, can be found in Table 32 in section 7.2.2.

The axis measurability indicates whether the value of the effect can easily be transformed into a monetary value. There is a distinction between subjective (cannot be converted in a monetary value) and objective (can be more easily converted into a monetary value).

The second axis is the term: here the effects are grouped on basis of the period in which the underlying services need to become "operational", meaning that 50% of the target audience uses the specific service and will therefore be impacted by the effect. A distinction is made between short term (the service is operational within 2 years after deployment of the network) and long term (the service needs more than 2 years to become sufficiently adopted). Examples of short term effects are the gains in travel time due to working at home, or the reduction in letters sent when changing to an e-counter at the administrative centre of the city. Long term effects are then for instance the reduction in operational expenditures of a company that allows its employees to work (partly) from home, or a reallocation of the administrative personnel of the city from front to back office.

The third and last axis of categorization refers to who benefits from the effects. The distinction is made between "government" (all local and general authorities), "companies" (all private entities, both SME's (Small and Medium Enterprises) and larger firms), "individuals" (inhabitants of the region under study) and "society" (a more general actor that accounts for e.g. environmental effects).

7.2.1.2 Quantification of the individual effects

After the identification of the different effects, the most important (and quantifiable) effects are monetarized by multiplying the amount of savings that can be gained for one entity (e.g. per person) with the total amount of entities influenced. A schematic overview of the different steps in the model is given in Figure 88.

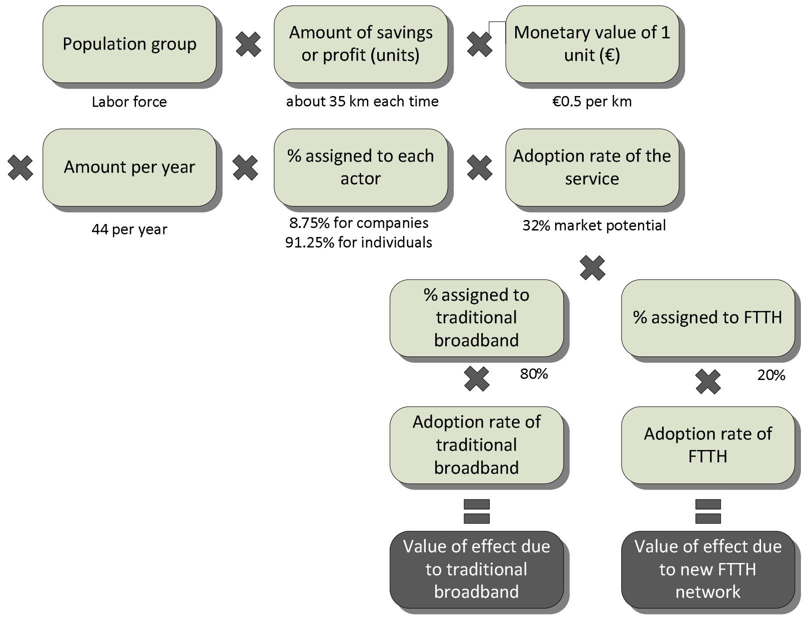


Figure 88: Overview of the quantification model with integrated example for teleworking

The model calculates the monetary value per effect by multiplying eight different parameters. The indirect effects of teleworking are used to elaborate on these parameters in the following paragraph.

Firstly, it is assumed that each specific effect only influences a specific section of society, so only the right *population group* is taken into account. For example, teleworking will only be possible for the labour force (people aged between 18 and 65). Secondly, the *amount of savings or profit* that can be made per member of the population group is evaluated (e.g. amount of km saved by avoiding commuting). This value should then be “transformed” into a *monetary value in Euro*. In our teleworking example, 1 km equals €0.5 (taking into account the fuel and insurance costs of the vehicle, according to own calculation based on [32] and [81]). If we multiply this with the *amount per year* (in case of teleworking, we assume that people work 1 day per (work)week from home, which leads to 44 days a year), it gives us the average saving for the entire population per year. Of course, these savings should be *assigned to the right actor* (in the example, around 90% of the cars are privately owned, while about 10% of the employees drive with company cars, which leads to 90% assigned to “individuals” and 10% to “companies”) and the *adoption rate of the service* should furthermore be taken into account. This adoption rate reflects how fast the service is adopted (relates to the short/long term classification), as well as the maximum percentage of the population group that is eligible for using the service - the market potential, 32% in our example [65]. Finally, the split between traditional broadband (up to 20 Mbps) and FTTH is made, where the *specific adoption rates of both technologies* are taken into account, as well as a *percentage* that indicates if traditional broadband suffices, or higher-speed FTTH is necessary.

This methodology can be followed for all the indirect effects individually. The results for the specific sector (e.g. eBusiness and eGovernment) and/or for specific actors (like “individuals” and “companies”) can then easily be calculated by summing the related values.

7.2.2 Identification and categorization of indirect benefits for eGovernment and eBusiness

Using the methodology described above, we will identify and quantify the effects for the sectors eGovernment and eBusiness, because in these sectors, the most important effects for the near future can be found [40].

eGovernment or electronic government utilizes the ICT environment in an integrated manner to offer public services to all, at any moment of the day. Using eGovernment will improve the quality and speed of those public services, and will enhance the support of the government policy and the democratic process [31].

eBusiness on the other side, is typically defined as the application of ICT for the support of all kinds of business activities. Using ICT in the working environment improves the efficiency of the employees, can help to improve the productivity of the company and allows flexibility in working hours and location.

This section will identify the most important indirect effects of both sectors, and will categorize them based on the three axes described in section 7.2.1.1. The abbreviations used in the identification tables, are shortly explained in the table below:

Table 32: Abbreviations used for categorization

S/O	S	Subjective
	O	Objective
Term	LT	Long term
	ST	Short term
Actor influenced	G	Government and local authorities
	C	Companies
	I	Individuals
	So	Society

7.2.2.1 eGovernment: from physical contact to electronic forms

Within the eGovernment sector, two main services have been identified, and their effects are summarized in Table 33. The first includes all applications for which the citizen needs to contact the administrative centre (e.g. extraction out of birth certificate, application for a driver’s license, etc.). Transforming this physical contact into an electronic format, saves the citizens (at least some of) the travels to the city hall. For the (local) authorities, this effect entails a huge amount of savings on paper and letters to be sent. One typical example of this electronic format is the online submission of taxes, which is now already used by a fair amount of the population in most cities.

Table 33: Identified services and effects for eGovernment

Service	Subservice	Effect	S/O	Term	Actor	Quantified?
eGovernment						
Government-citizen transactions	Switching from personal contact to electronic contact (income tax preparation and return, applying for licenses,	Reallocation of the time of the administrative personnel (capacity can be used for other services, like back office)	O	LT	G	Yes
		Time gain	O	ST	I	Yes
		Travel cost saving, both fuel and parking costs	O	ST	I, C	Yes

	paying for tickets, etc.)	Decreased consumption of paper (e.g. sending letters)	O	ST	G	Yes
		Decreased traffic jams and road accidents	O	LT	So	Yes
		Less stress	S	LT	I	No
		Reduced CO_2 emission (and other harmful gasses)	O	LT	So	Yes
	Providing information and resources for citizens online (e.g. e-newsletters, city information, personal profile, etc.)	Time gain	O	ST	I, G	No
		Reallocation of the time of the administrative personnel	O	LT	G	No
		Travel cost saving	O	ST	I, G	No
		Decreased consumption of paper (e.g. brochures)	O	ST	G	No
		Retrieving information outside office hours	S	LT	I	No

7.2.2.2 eBusiness: travel savings from teleworking and distance training

In eBusiness, the most important services that create indirect effects are teleworking (also referred to as working-at-home) and training of employees (from a distance). A high-speed broadband connection (preferably over fibre) will allow people to access their files at home as quickly as they would be able to do from the office, or enable employees to discuss with colleagues all over the world through real-time HD videoconferencing. These options permit employees to work (partly) from home, reducing their commuting time and cost, give the companies the opportunity to cut back their operational expenditures (e.g. rental fees for office space), while videoconferencing decreases the necessity of business travel. These services and their categorized effects are summarized in Table 34.

Table 34: Identified services and effects for eBusiness

Service	Subservice	Effect	S/O	Term	Actor	Quantified?
eBusiness						
Teleworking	Working from home	Reduced travel (time and costs for both fuel and parking)	O	ST	I, C	Yes
		Decreased traffic jams and road accidents	O	LT	So	Yes
		Reduced emission of CO_2 (and other harmful gasses)	O	LT	So	Yes
		Reduced stress	S	LT	I, C	No
		Decreased number of absenteeism by illness	O	LT	C, G	Yes
		Reduced office space and operational expenditures	O	LT	C, G	Yes
		Higher independency and flexibility for the employee	S	ST	I	No
		Reduced spending on human resources	O	LT	C, G	Yes
	Videoconferencing	Less business trips	O	LT	C	Yes
Training of employees	Grouped management of ICT infrastructure for clustered companies	Reallocation of the time of the support staff	O	LT	C	No
		More efficient use of network- and ICT services	O	LT	C	Yes
	Online training (possibly from	Reduced travel (time and costs for both fuel and parking)	O	ST	C, I	Yes

	home)	Reduced stress	S	LY	C, I	No
		Reduced emission of CO_2 (and other harmful gasses)	O	LT	So	No
		Decreased traffic jams and road accidents	O	LT	So	No

7.2.3 Evaluation for Ghent: an urban area

7.2.3.1 Overview of the input parameters

The model will be applied to a specific case study in the city of Ghent, an urban city in Belgium with a well-developed DSL and cable network (but no FTTH yet). The city was chosen because it definitely has the characteristics to possibly benefit significantly from a fast and reliable broadband network. The city houses a well-established university with comparable number of students, as well as a business campus where lots of smaller high-tech enterprises are settled (among which grew as spin-off companies from the respective universities).

Table 35: Regional data for Ghent [71]

Parameter	Ghent
Number of inhabitants	246,719
Number of households	106,805
Number of SMEs	7,289
Number of students at the university	31,445
Commuting population	138,597

If comparing these regional data with the data from the parametric areas as defined in OASE (Table 11), we see that we can clearly qualify Ghent as an urban area (household density is about 600/km^2, SME density 45/km^2). The calculation period will be limited to 2012-2030, and the discount rate set at 10%. We assume an FTTH deployment at the start of the business case analysis (2013), which means that first FTTH effects will be visible in 2014.

7.2.3.2 Results from the bottom-up methodology

. We will first discuss the total value of the indirect effects for both sectors, identify the most important effects, to finally evaluate the value per actor (according to the categorization axes as described in section 7.2.1.1).

<u>Total value</u>

The first result we show is the total value for both sectors (Figure 89). This total value represents the addition of the effects due to current broadband and the effects of fibre. The total value for Ghent sums to €930 million (cumulative and discounted until 2030). Clearly, the value of the indirect effects from the eBusiness sector is much higher than the value for the eGovernment sector (about a 1/10 ratio). The explanation can be found in the individual effects that make up this total value, on which will be elaborated further in the next paragraph.

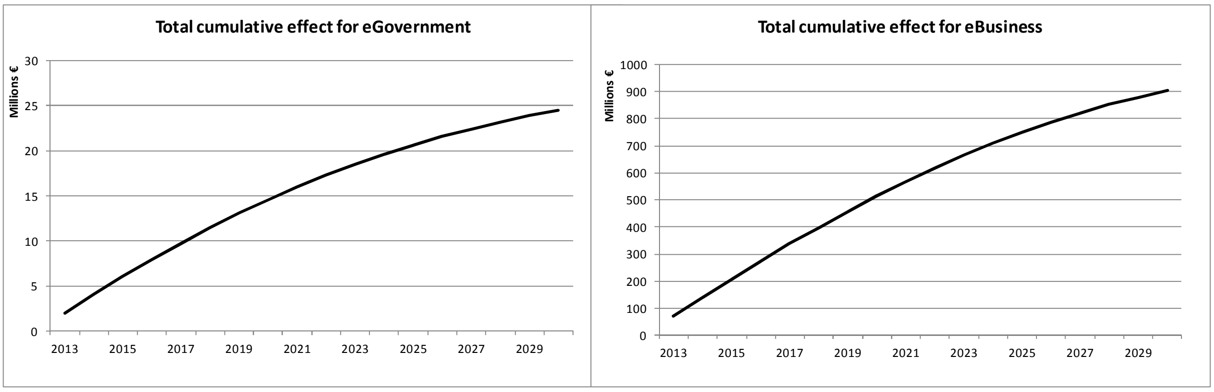


Figure 89: Total cumulative effect for both sectors (cumulative and discounted with 10%)

Evaluating this total value is of course relevant, but calculating down to the value per individual (for eGovernment) or per company (eBusiness) might give a better insight. These values are shown in Figure 90 (cumulative and discounted over 20 years), where a distinction is made between the value obtained by customers that have "normal" broadband, and those who are subscribed to fibre.

A more important result that can be concluded from this graph, is that there is a clear advantage of broadband and fibre for both sectors, although the value for eGovernment is limited to €100 spread out over 20 years. This can however easily be explained by the types of services identified for eGovernment: most of them can also easily be used on "normal" broadband (for more details on these services, see Table 33). The value of about €150,000 per company, on the other hand, is significant.

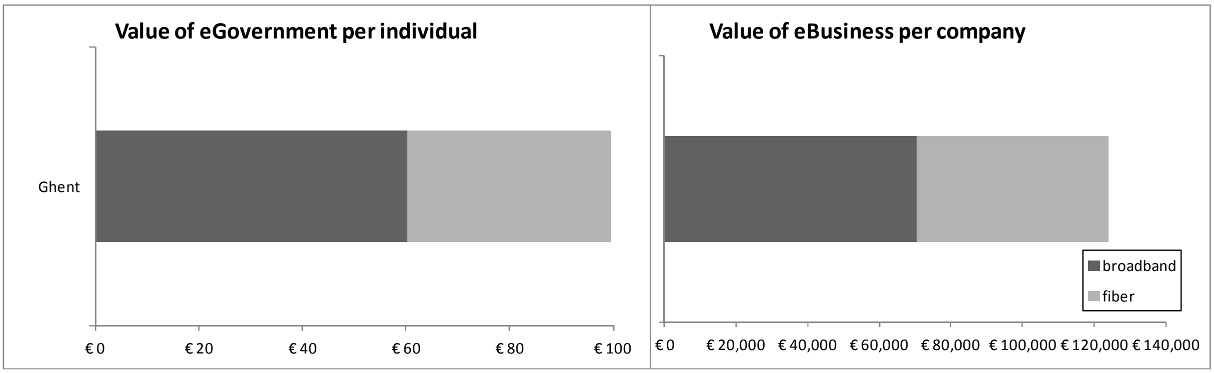


Figure 90: Value of the indirect effects for eGovernment per individual, and eBusiness per company

Most important effects

To identify the most important effects, we step away from the adoption curve of the technology, but only look into the maximum potential of the service itself. Referring to Figure 88, only the first six parameters are taken into account. We opted to compare the services in this way to exclude the impact of adoption of the technology, so that we can compare both cases on a fair basis.

The comparison for eGovernment is made in Figure 91. The travel savings take up the largest part (88% respectively). These savings include savings on time, fuel costs, parking costs and other costs related to automobiles, like insurance. It has to be mentioned that these costs only apply to inhabitants that visit the administrative centre of the city hall by car. We didn't take public transport or biking into account, so this value could even be higher. The other effects are much smaller, but not negligible.

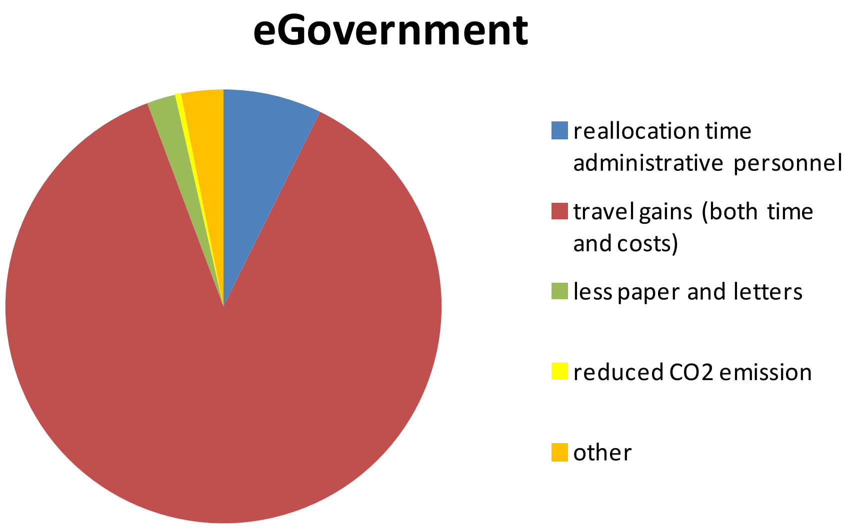


Figure 91: Indication of the most important effects for eGovernment

The same analysis can be performed for the eBusiness sector (Figure 92). Here, about 80% is taken up by savings in travel and office space (about €103,000 per company). Allowing people to work from home, can on the long term reduce the amount of office space needed. On a shorter term, these effects are already translated in operational savings (for e.g. lightning, electricity, cleaning staff, etc.). A common remark made on these operational savings is that they are not really saved, but transferred to the employee itself (since this employee now has to pay for the electricity, heating, etc. at home). However, this electricity cost represents only a small part of the total savings, the largest part of the savings is made by renting costs for office space and furniture (calculated here as the savings in office space if 16% of the working population would work feom home at least 1 day per week). Quantifying these savings might therefore provide companies with the incentive to pay the internet subscription of their employees at home, which in turn can provide a higher willingness to pay and as such an incentive to deploy fibre networks.

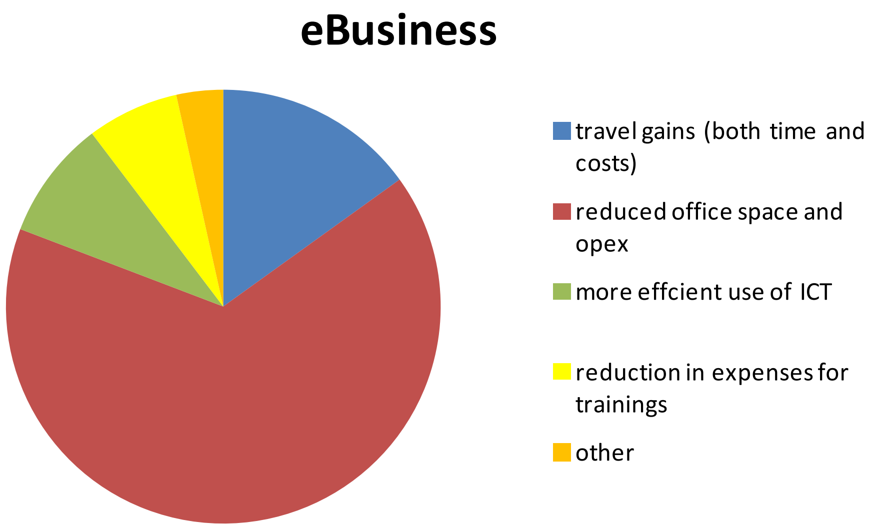


Figure 92: Indication of most important effects for eBusiness

The same reasoning holds for a more efficient use of ICT: if a fast broadband connection is present, companies can centralize their ICT infrastructure (servers etc.), which allows sharing this infrastructure among different locations.

Although not included in the eGovernment sector (we assumed one administrative centre location in each city), this sharing of ICT infrastructure could also entail large savings for the authorities, and should be kept in mind when evaluating public investment in fibre infrastructure.

Value per household

To conclude this results section, we give an overview of the value that these indirect effects can entail per household, since the costs for broadband connectivity or telecommunications in general is to be paid per household, and not per individual. When dividing the total value for both eGovernment and eBusiness by the number of households, we arrive at a total sum of about €8700 over the calculation period of 2013-2030. This is of course a very high number, and perhaps too optimistic, since in this fast calculation, all the benefits were subscribed to the households. More fair is to allocate only those benefits to the households or individuals, which were identified as being beneficial to them in reality (Figure 93).

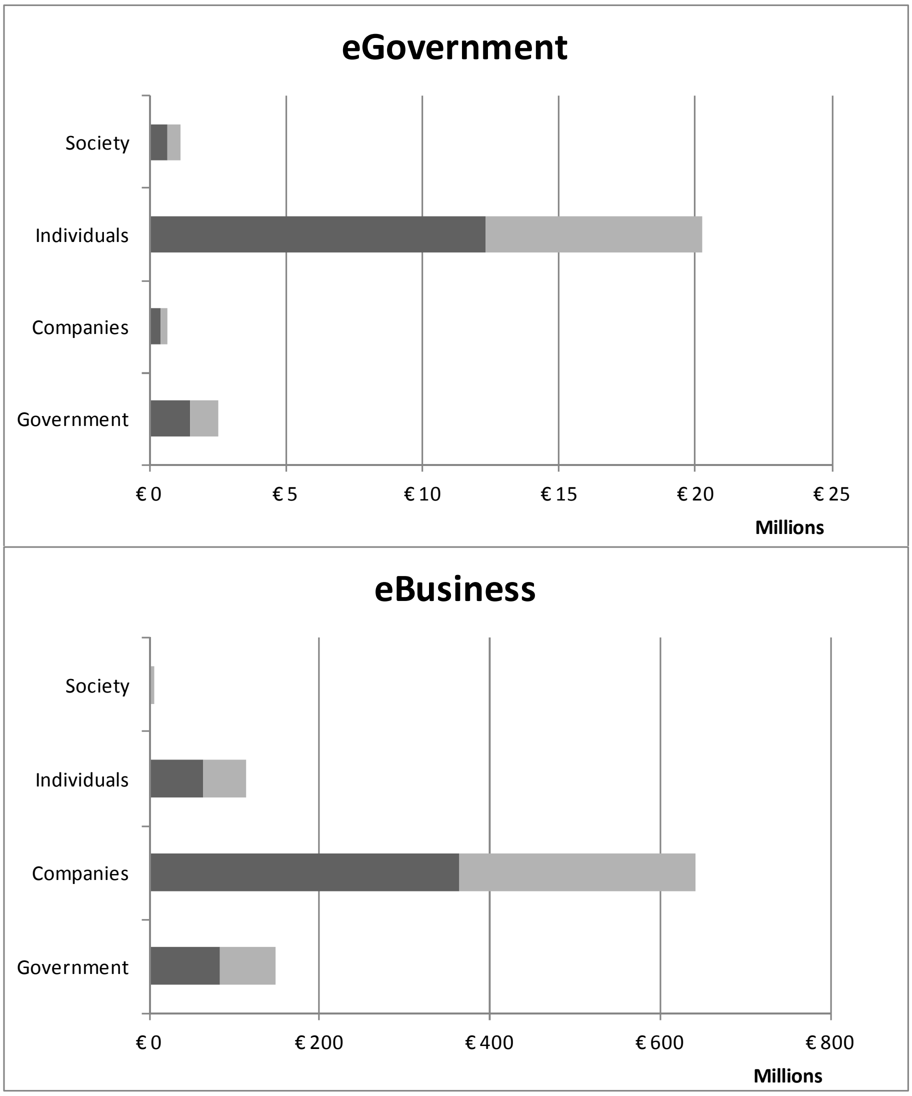


Figure 93: Value per actor for eBusiness and eGovernment

If we then use these number for calculating the value per household (talking into account 2.22 individuals per household [71]), we arrive at a total benefit of having broadband of about

€1250 per household over the total calculation period, and a total benefit of having fibre of about €530. If this €530 would be used to invest in fibre deployment, the business case would look a lot better… It is however uncertain that this amount of money will be invested by the households themselves, but it could provide for a good convincing argument to make people pre-subscribe to a fibre offer (thereby helping the demand aggregation).

7.2.4 Benchmarking our results: comparison to other studies

To benchmark our results, we will compare them with other studies available in literature. Based on transparency and degree of comparability, three studies were selected, among which two of them also used the bottom-up approach (New Zealand Institute, 2007 [80] and Columbia Telecommunications, 2009 [17]), the third study opted for a top-down methodology (Katz et al., 2009 [44]).

7.2.4.1 Comparison with other bottom-up studies

Both studies identify different types of effects, but chose to only quantify the more objective effects (similar to the strategy followed here). Furthermore, they both claim to quantify the incremental effects of high-speed broadband on top of existing infrastructures. Although this seems to be the case for New Zealand, the meta-study of Hayes [40] showed that the baseline for Seattle is no broadband at all. We will therefore compare the results of New Zealand with the incremental effects of FTTH found in this study, and the results for Seattle with the total effects of this study (from traditional broadband and FTTH combined).

The methodology of the New Zealand Institute is most comparable to the methodology used in this paper: they also start from a number of sectors, for which they expect indirect benefits. Evidence and values for these indirect effects are gathered from national and international sources. The main difference is that they quantified the value for the each effect at once, and did not start from the value per individual or unit, as was done in this paper.

The study of Columbia Telecommunications is less transparent in its methodology, the main similarities with our study are that they also used a categorization tree, they only quantified actual monetary savings, and they used interviews with experts on the field to identify the effects and gather input data.

Comparison with New Zealand for eBusiness effects

Unfortunately, the New Zealand Institute did not quantify the effects for eGovernment, so there is no basis for comparison here. They did quantify the effects for eBusiness extensively, allowing us to make a detailed comparison. Starting from the cumulative total values found in Figure 89, we calculated the value per capita and per year for Ghent, by dividing by the number of people living in the area, and by the planning horizon (20 years in this case). Table 36 shows that the results for New Zealand and Ghent are very comparable. The highest benefits for eBusiness for New Zealand were also found in remote working (or teleworking) and reduced travel costs in general.

Table 36: Comparison of the monetary value of the incremental effects of FTTH, per capita and per year, for eBusiness

	This study – Ghent	New Zealand
eBusiness	€15	€12

Comparison with Seattle

Comparing the results of our study with the study of Columbia Telecommunications (2009), is less straightforward than the comparison with the study for New Zealand, because the report is not very transparent in explaining its methodology. The positive point is that they did calculate values for eGovernment. Table 37 shows that the results are in same order of magnitude.

When comparing eBusiness, it is clear that the value found in Seattle is higher than the results of this study (around triple). This can however be explained by the type of effects that were taken into account in both studies: in Seattle, more than two third of this value can be accounted to a reduction in traffic congestion, an effect that we did not quantify (because of subjectivity, and a lack of available input data).

The same, tripled, result is found for the eGovernment sector. Again, this value can be explained by the fact that this study did not take an effect into account that was rather important for Seattle: the more efficient use of ICT by sharing infrastructure amongst governmental buildings. As mentioned before, we did not take this value into account because we started from the assumption of one administrative centre per city.

Table 37: Comparison of the monetary value of the total effects of broadband and FTTH, per capita and per year, for both eBusiness and eGovernment

	This study – Ghent	Seattle
eBusiness	€193	€547
eGovernment	€5	€15

7.3 Comparison between top-down and bottom-up results

It is relevant to compare the results of the top-down and bottom-down approaches presented above. Taking the results from the top-down approach in Section 7.1.8, and converting them to 100% coverage (those results were obtained assuming a starting penetration of 30%), and to euro (using an exchange rate €/SEK=9), we obtain a socio-economic return of €9.2 billion, after five years, or €205 per capita per year.

Katz et al. (2009) investigated the impact of broadband on the German economy, using input-output analysis on two investment scenarios, a national broadband strategy (50 Mbps for all by 2014), and an ultra broadband strategy (at least 50 Mbps on VDSL, 100 Mbps on fibre by 2020). The results of this study predict that the German GDP (Gross Domestic Product) will grow with €170.9 billion between 2010 and 2020.

This total value counts both direct and indirect effects, and includes all sectors (so doesn't limit to eBusiness and eGovernment). The direct effects include the direct economic activity related to the deployment of the network (job creation and the purchasing of expensive equipment), the indirect effects consist of a faster innovation process and the creation of new business activities.

It is of course far from straightforward to compare a macro-economic analysis starting from general economic indicators with a bottom-up analysis that identifies the value for the different effects separately. We opted for an estimation of the importance of eBusiness and eGovernment vis-à-vis the other sectors (like eHealth, eEntertainment etc.), and used this percentage to calculate the macro-economic value of eBusiness and eGovernment, as found by Katz et al.

Based on [86], the combined share of eGovernment and eBusiness in the total share of possible indirect effects, is 59%. Calculating the value found by Katz et al. down to this percentage (Table 38), leads us to the conclusion that these values are very similar.

Table 38: Comparison of bottom-up to top-down (yearly basis)

	Total value per capita	Percentage allocated to eBusiness and eGovernment	Result: value per capita for eBusiness and eGovernment
This study (Ghent)	€198	100%	€198
Katz et al. (Germany)	€333	59%	€196
This study (Sweden)	/	/	€205

8. Conclusions

The focus of this deliverable was on the cost-benefit analysis for multiple actors in the field of FTTH deployment and operations, looking at multiple scenarios and business models. Based on the expected costs (from WP5) and revenues (from Task 6.2), a quantitative evaluation and comparison of the proposed business models and value networks (from Task 6.1) were performed.

The revenue potential for the different scenarios was quantified both bottom-up, by using existing regulated prices and input from case studies, as well as top-down, based on an extrapolation of existing market shares and by using different scenarios for inter- and intra-platform competition.

The total costs, originating from WP5, were split up according to PIP (Physical Infrastructure Provider) and NP (Network Provider) responsibilities. To this base cost, the cost of open access was added, which relates to equipment, management and business. Equipment related costs include the extra equipment and infrastructure that need to be foreseen that connect the PIP to the different NPs or SPs on a fair, secure and transparent way. Management and process related costs consist of all wholesale core processes of a retail business, as well as all kinds of patching to physically or logically connect the customers to the right SP or NP. Business costs, finally, relate to the costs linked to the transaction between the different players itself (contract issues etc. between PIP/NP and NP/SP resp.). All these costs were evaluated for a short-list of architectures, which matches the main business requirements (multi NP-support, inter-NP isolation, no master NP, technology agnostic PIP).

Combining these inputs with more general geographical, demographical and economic parameters (household densities, adoption rates, etc.), allowed us to evaluate costs versus benefits for the different actors involved. This evaluation led to the conclusions that, in the reference scenarios, the business case for the PIP will never be positive, even if the cost for the in-house cabling is excluded and recouped in another way. Several refinements that can improve the case were therefore suggested. A level of demand aggregation of 40% can nearly make all scenarios in urban and dense urban areas profitable. Taking advantage of duct reuse has an important impact on the cost base and leads to significant decreases of the trenching costs. Another option is to look for other types of customers than the pure residential ones: additional revenues from public institutions or businesses (both large, medium and small enterprises as well as mobile operators) can help to improve the case. Furthermore, as we are considering an infrastructure investment, it might make sense to prolong the planning horizon beyond 20 years. A discounted payback time of less than 40 years was observed in the dense urban scenario, independent from the adoption curve. As there are multiple possible actors to take up the role of Physical Infrastructure Provider, and taking into account their different financial and economic background, the impact of the weighted average cost of capital (WACC) on the business case for the PIP was evaluated. Taking a variation of WACCs of 0% to 15% leads to a huge impact on the needed revenue per user per month (e.g. in the dense urban case varying between €18 and €120).

The business case for the NP depends strongly on the inclusion of the in-building infrastructure and ONT. If the most dominant cost, the in-house infrastructure, could be shifted to another player, the business is positive for all scenarios (areas and adoption curves), with slight cost advantages for GPON 1:32 over AON. With demand aggregation, the business cases could be improved a lot, reaching a break even including the in-house costs with a level of 40% penetration at the beginning of the project. Besides the traditional FTTH technologies, the analysis for three different future technology options was performed: NG AON, WS WDM PON and Hybrid PON. For these NGOA technologies, there is a reasonable business case in the order of the desired €10 per month that results from the bottom-up revenue analysis, assuming a high take-up, which seems to be reasonable in the future.

Adding open access on the fibre layer, and thereby allowing competition on the NP layer, would increase the needed revenue per customer per month with about €1.70, while switching will cost them about €150. Theoretically, open access on wavelength layer is possible, and the cost increase needed is marginal. However, the diseconomies of scale associated with the use of PON architectures by network providers make this scheme not cost efficient at all. Finally, there are no real extra costs for equipment or infrastructure when offering open access on bitstream layer, only an increase in transaction costs, leading to an overall increase in needed revenues of about €0.30 per month.

Offering this open access interface enables the interaction between multiple players on different levels in the value chain. We therefore also looked into the objectives of these different market players, like Housing Corporations, Equipment Vendors, Regulators, etc., their power relations and strategic actions in different settings. We performed this analysis both qualitatively, using a MACTOR approach, and quantitatively, using game theoretic modelling. During our qualitative analysis, city networks emerged as the most promising co-operation. For our quantitative analysis, we therefore focused on the case of a fibre infrastructure deployed by a municipal infrastructure provider (which was indicated as most promising by the qualitative analysis). Although a closed infrastructure could also be an equilibrium situation (where the Telco and other NPs are forced to stay on the legacy network), an open infrastructure clearly leads to a more preferable equilibrium situation with a better business case for the Municipal Infrastructure Provider (which remains difficult though). Since the municipality not only focuses on profitability of the fibre network, but also on social welfare, it can even push the market towards the more preferred equilibrium.

The choice of opting for a closed or open municipal fibre network seemed crucial, and was therefore further investigated using real options theory. First, it was shown that deploying an open access network without any other players migrating to it, already has a large negative effect on the viability. However, under competition, it is always more interesting to open up the network indeed, as existing players will choose to migrate to the network. The extra revenues due to the increased uptake on the fibre network clearly offset the upfront and provisioning cost. Secondly, transaction costs are expected to play a major role. These can amount up to 20% of the yearly Municipal Infrastructure Provider revenues, and will as such affect the profitability of this player. While the prevailing competitive equilibriums remain, the Municipal Infrastructure Provider suffers from a negative payoff in all cases when transaction costs are above 15% of the yearly revenue.

Because, despite all the improvements proposed, the business case for a PIP, especially a municipal PIP, still is not too optimistic, the final chapter of this deliverable looked into other advantages a FTTH deployment would entail. We identified these so-called indirect benefits, and quantified them according to two methods: bottom-up and top-down. The analysis concludes that there is an additional gain form indirect benefits, which can of course significantly help to improve the business case.

A.Overview of existing fibre initiatives

In order to evaluate and compare the costs and revenues for the different actors involved, it is necessary to get a good overview of their responsibilities. In D6.1 [57], an overview of possible business models was given, ranging from a vertically integrated operator taking up all the roles (g) to more open business models (c, d) where competition on both network and service level is encouraged. This section will describe the business model used in each of the cases described in D6.2 [54], as well as give an indication of the revenues that flow in between those actors. Analyzing the case studies while focusing on the revenue and interaction flows, will provide us with more insight in the practicalities of the operational functioning of the different business models represented below, and will help us when defining qualitative and quantitative interaction models for the different actors involved in an FTTH network deployment.

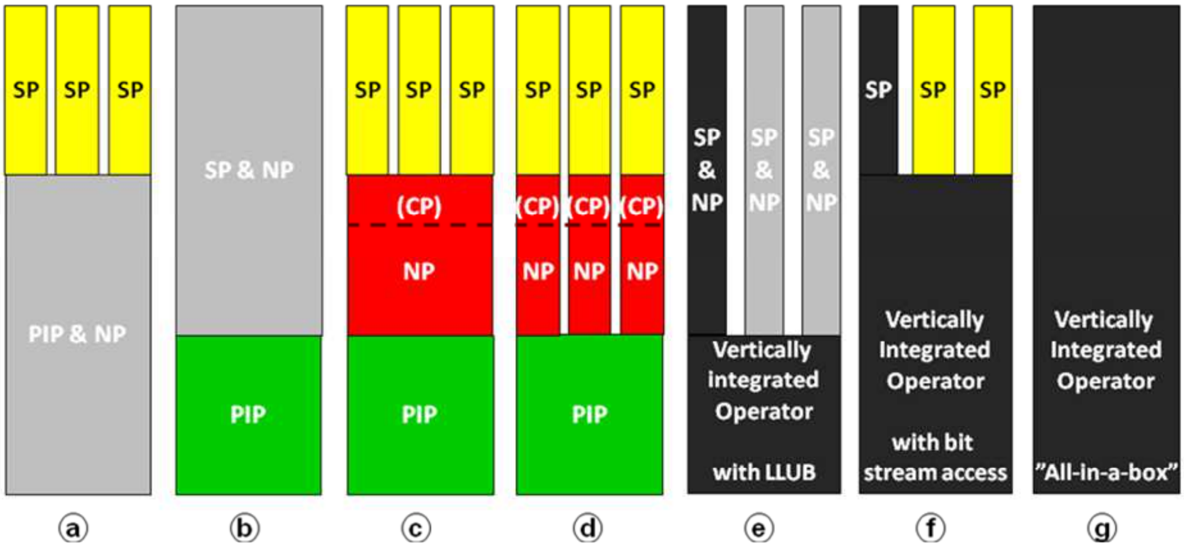


Figure 94: D6.1 business models

A1. Stockholm (Sweden)

The first case describes the FTTH network in Stockholm, Sweden. This network is an example of business model c, since every network provider (NP) has its own geographical region (no network equipment needs to be shared in the different regions, so no cost or revenue allocation in between different NPs is needed here).

The PIP role is taken up by Stokab; the company was started in 1994 following deregulation of the telecoms market. The company was started when no operator showed any interest in deploying passive fibre in Stockholm, but the municipality felt there was a commercial need for it. The city wanted good IT infrastructure to help contribute to growth, and so formed Stokab, a company 100% owned by the municipality. It was felt important that the broadband infrastructure and services were split in order to fully promote competition. One indication of success is the price of Internet access throughout Stockholm. A recent publication "Computer Sweden" marked the price of 100Mbit/s broadband in Stockholm at €550 per year (compared to an average of €950 for the rest of Sweden). This low price is stimulated by the 90+ service providers in Stockholm, which is much more than in most other cities in the EU. In total, Stokab has over 800 business customers. The first of these customers came from banks and finance houses who wished to control their own networks. One of the key success factors was that Stokab did not try to compete with its customers. Stokab maintained this role to promote stability for its customers.

A1.1. Overall business model

The passive infrastructure is owned and operated by one single PIP: the publicly-owned Stokab. Stokab is responsible for the deployment and operations of the dark fibre network, and they also rent space in the basements of the large apartment buildings, where they install empty racks that can be leased out to the NPs for installation of the active equipment.

The NP-layer is split up in between one public and several private NPs. The public NP, St. Erik Kommunikation, is responsible for connecting the city's own buildings and administration, as well as for the in-building wiring. St. Erik Kommunikation provides no services itself, they put out tenders for e.g. telephony, internet etc. Tender winners get the monopoly of operating the specific public service for a limited amount of time (a couple of years), after which a new tender procedure is set up. (The changing tender winners for the public services are the reason no specific names are indicated in Figure 95). As mentioned before, several private NPs offer connectivity using Stokab's network, each operating in its own geographical region. There are firms that only act as a NP, making contracts with different SPs for offering services. Other actors (among which the incumbent TeliaSonera and the former cable network operator ComHem) act as both NP and SP, offering their own services.

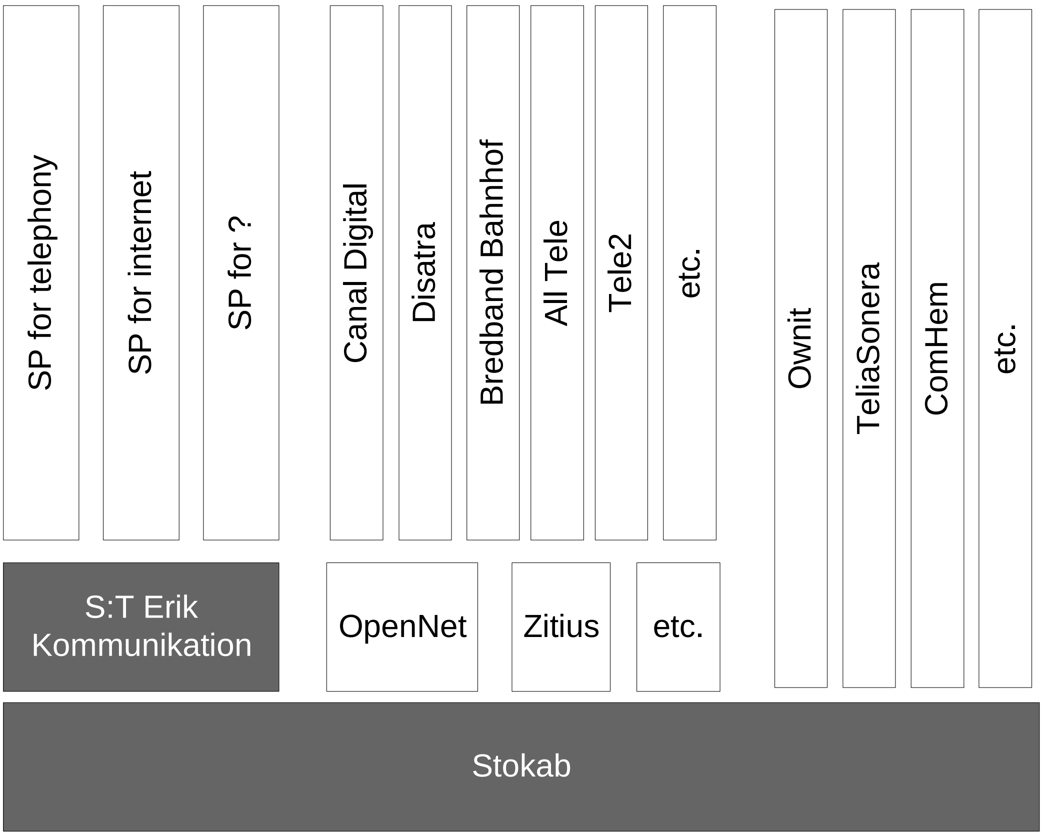


Figure 95: The different companies active on the FTTH network in Stockholm

A1.2. Division of roles

The figures below describe the business model presented in [54] in more detail based the responsibilities in the different network lifecycle phases and physical connection points (PCPs).

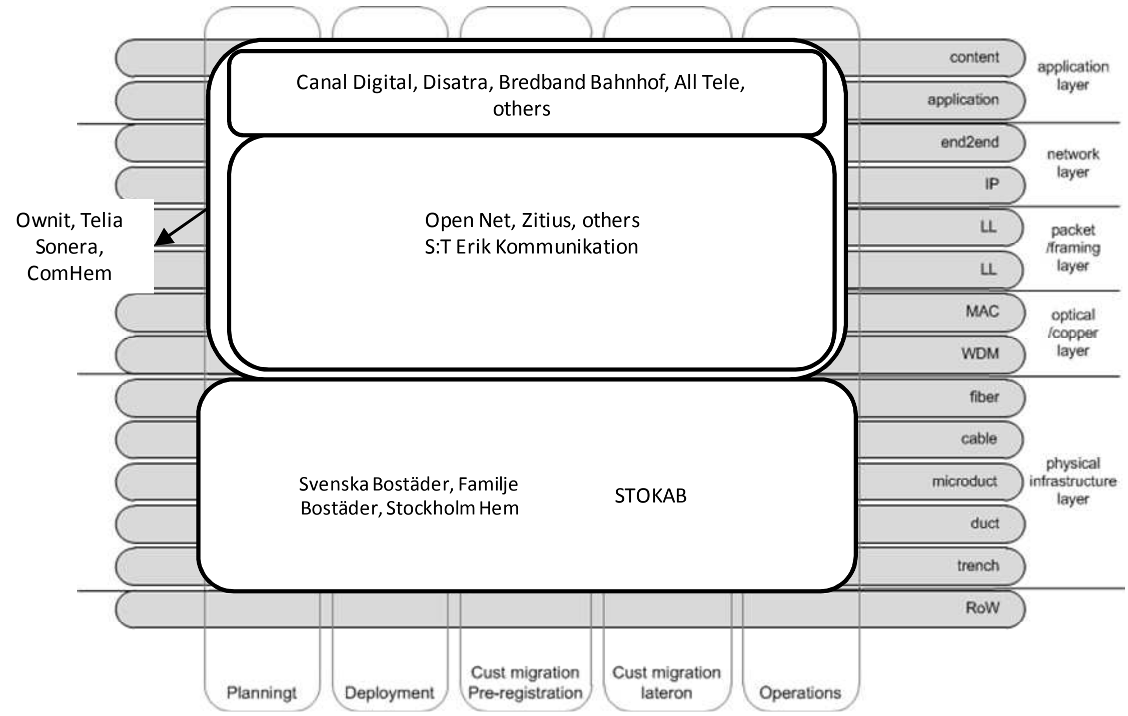


Figure 96: Division of roles based on network lifecycle phases (Stockholm case)

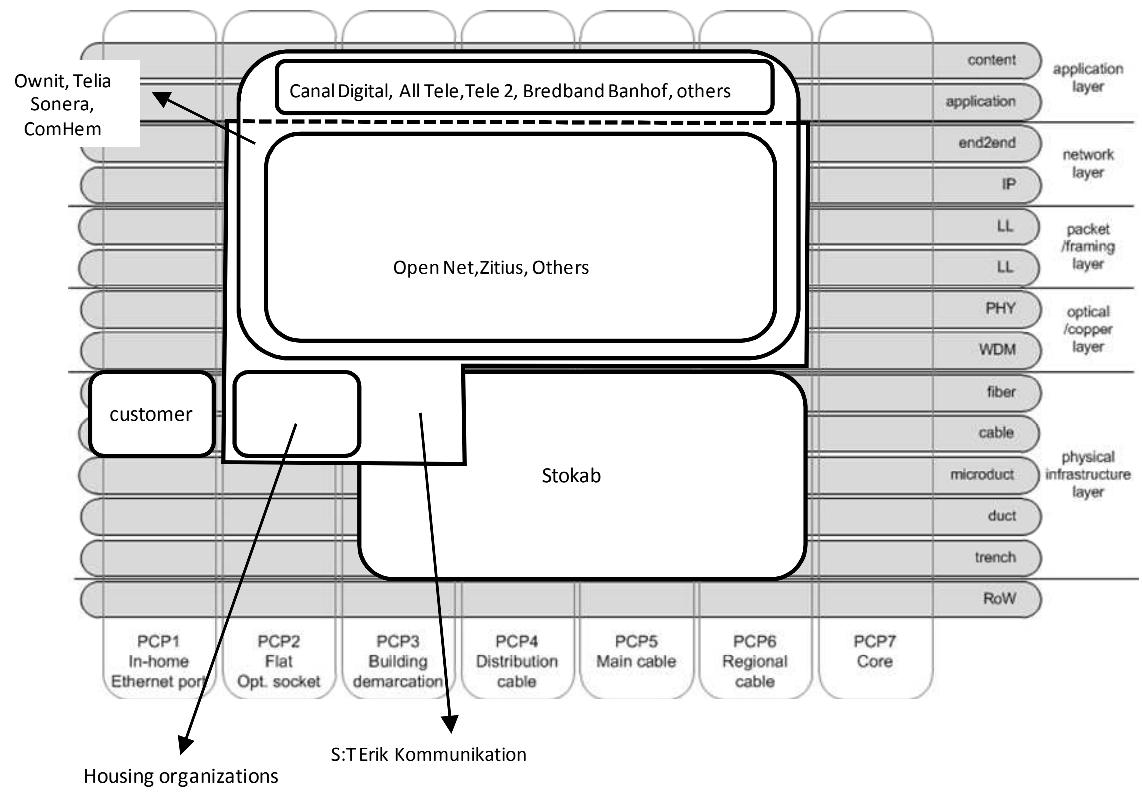


Figure 97: Division of roles based on Physical Connection Points (case Stockholm)

A1.3. Revenue models

Now it is clear which actor takes up which responsibility, we should look how the different actors interact. They share technical requirements, and thus costs, but of course, they also share revenues. Basically, all the revenue flows start from the end customer, and find their way through the value network. A graphical representation of this value network for the Stockholm case is given in Figure 98.

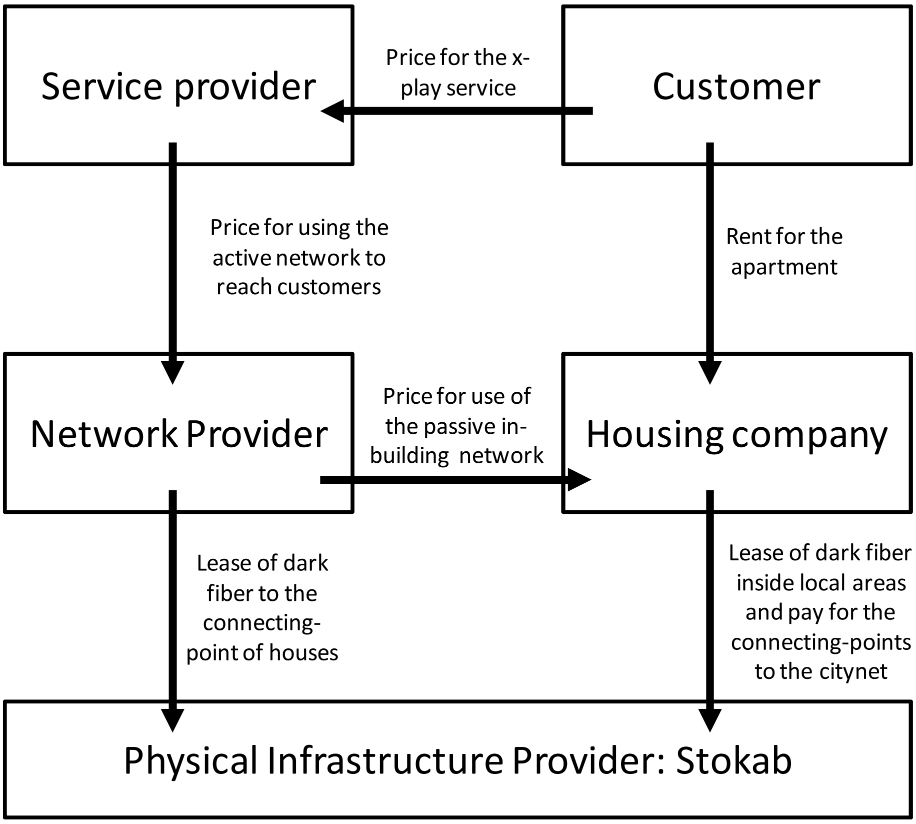


Figure 98: Revenue streams for the Stockholm case

The end-customer pays a monthly subscription fee per service (or for a bundle of services) to the SP and of course they pay rent to the housing company. Monthly fees range from €20 per month for basic broadband (1 Mbps download speed, 1 Mbps upload speed) to about €50 per month for very fast broadband (100 Mbps down, 100 Mbps up) (for details of these monthly subscription fees, see section 4.2 of D6.1 [57]). The end-customers don't pay directly to the NP for end-to-end connectivity. This actor receives revenues from the SP and in return offers the use of the active network and marketing through his website. The NP pays Stokab for the use of the dark fibre access network and the housing companies for the use of the in-building network. Stokab receives money from the NP and/or housing companies for using the access network. Stokab charges the NP's about €200 per km or €5-7 per customer (dependent on the number of customers the NP serves) for the customers living in the inner city (regardless of distance).

It is important to mention here that these revenues are sufficient to make the involvement in the FTTH network into a viable business case. Stokab, for example, had a turnover of €63 million in 2010.

A2. Norderstedt + Hamburg (Germany)

The wilhelm.tel GmbH is a regional provider of telecommunications services based in Norderstedt, Germany. The company operates its own fibre network that is deployed up to the individual households and is 100% owned by the city of Norderstedt. In addition, it operates in different other cities / regions of the federal state of Schleswig-Holstein covering an area about 1200 km² with about 1 million households and close to 2 million residents. The company operates under two major brands, willy.tel (in Hamburg) and Wilhelm.Tel (in all other areas).

Wilhelm.Tel (WT) was the first company that offered a complete multimedia package (triple play) throughout Germany. Today Internet access with data rates up to 100 MBit/s downstream and 5 MBit/s upstream are available.

A2.1. Overall business model

In principle, Wilhelm.Tel is a public company (fully owned by the city of Norderstedt – Schleswig-Holstein, Germany) that is responsible for the deployment and the operations of the passive fibre infrastructure connecting the central office to the basements of the residencies. WT uses mainly FTTB (Fibre-to-the-Building), although some minor parts are FTTH. P2P topology is utilised (based on a ring-topology) with single-mode fibre which includes “the last mile”. In general the choice of technology depends on the network operator, although Ethernet is mostly used for the last mile.

The fibre network of WT is shared (in Hamburg) with Telefónica/HanseNet. Willy.tel is a co-operation between Wilhelm.Tel and Thiele GmbH. A big advantage for WT is the strong interaction and co-operation with apartment associations and building companies in Hamburg (e.g. SAGA_GWG). By doing so, the in-house wiring becomes the responsibility of both apartment management and WT and the customers are “forced” to use WT’s offer. In some cases, the apartment associations and building companies could make WT a mandatory part of their rental package and increase the rent by the monthly fee.

The private network providers don’t own a network, but offer services. Telefónica, (in particular with the brands HanseNet and O2) rents the license to offer fibre-based internet to its customers, using the fibre network of WT.

WT is an infrastructure, network and service provider at the same time. A large portfolio, where the focus is strictly on the “full media” (internet, phone and TV) package, is offered to the end-customers and supported by a 24-hour service line/website. Some examples of several services by different providers are given in D6.2 section 4.3.4 [54].

Both public and private housing associations exist in Hamburg+Area. An example is SAGA-GWG owned by the City of Hamburg, and a leading real estate company in Hamburg and the surrounding area, with more than 130.000 apartments just in Hamburg. In Hamburg the operation of the network is outsourced to several network operators. SAGA is in close co-operation with WT concerning the internet/telephony and television service. Using this channel provided by SAGA-GWG, WT can reach many high-potential customers directly and try to create a monopoly-like situation.

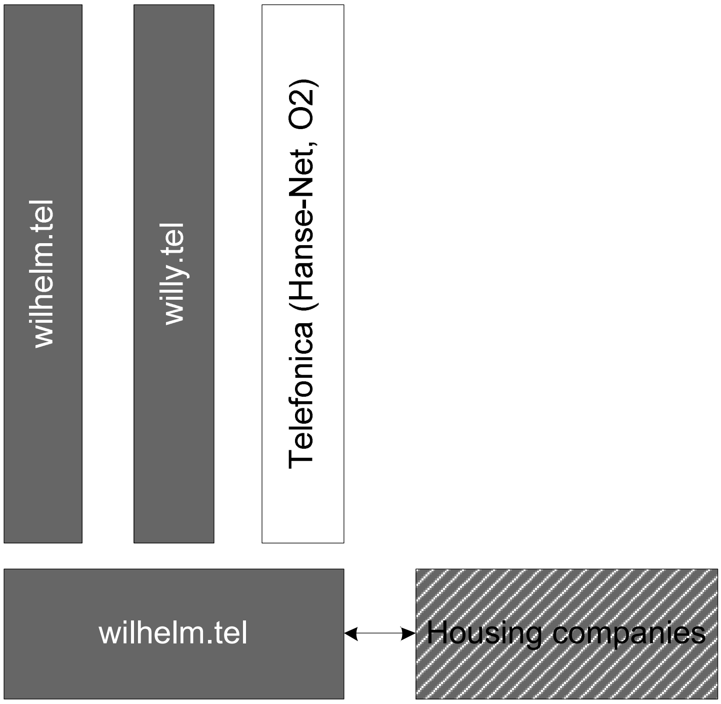


Figure 99: The different companies active on the FTTH network in Norderstedt / Hamburg

A2.2. Division of roles

Figure 100 and Figure 101 below give a more detailed representation of the actor's responsibilities. First, a mapping of the actors on the different phases versus the network layers is given (Figure 100), which stresses the responsibilities of the integrated provider wilhelm.tel on the operations of both active and passive infrastructure. The public and private housing companies act in different manners, for example the ImmoMediaNet company was built to organise failure management between WT and SAGA-GWG. The second Figure, Figure 101, represents an analogous mapping, but focuses on the seven Physical Connection Points (PCPs), which were described earlier in D6.1 [57].

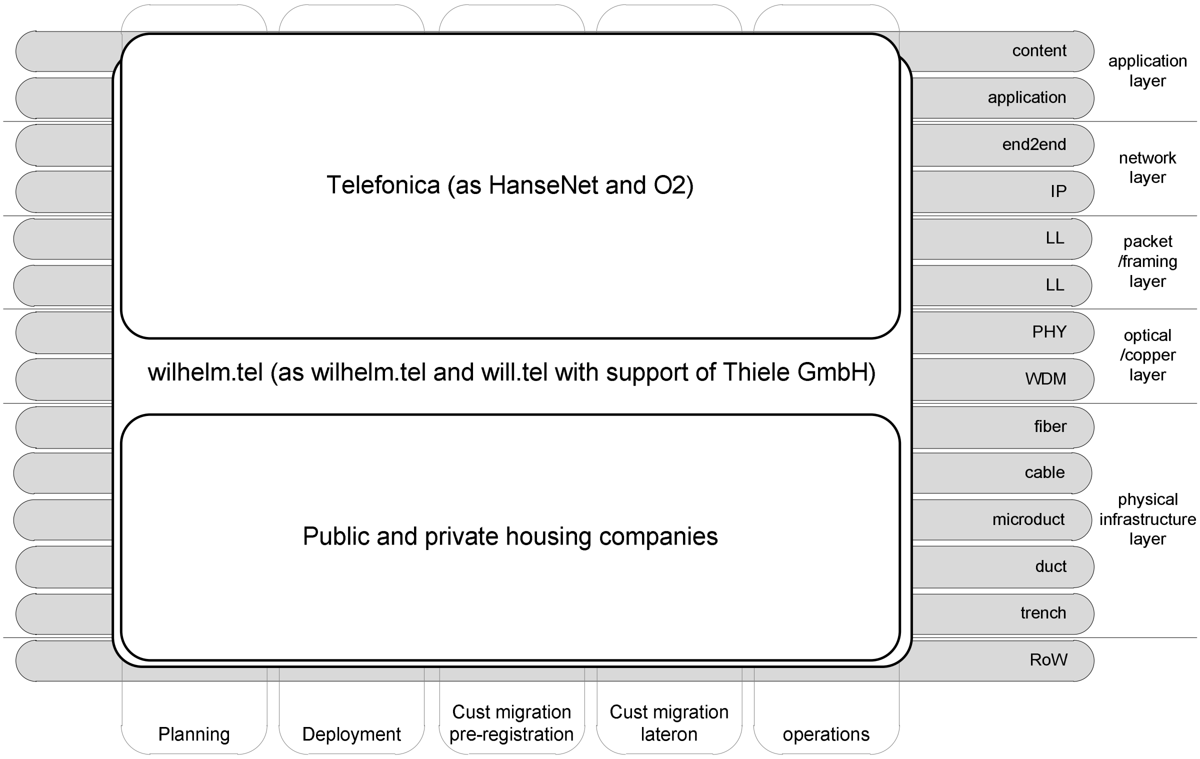


Figure 100: Division of roles based on network lifecycle phases (Norderstedt/Hamburg case)

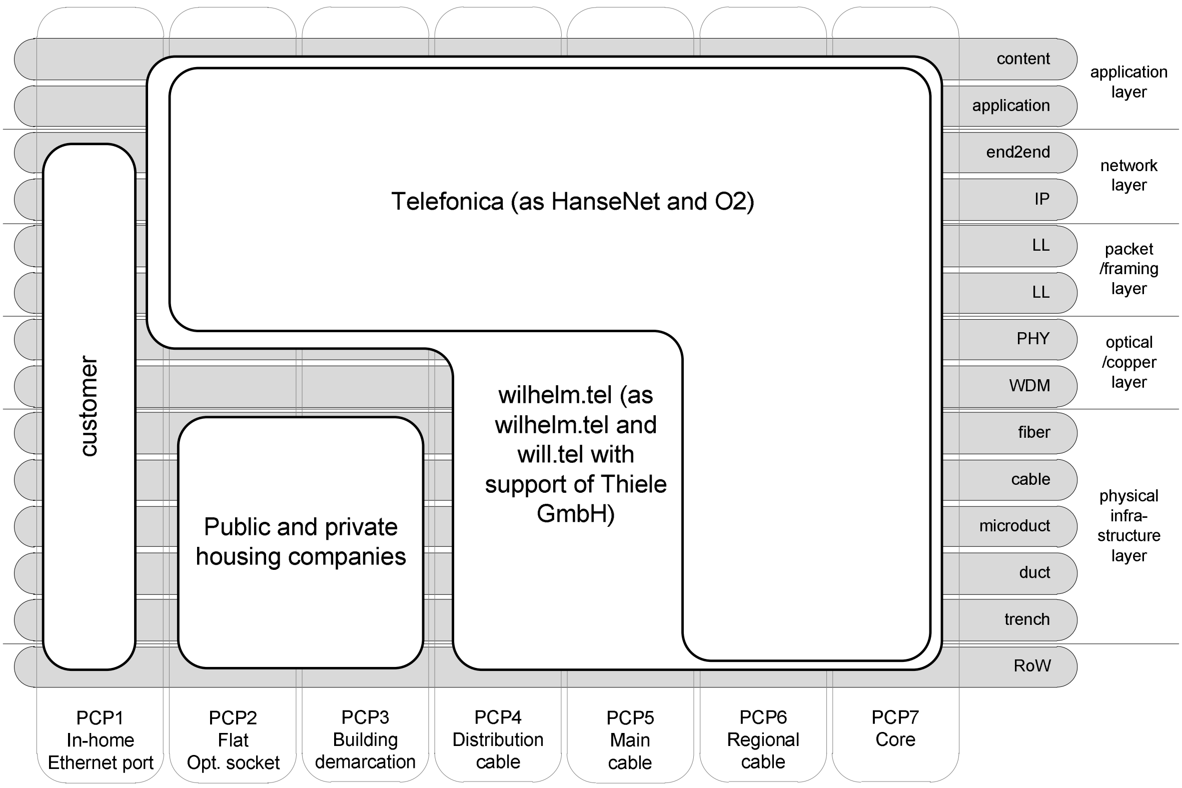


Figure 101: Division of roles based on Physical Connection Points (Norderstedt/Hamburg case)

A2.3. Revenue models

The revenue flows within the FTTB/H network are similar to an integrated operator model, both for Wilhelm/willy.tel and Telefonica. Both are providing to Wilhelm.Tel the part of the revenues required for operating the network. It is unclear whether the network provider pays directly the housing company for use of the in-building network or indirectly via the physical infrastructure provider. Based on some analysis, it seems that the customer has to pay the housing company as part of the rent a certain fee for the in-building network too or at least has limited possibilities in choosing other operators.

The fees paid by the end-customer range from around €30 per month with several options to add other services, depending on the customer demand (see section 4.3 of D6.2 [54] for more details).

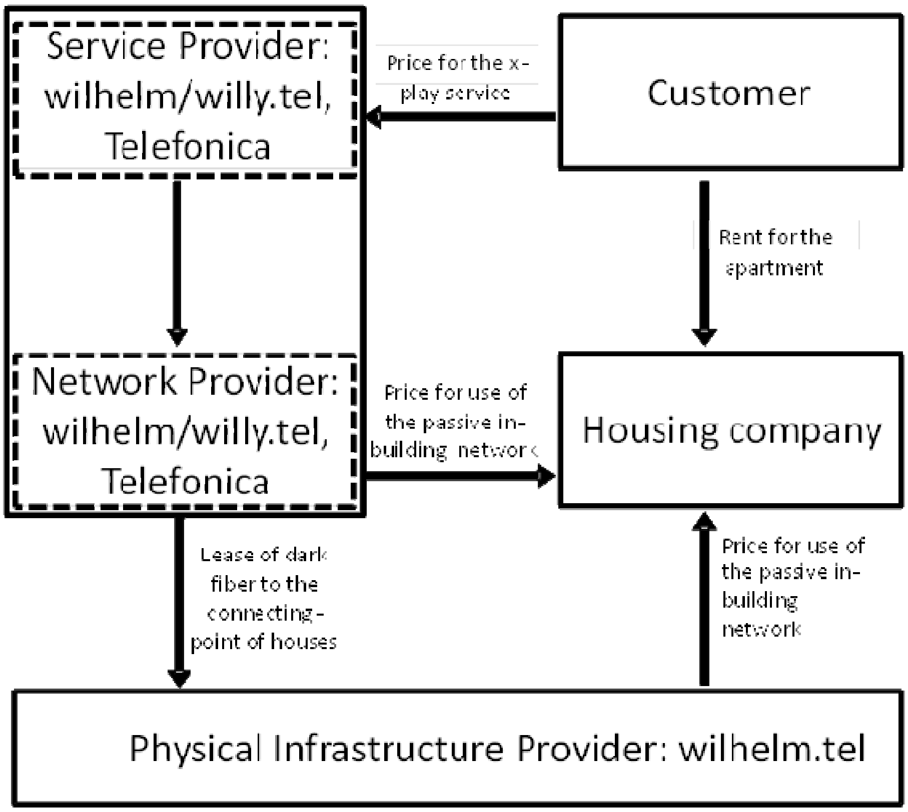


Figure 102: Revenue streams for the Norderstedt/Hamburg case

A3. Bavaria (Germany)

The M-net of Communications GmbH is a regional telecommunications provider in Bavaria and operates its own telecommunications network. The company was founded on 30 July 1996 and the main shareholder of the company is the public utility company "Stadtwerke München". Originally M-net provided data services and leased lines in the greater Munich area for business customers only. In 2004 telephone and Internet services were offered to private customers and the company started a continuous expansion of the own network in the Munich and Nuremberg area.

The classical network covers an area about 50,000 km² with approximately 12.6 million residents in 6 million households. In October 2007, M-net started the construction of a new fibre-optic network in Munich and Augsburg.

In addition, M-net is heavily involved in the broadband for rural areas in Bavaria, but this is mainly based on FTTC and out of scope of this analysis. In certain areas, M-Net cooperates with LEW TelNet, another integrated operator.

A3.1. Overall business model

In principle, M-net is a public company (fully owned by the Stadtwerke München, which is owned by the city of Munich) that is responsible for the deployment and the operations of the passive fibre infrastructure connecting the central office to the basements of the residencies. M-net mainly constructs new outdoor locations for FTTC in combination with VDSL technology for residential customers and SDSL for business customers although some parts are FTTB. For the FTTB technology, m-net implements a "Multi-Dwelling-Unit" into the basement of the buildings to redirect the signals to the apartments via already installed infrastructure within the buildings. The topology of the fibre-network is based on a ring-topology, to provide flexibility and independency. Some minor parts in Bavaria are going to be built completely new and therefore have a first installation of broadband internet at all, e.g. "Westside". In those areas M-net is trying to implement FTTH because the cost difference between xDSL and fibre is not that high if there has been no first implementation of a DSL network before. An important key fact here is that M-net currently only plans to build FTTH in places, where they do not have VDSL already integrated. For their fibre network M-net uses the GPON (Gigabit Passive Optical Network) technology, which enables in addition to telephony, a speed of 100 Mbit/s and digital television with HD quality. For residential customers, m-net uses the GPON (Gigabit Passive Optical Network) technology, which enables in addition to telephony, a speed of 100 Mbit/s and digital television with HD quality. In contrast business customers are attached either by the shared infrastructure and GPON technology or with separated fibres and other technology choice like SDH which provides up to 10Gbit/s. So, M-net is an integrated operator which cooperates with LEW TelNet for physical access.

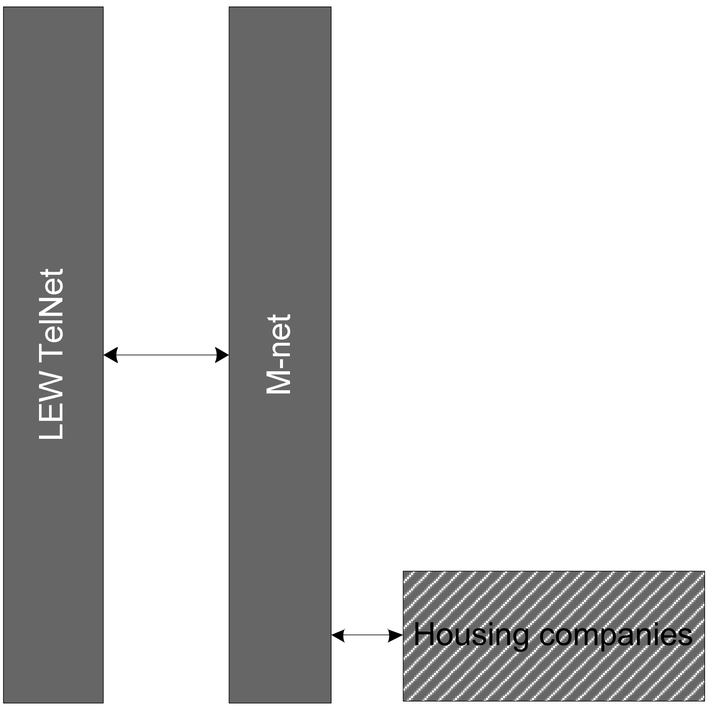


Figure 103: The different companies active on the FTTB/H network in Bavaria case

A3.2. Division of roles

Figure 104 and Figure 105 below give a more detailed representation of the actor's responsibilities. First, a mapping of the actors on the different phases versus the network layers is given (Figure 104), which stresses the responsibilities of the integrated provider M-net on the operations of both active and passive infrastructure. The public and private housing companies act in different manors, but detailed information was so far not available. But it can be assumed that some political willingness will lead to cooperation between publicly owned housing companies in Munich or Augsburg area with M-net. The second Figure, Figure 105, represents an analogous mapping, but focuses on the seven Physical Connection Points (PCPs), which were described earlier in D6.1 [57].

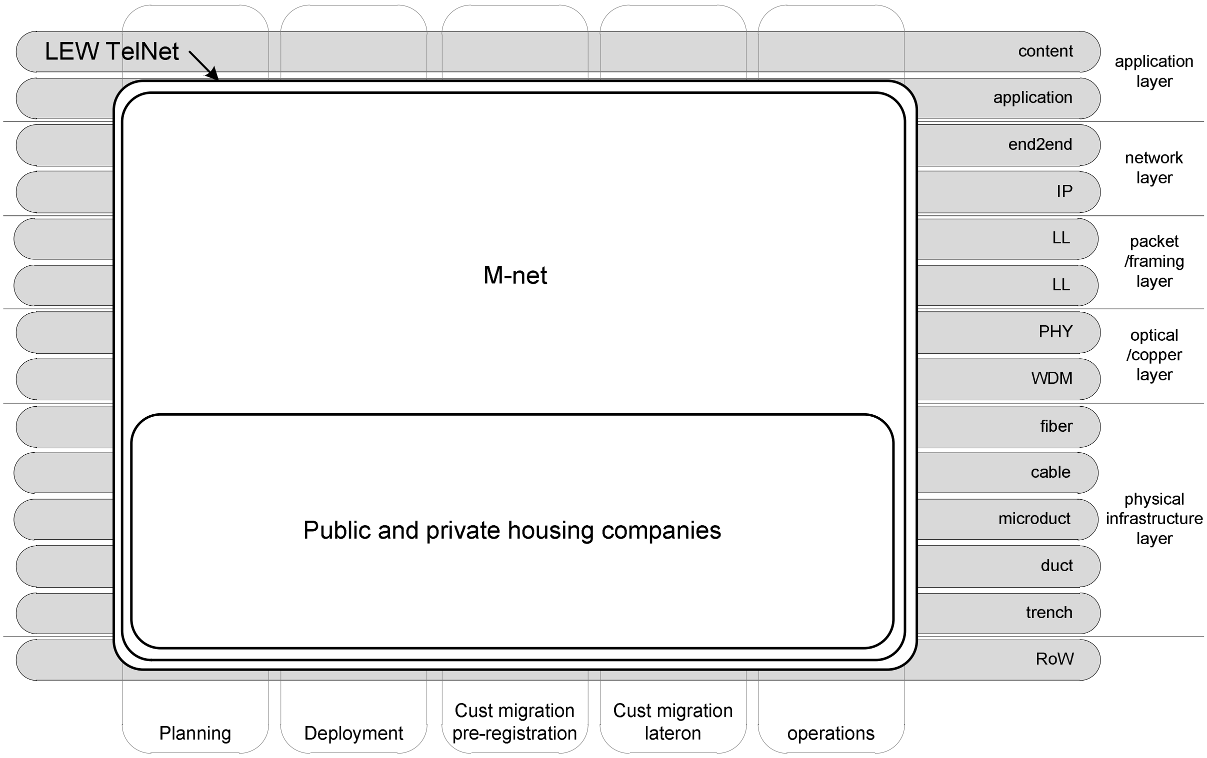


Figure 104: Division of roles based on network lifecycle phases (Bavaria case)

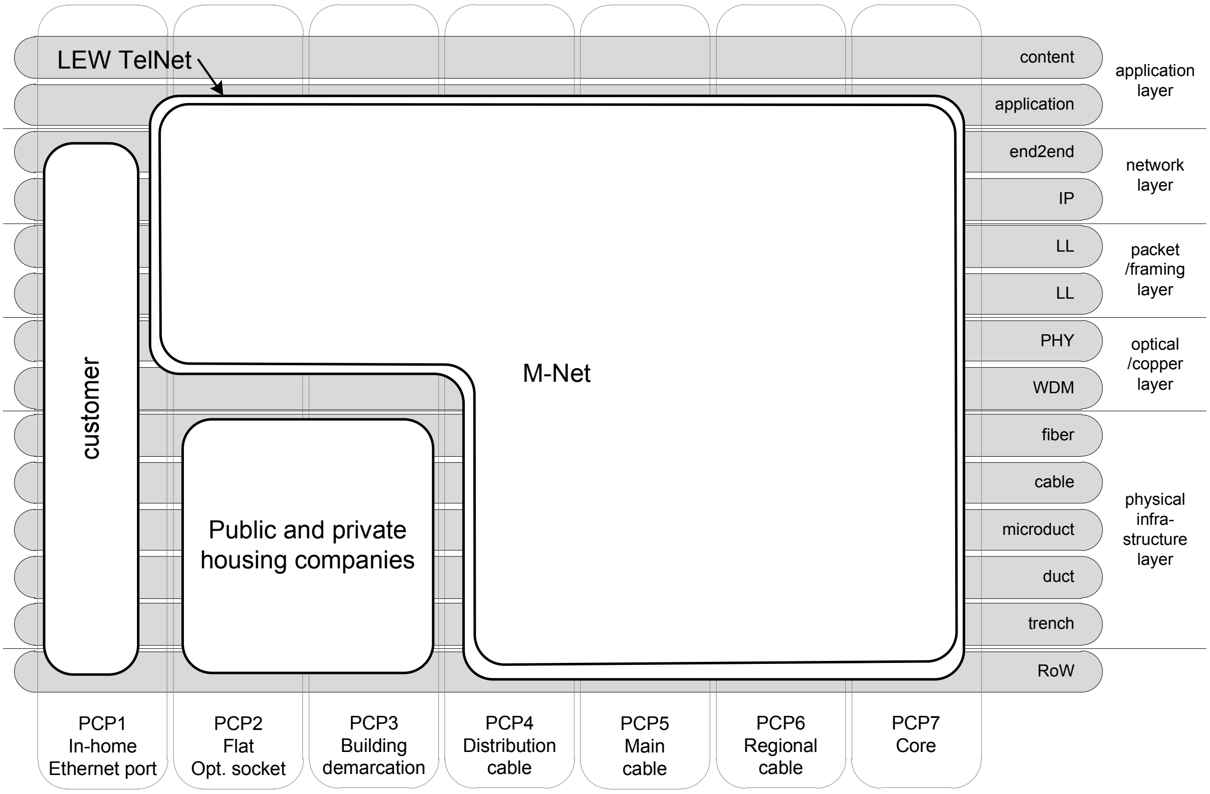


Figure 105: Division of roles based on Physical Connection Points (Bavaria case)

A3.3. Revenue models

The revenue flows within the FTTB/H network are similar to an integrated operator model, both for M-Net and LEW TelNet. It is very similar to the Norderstedt/Hamburg case except that the dualism of service and network provider is extended to the Physical Infrastructure Provider as well. It is unclear whether the network provider pays directly the housing company for use of the in-building network or indirectly via the physical infrastructure provider. Based on other cases, it seems reasonable that the customer has to pay the housing company as part of the rent a certain fee for the in-building network too or at least has limited possibilities in choosing other operators.

The fees paid by the end-customer range from around €30 per month with several options to add other services, depending on the customer demand (see section 4.4 of D6.2 [54] for more details).

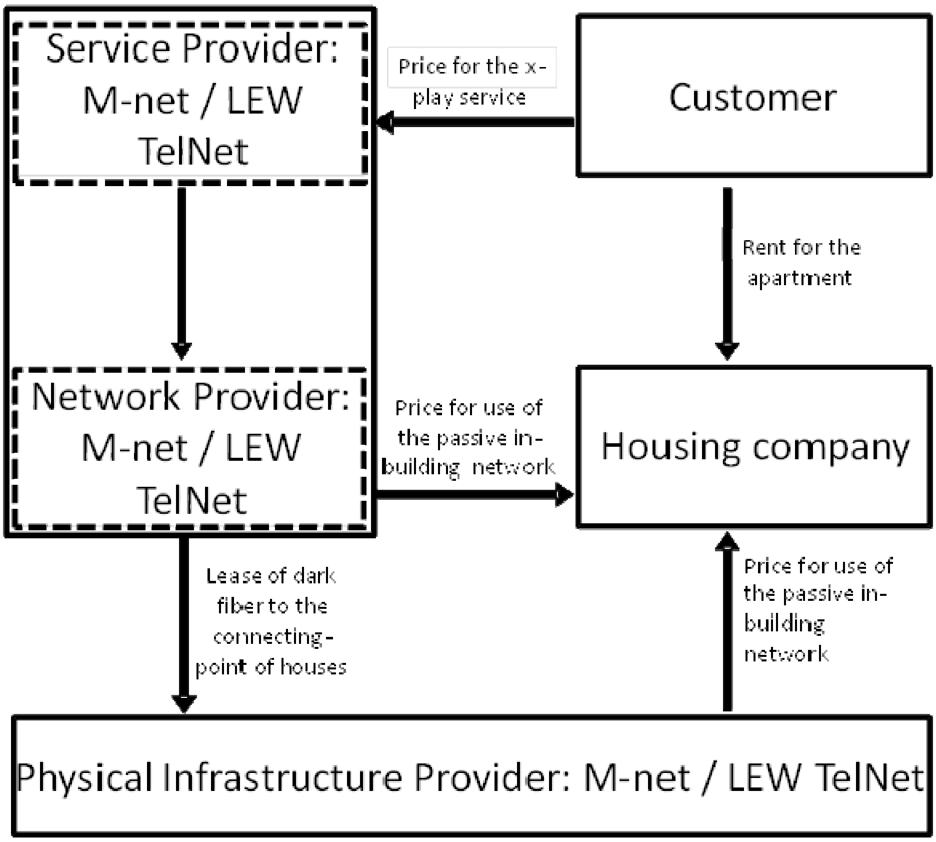


Figure 106: Revenue streams for the Bavaria case

A4. Amsterdam (The Netherlands)

The business model for the network in Amsterdam can be categorized between model c and model d (see Figure 94). At first, there was only one network provider that was chosen through a tender procedure. Nowadays, the active equipment is operated by both BBned (now Tele2, the original tender winner) and KPN, the Dutch incumbent operator.

A4.1. Overall business model

The planning and deployment of the passive infrastructure falls under the responsibility of Glasvezelnet Amsterdam (GNA), which is a company with many shareholders: 70% is owned by a joint venture between Reggefiber and KPN, while the other 30% is in the hands of the city of Amsterdam and the major housing organizations. The operations of the passive infrastructure are outsourced through a tender procedure, which is always limited in time.

Currently, there are two network providers responsible for the active equipment: the incumbent KPN, which also delivers its own services, and the original tender winner: BBned.

On the service layer, we find competition. Apart from the service offered by KPN, three other main service providers compete for customers: InterNLNet, Alice and ConceptsICT. More information about their current offer can be found in D6.2 [54].

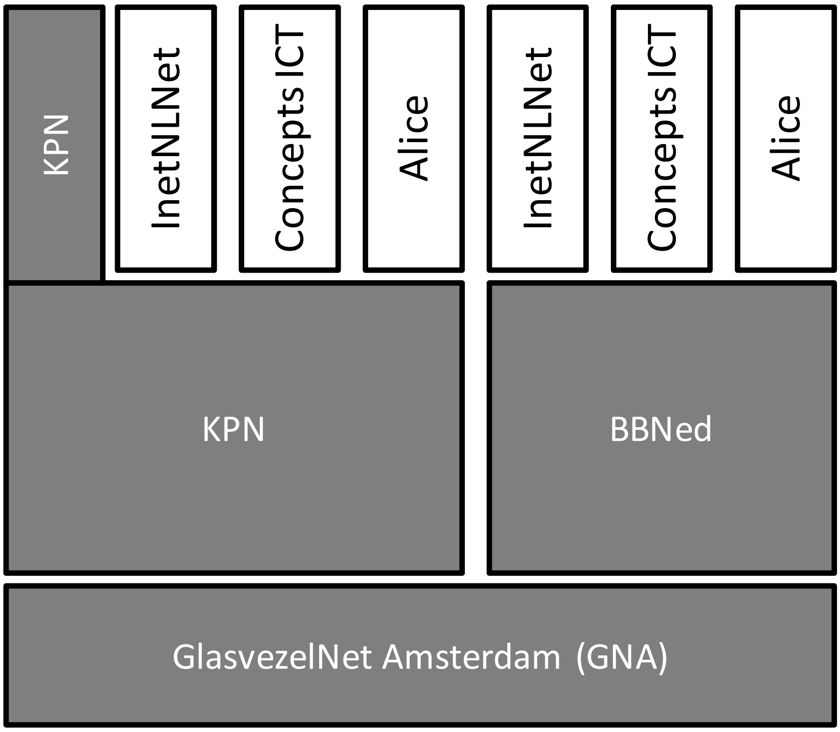


Figure 107: The different companies active on the FTTH network in Amsterdam

A4.2. Division of roles

Figure 108 and Figure 109 below give a more detailed representation of the actor's responsibilities. First, a mapping of the actors on the different phases versus the network layers is given (Figure 108), which stresses the responsibilities of the network provider on the operations of both active and passive infrastructure. It needs to be indicated that we have chosen here to put BBned's name on this operational responsibility, but, as mentioned before, this role is granted to a certain actor based on a tender procedure which is limited in time. The second Figure, Figure 109, represents an analogous mapping, but focuses on the seven Physical Connection Points (PCPs), which were described earlier in D6.1 [57].

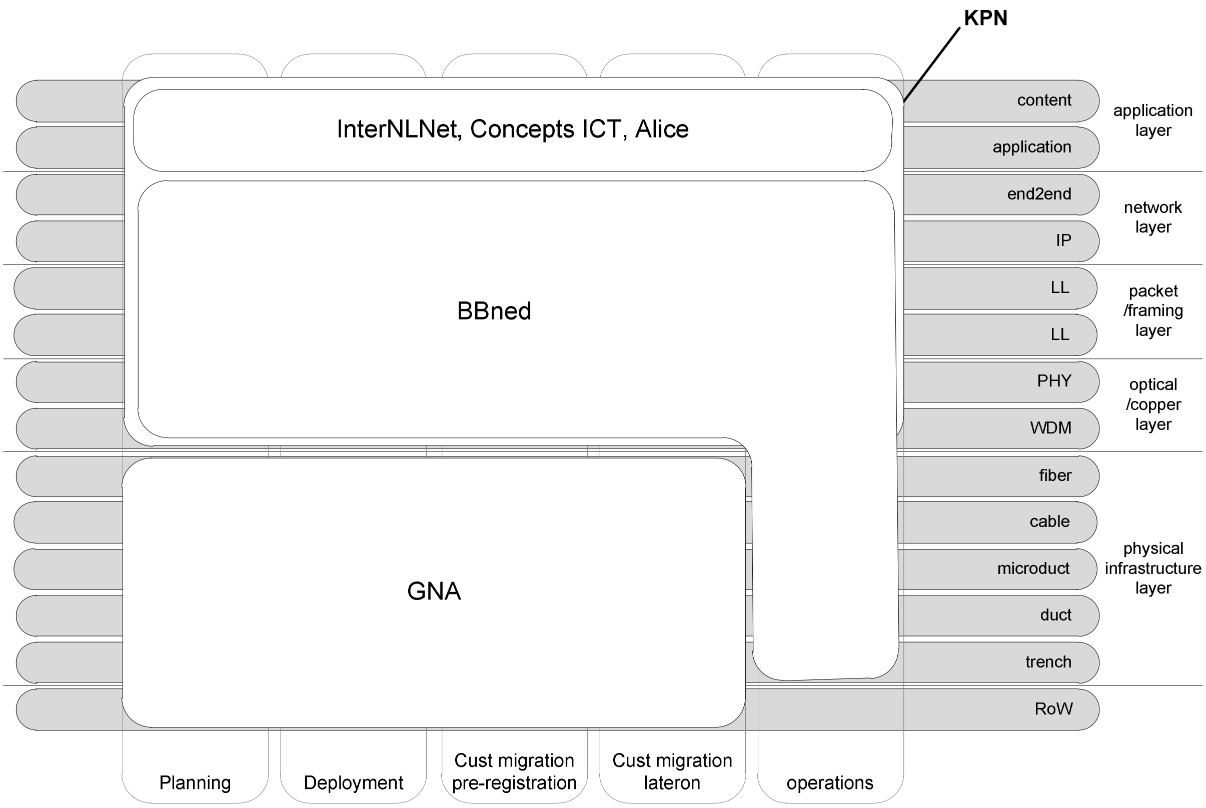


Figure 108: Division of roles based on network lifecycle phases (Amsterdam case)

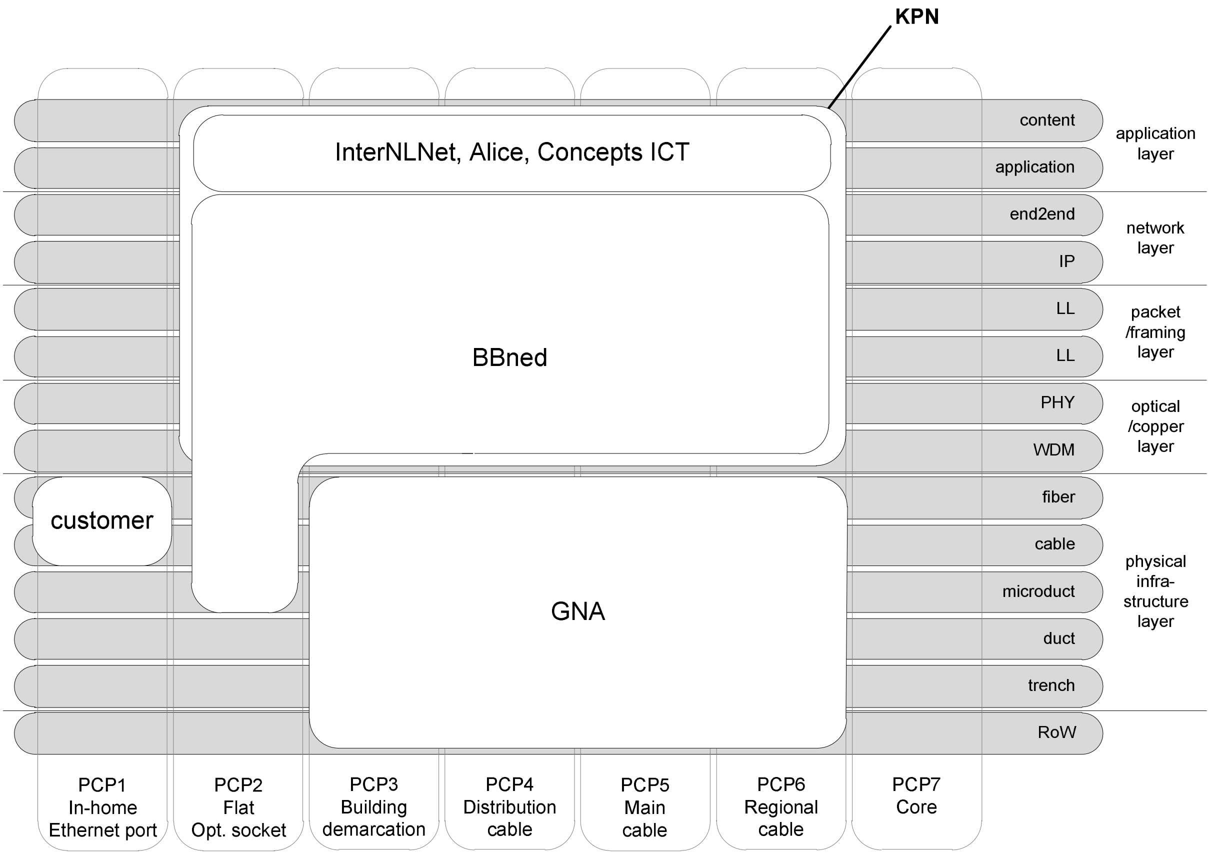


Figure 109: Division of roles based on Physical Connection Points (case Amsterdam)

A4.3. Revenue models

The revenue flows within the FTTH network of Amsterdam are quite similar to that of Stockholm. Revenues originate from the end-customer and find their way to the PIP, passing by Service and Network Provider. Interesting here is that KPN acts both as SP and NP at the same time, so there is only one intermediate "stop" in between end-customer and PIP. On Stokab's network, there were also companies acting both as NP and SP, so a similar reasoning can be followed there.

The fees paid by the end-customer range from around €30 to €100 per month, depending on the bandwidth you get (see section 4.5 of D6.2 [54] for more details). Details about the revenue flows to the NP and PIP are however much harder to find.

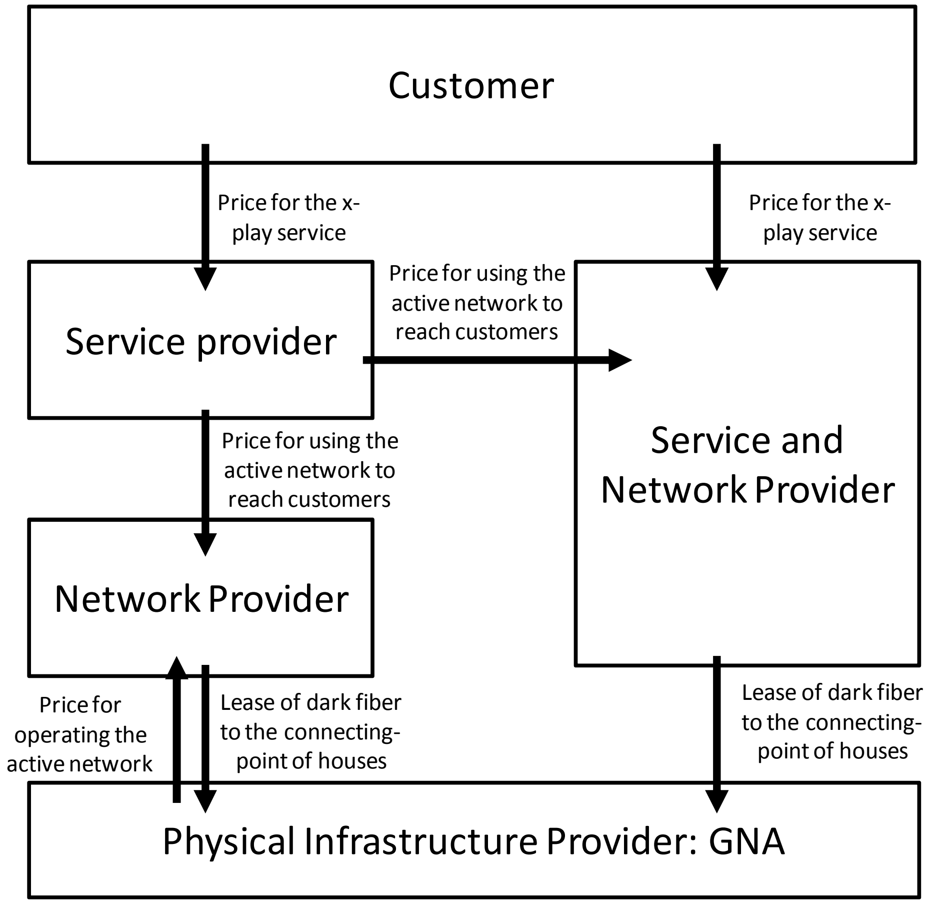


Figure 110: Revenue streams for the Amsterdam case

A5.Säffle

The Säffle Municipality (Säffle Kommun) is a municipality in Värmland County in west/central Sweden. Its seat is located in the town of Säffle. The municipality covers a peninsula in Lake Vänern (Värmlandsnäs), and has a large fresh water archipelago. Its geographical and demographical characteristics are summarized in Table 39.

Table 39: Geographical and demographical characteristics of Säffle

Municipality	Population	15,600 inhabitants
	Land area	1,221 km^2
	Density	6.2 inhabitants/km^2
Säffle town	Population	9,156 inhabitants

In the town of Säffle itself, the economy is largely based on industry. Säffle has continued to grow as the pulpwood industry has expanded in Sweden. The pulp mill in Säffle has been a major driver of the local economy.

In the rest of the municipality farming is important. The Värmlandsnäs peninsula is very significant to the economy by the produce of pork. The area supplies more than 200,000 people with pork. The archipelago off the peninsula (which also has old rune stones and other ancient monuments) is a touristic attraction.

The territory is largely rural with smaller localities of few hundred inhabitants each. Two thirds of the population are however concentrated in the main town, so the fibre deployment is of three very different characters: urban in town, covering the largest portion of the population, “sub-urban” in the villages, and sparse rural in the largest part of the territory.

In its broadband strategy, the Säffle municipality believes that every household should have access to a high-speed network. Due to the lack of commercial operators ready to invest in broadband in the municipality, it decided to start a fibre deployment project through a municipality-owned company called Säkom. All investments have been made on commercial terms, and have received financing partly by EU structural funds, partly through commercial loans.

The work started in rural areas because that was where broadband was lagging. Säkom has built a 930 km long fibre-optic network that connects 92% of households and businesses in rural Säffle. This 930 km networks consists of 50% backbone, 50% distribution network, 92% connection (100% within a few hundred meters), connecting from 30 to 50 households each year. The project in rural areas is now complete (2300 homes connected of 2500 possible) and Säkom moved to the expansion of urban areas in Säffle, with 1227 apartments, which will shortly replace cable TV with TV over fibre. All types of property (apartment buildings, villas and other properties) are offered connection to the Säffle fibre network.

A5.1. Overall Business model

Säkom operates a “pure” open access business model (variant (c) in Figure 94). The NP role is taken up by Telia (agreement autumn 2009), and although initial pledges were made that Telia would not be allowed to sell services, difficulties in guaranteeing enough SPs (the agreement stated at least 5 SP and 3 TV providers) made so that Telia is now allowed to offer their customers services for Internet, telephony and television (Figure 111).

Säkom is a small organisation, of which the CEO likes to define a group of "qualified purchasers". Säkom needs to be financially independent in the long term, but should not generate profits.

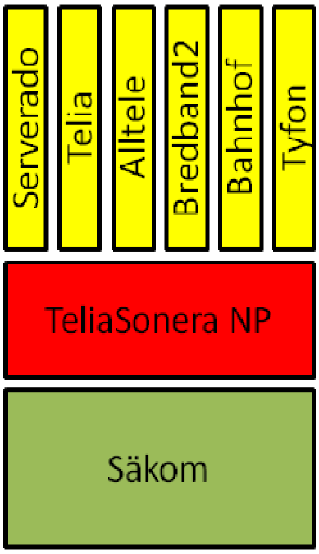


Figure 111: The different companies active on the FTTH network in Säffle

A5.2. Division of roles

The figures below detail the mapping of the different actors involved on both the network layer versus network lifecycle phase matrix, as well as on the network layer versus physical connection point (PCP) layer. The division in between SP-NP-PIP as described in the beginning of this chapter, is clearly visible here.

Telia was awarded the NP contract and initially was not allowed to sell services. The reason for this was that if Telia had been there in the beginning to sell services, other SP would have found it hard to establish themselves, but it was not very popular with all citizens. This ban was then later removed, once other SP had the time to become established, and Telia is not considered dominant anymore. Moreover, meanwhile Telia changed their overall business model with the introduction of Telia Open Fiber.

The separation of the PIP and NP role makes the business case viable for operators to come and provide connectivity and service provision, because the long-term investment for the infrastructure deployment is no longer weighing on them, which typically have a return horizon of five to ten years or less. On the other hand, the municipality can rely on a longer term return on investment and take over the infrastructure capital investment, while avoiding meddling in technical issues on which it does not have competence. Moreover, the bid of the NP contract goes to a national operator, which can rely on significant economy of scale, bringing down the operating cost of the network.

The business case for service providers is enhanced by the existence of infrastructure *and* connectivity, so they can focus on efficient service provisioning (with cost reduction coming from know-how and economies of scale due to their national or sometimes international scale), customer care, marketing and product development. Efficient service provisioning is especially important for Internet service (increasingly seen as a commodity), where price and reliability are the major selling points, whereas for TV product offering is an important differentiating factor.

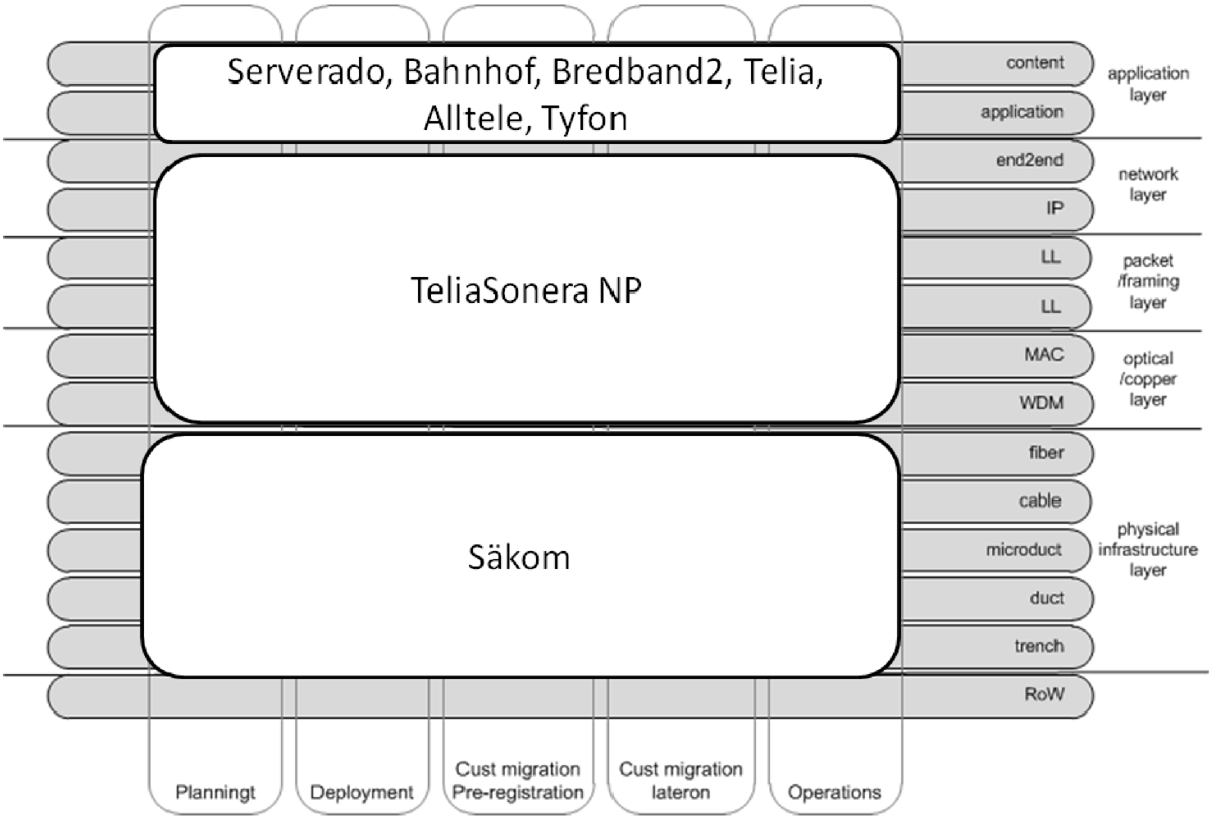


Figure 112: Division of roles based on network lifecycle phases (Säffle case)

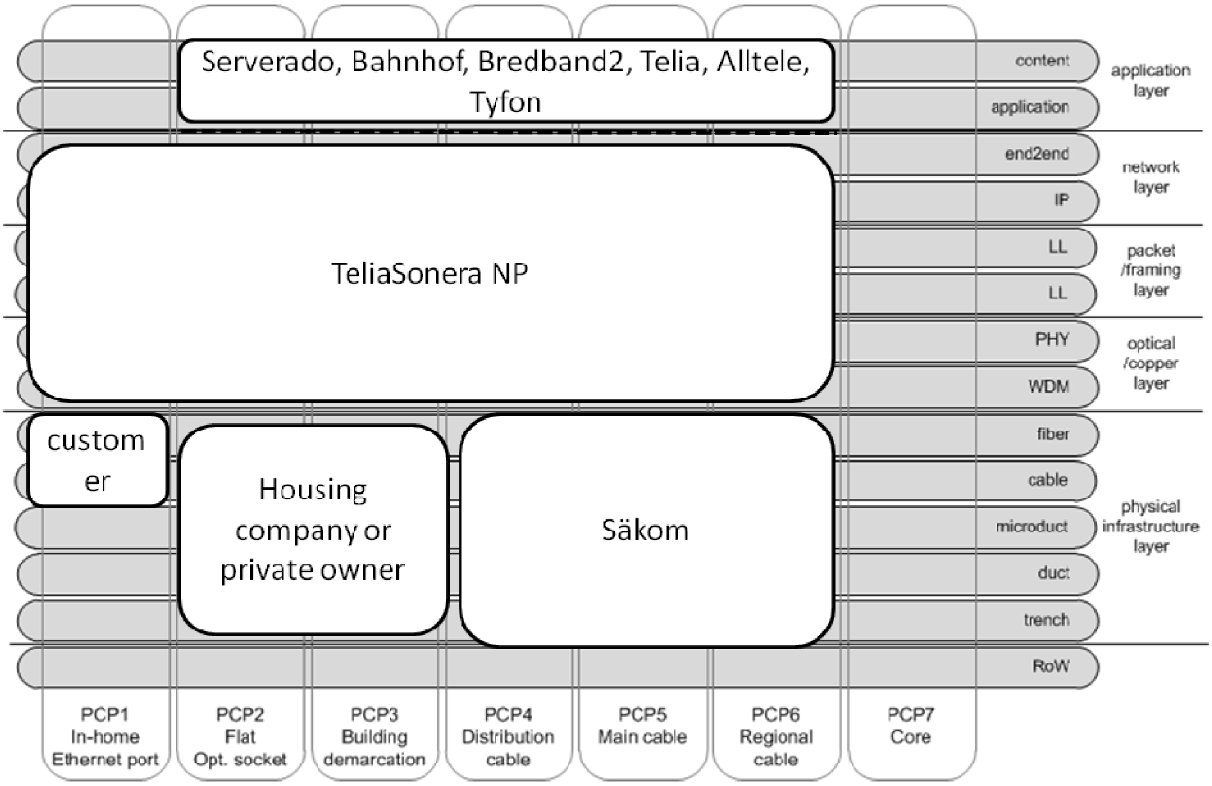


Figure 113: Division of roles based on Physical Connection Points (case Säffle)

A5.3. Revenue model

The digging cost is 4.5 €/m on average (varying between €2 to €11 in the rural area, and around €35 in town), around €8 to €10 per metre if connections costs are included.

Housing cooperatives and housing companies pay €2,200 to connect to the fibre network, while the in-building network is their own prerogative (and have to finance that by themselves). Private property owners do not see a real motivation to do that (they see the cost, around €400 to €500 per apartment, but they do not really get the concrete benefit), so that is for the moment not really picking up that fast there.

Housing companies on the other hand are now 100% FTTH connected (and of these, after six months 100% subscribe to IP-TV, and around 15% to internet). One effect of the housing companies having fibre cabled their dwelling units is that more young people moving in, and that there are now no empty apartments, which was the case before). An agreement was reached thereby housing companies pay €11 per month per apartment and the tenant pays €2 to Säkom for 15 years.

When it comes to other revenue streams than the retail sector, Säkom is offering dark fibre rental. Among current clients are "Net for Mobility" (dark fibre rental for ten years), the municipality, the Swedish Church. Business that have expressed interest for dark fibre we find the ICA food chain, TDC, and others. Capacity is not really demanded, especially since there is so much fibre installed (96 fibres in the backbone network, 24 to the nodes).

Currently per-kilometre pricing is followed, but other models like price per connection, or specific price for specific fibre spans (some are more popular than others) are being considered. Large firms are currently connected to copper 100 Mb/s, and they are generally bound by long-term contracts. When these run out, they are likely to migrate to fibre.

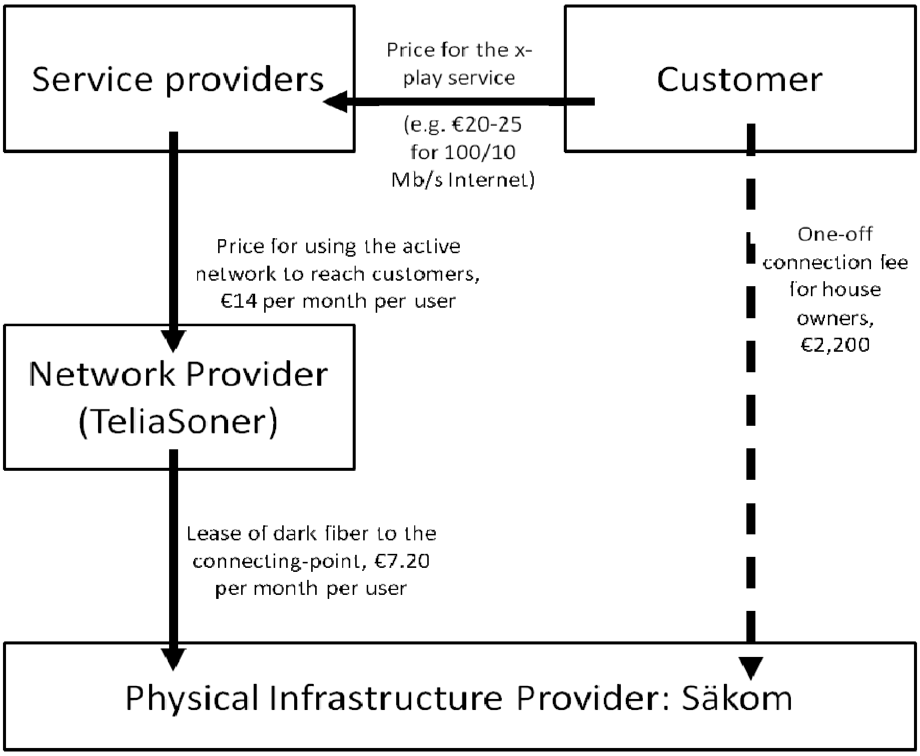


Figure 114: Revenue streams for the Säffle case

The services currently offered over the network are the following:

- Internet service (five providers present), at price of €20-30 for symmetrical 10 Mb/s, and €25-35 for 100 Mb/s downstream and 10 Mb/s upstream. Symmetrical 100 Mb/s is also offered but at rather high price (above €50).
- TV is provided by three SP: Alltele, Telia and the open platform Severado; the base

package is offered free of charge (the national broadcaster's four must-carry channel, plus three other channels), other channel packages can be bought on the Telia or Severado portals. A service separator is needed and provided free of charge by the NP. In the case of Telia, a set-top box is loaned, while for Severado the open set-top box must be purchased for €150. A degree of complexity (service separator, set-top box, internet, NP, SP, etc) means the solution can sometimes be perceived as challenging.

- Telephony, two providers (Alltele and Telia), the cheaper one for €4 per month for a basic plan, or €15 for flat plan.

A5.4. Examples of socio-economic impact of fibre

One positive effect that is being observed already is the creation of a new industry related to the fibre network installation in the municipality: fibre installers (now building other networks), maintenance activities which are local, on contract from the national NP and SPs.

Another welcome effect is that businesses can expand within the municipality now and are not threatened to move. Interestingly, also, some companies were able to move from the urban areas in order to save on rents.

A5.5. Successes and challenges and future directions

Säkom was started in 2007 and is still showing red numbers, but the ambition is to reach breakeven in 2016. Information towards the population is seen as very important to generate support for deployment and increased take up.

In the countryside power goes down now and then, so that may give problems because the nurse alarm for elderly and reduced mobility citizens (*trigghetslarm*) needs to be active at all times, so providing e-health services over fibre has to take these practical problems into account.

Säkom is satisfied with Telia as NP. There is however an issue with the interface interworking with SP using different equipment, and it is indeed the case that NP equipment works better with Telia's services (according to the authors, this shows in a neat way why NP and SP roles should be taken up by independent entities in order to guarantee fair and non discriminatory conditions for all SP). According to Säkom's CEO, it would be good to have a standard for open networks to NP uses Open Access equipment, but she thinks it is going to be hard.

A6. Impact of regional differences on the business case

In this final paragraph of this appendix, we will compare the results of the case studies with the outcome of the model as developed in OASE. In order to cope with the regional differences in between the three countries under study (the Netherlands, Sweden and Germany), we use different input values for those parameters that are influenced by the economic and cultural differences in between countries, which are summarized in Table 40. For an overview of used references, we refer to section 8.2 of D5.3 [61].

Table 40: overview of the values for the regional varying parameters

	the Netherlands	Sweden	Germany	TONIC
energy indoor (€/kWy)	1402.50	1297.50	1795.50	2700.00
energy outdoor (€/kWy)	1662.50	1537.50	2127.50	3200.00
energy ONT (€/kWy)	1935.50	1839.00	2227.50	1925.00
floor space (€/m^2*y)	123.50	123.50	123.50	166.50
labour costs (€/h)	50.50	54.00	43.50	45.00
final BB penetration (% of people)	84.70	66.57	64.00	74.02

When comparing the input data, we see the energy costs in TONIC are typically higher than the regional data found in our case study countries, while the labour costs are mostly lower. For the final BB penetration (i.e. take-up in year 2030), TONIC provides an average. We can now adjust the TONIC model to cope with these new input values for the different case study countries, and verify if the needed revenues that result from our calculations reflect the real-life values better once these ranges are taken into account.

A6.1. Evaluation for a vertically integrated operator

We will first take a look at the business case for a vertically integrated operator, i.e. an operator taking up both NP and PIP responsibilities. Figure 115 shows the monthly revenue per customer that is needed by the vertically integrated operator to recoup its investment costs in a 20-year timeframe, for different levels of demand aggregation. The results are averaged out over all areas (dense urban – urban – rural), different levels of duct reuse, different node consolidation scenarios and different architectures. It is clear that the impact of start penetration is huge: starting from a 30% subscription rate reduces the needed monthly revenue in all cases with over 50% vis-à-vis the 0% case! This graph therefore justifies the strategy followed by Reggefiber [13]. A second important conclusion that can be drawn from this graph, is that the impact of start penetration is higher for Germany and Sweden than for the Netherlands, and that the overall needed revenue for the Netherlands is lower. The main explaining factor is the final broadband penetration, which is significantly higher estimated in the Netherlands.

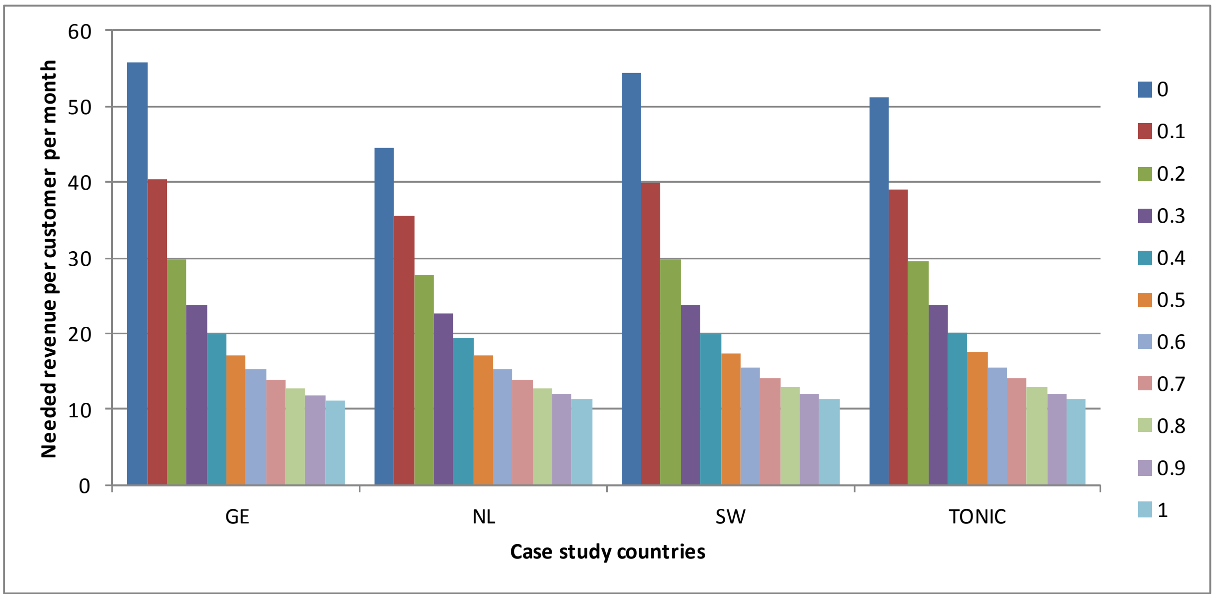


Figure 115: Needed revenue per customer per month for the three country case studies, to recoup the initial investment in a period of 20 years for a vertically integrated operator, for different levels of demand aggregation (ranging from 0 to 100%)

When comparing the needed revenues calculated here to the average revenues that resulted from the different countries (see Table 41), we see that they are in the same range. The revenues from Table 41 are slightly higher, but include a fee for offering services, while the costs for services was not taken into account in the TONIC model.

Table 41: Average revenue for low-end double play and high end multi-play [54]

Country	Average Revenue low-end (€)	Average revenue high-end (€)
The Netherlands	26.09	68.42
Sweden	21.38	60.33
Germany	27.04	42.42

A6.2. Evaluation for the Network Provider

Secondly, we will evaluate the business case for the Network Provider (NP) only. We take the CapEx, OpEx and service provisioning, but include also all CPE costs (including in-house cabling and ONT costs). Figure 116 visualizes the needed revenue per customer per month for different timeframes. For this analysis, we used the reference case for WP6: Greenfield deployment (so no duct reuse), no node consolidation (so the 7500 scenario). We did we average out for area and architecture. It is clear that, apart from the impact of demand aggregation as shown in the previous paragraph, the impact of the timeframe for analysis also is very important.

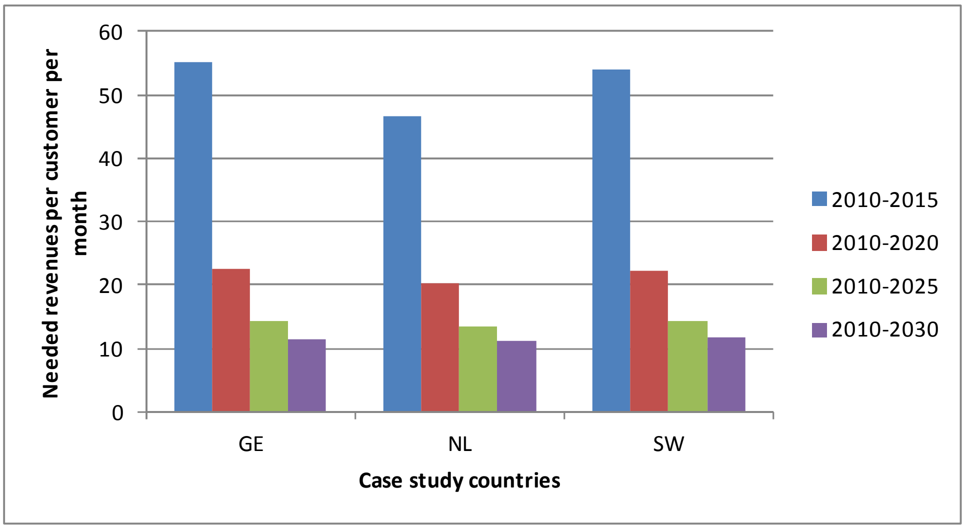


Figure 116: Needed revenue per customer per month to recoup the NP investment on different timeframes

The sharp shift in needed revenue when considering a longer planning horizon can be explained by the high impact of the upfront CPE costs, which are divided over a higher number of customers if the planning horizon is longer. Here, the higher final broadband penetration for the Netherlands (and thus higher percentage of customers in each year) helps to reduce the needed revenues per customer from the start. The decrease in needed revenues is however larger for Sweden and Germany, which can be explained by the lower energy (for Sweden) and labour (for Germany) costs. These costs will only become important in the longer run, as they are administered when needed: labour costs will, in the NP case at least, be most used when customers need to be connected, while energy costs are typical operational expenditures.

A6.3. Evaluation for the Physical Infrastructure Provider

Finally, we shortly look into the business case for the Physical Infrastructure Provider (PIP). As the analysis of section 4.3 showed is there a significant impact of the area (dense uran, urban or rural) on the needed revenues per customer. Figure 117 shows the needed revenue per customer and per month to recoup the PIP investment over a time period of 20 years (2010-2030). The graph was built under the assumptions of a no node consolidation, Greenfield scenario, where the impact of start penetration (ranging from 0-100%) and architecture (AON versus PON) was averaged out.

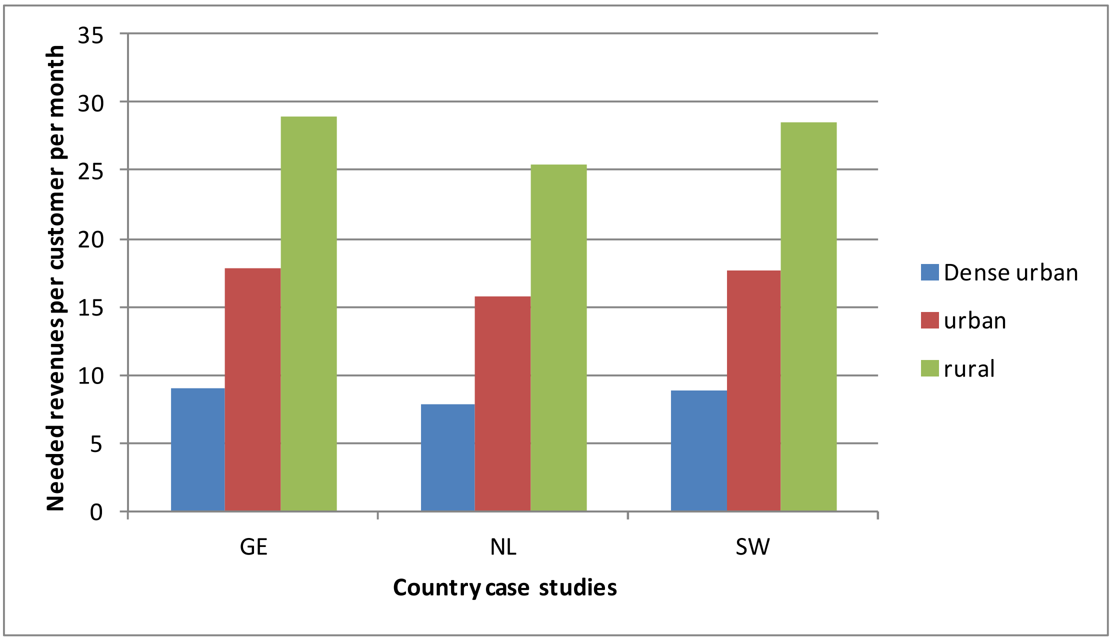


Figure 117: Needed revenue per customer per month to recoup the PIP investment for different areas

This figure is interesting when being compared to the actual case study scenarios, because those were analysed for a specific region in a country, rather than for the country as a whole.

For the case study of the FTTH deployment by Stokab in Stockholm, we can agree that the results obtained here match closely to the actual revenues charged for the use of the passive infrastructure (being €5-7 per customer per month for the inner city), see also section A1. The values obtained here are slightly higher, but it is likely to assume that Stokab, being a publicly owned company, can justify with longer return on investment (ROI) periods than the 20 years we worked with here.

For the case study of Amsterdam, we use the revenues as charged by Reggefiber. These revenues are variable per area type, and therefore reflect the difference in cost better. In section 4.3.1.6, we already evaluated the business case for these revenues, and noticed that it never reached a positive NPV. However, this doesn't mean that our model doesn't hold. We can again use the argument of using a longer ROI period (we didn't find the period Reggefiber or OPTA assumed for their calculations), and we didn't take demand aggregation into account in section 4.3.1.6. When we do take into account some level of demand aggregation (being here averaged out between 0 and 100%), we see the needed revenues drop significantly, and see that they are in the same range as the revenues charged by Reggefiber (see also Table 13).

For the case of Norderstedt/Hamburg, the comparison is more difficult, because the operator wilhem tel is not a PIP only. We can compare the here calculated revenues with the subscription fee (flat fee) the operator charges for the 'telefonanschluss', the minimum connection required before being able to receive access to services. This fee is set at €12.30 per month (see also [90]), which is slightly lower than our values (around €17).

For the case of Säffle, which truly is a rural area, the comparison is also not easily made. Although the revenues charged for the physical infrastructure are known, they are not only charged in monthly fees (€7.20 per month), but also include a one-off connection fee of about €2200. Assuming a ROI period of 20 years, our calculations would generate a total (non-discounted) revenue of around €6500, while the calculating the revenues according to the case study leads to €2200+7.20*12*20 = €4000, which still is a significant difference. This could again be explained by a possible longer ROI period, but this we cannot state with certainty.

Finally, the case for M-net included no revenues for the PIP case, so we refrain from making statements about the comparison of our model.

A6.4. Conclusion

This section compared the results of the TONIC model to real-life data for different countries and specific case studies. In general, we can conclude that the overall needed revenue that results from our calculations matches with the revenues found for the different countries. Where possible, we also compared the specific regional results (for our generic dense urban, urban and rural area definitions) with the real-life revenues that are being charged in the studied cases, and concluded that, at least for the PIP, the revenues are of the same order of magnitude.

Furthermore, we proved the significant impact of performing demand aggregation and can therefore agree with the strategy performed by Reggefiber (that only starts deployment after a certain take-up rate is ensured).

Finally, we confirmed the importance of different parameters, like the estimated final broadband penetration, the energy and labour costs, etc. on the evaluation of the business case for different countries. We can therefore only stress the importance of a good estimation of all the input parameters, and the dependence of every techno-economic model on them.

B. Market modelling module

The market modelling module aims at calculating the market shares of different players, based on their strategy. Price, or quality-corrected price, is the typical strategy on which market division can be based. However, not only the market division is influenced by price, the total market size is also driven by this factor. In economy, price elasticity is used to indicate this effect. It gives an indication of how the total demand varies in function of price changes.

The calculator present in this module allows estimating the elasticity based on different factors. For example, the price that impacts the total demand could differ. For some products or services, it is possible that an increase of the highest price on the market has a positive effect on the total demand (in case of Veblen or Giffen goods). This is typically the case for luxury products, where the prestige linked with the product rises with the price and thus increases demand (Veblen). Otherwise, it can also occur for common products. A rising price for bread results in a higher demand, since lower income groups notice a large effect of this price on their income, so they start substituting other more expensive food with bread.

However, in general it is the average price level or the lowest price on the market that drives the demand. The price drop for computers, cars or plain tickets has had a positive effect on demand. An example of how a decrease in prices influences the total market is shown in Figure 118.

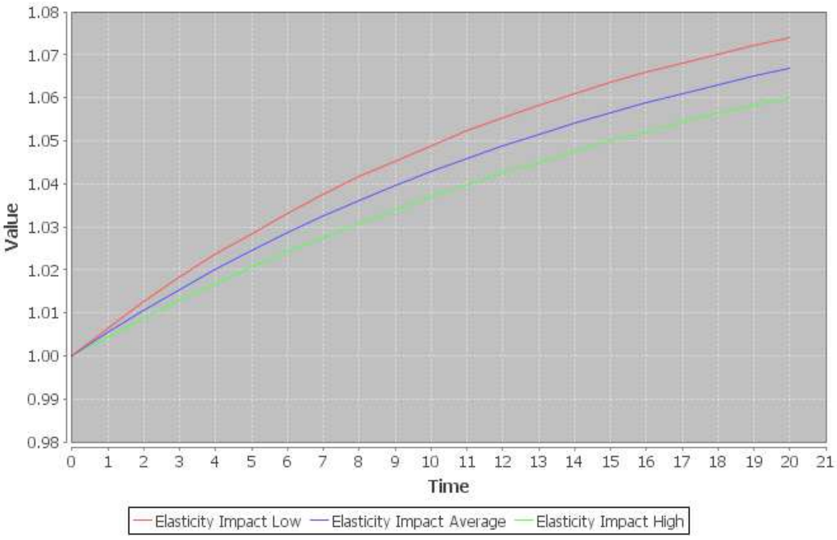


Figure 118: Impact of two decreasing prices on demand

The elasticity concept as described above has an impact on the total market. This object is also available within the market module, and it allows defining a market based on a minimal, maximal and expected market potential, together with elasticity. When strategies are defined for the market, a corrected yearly market potential is estimated based on the elasticity.

With the total market estimated, it has to be divided between the different actors active on the market. Before estimating the total market share of each actor, it has to be decided which part of the market is available to be divided between the different actors. The introduction of a new product or service will not immediately change the entire market distribution, since only a percentage of all customers can change between offers. A subscription can only be stopped after x months or lock-in of customers all have the effect that some customers cannot switch between offers. Only a part of the market can redistribute between offers, the so-called free market. This free market constitutes of the customers who consider switching, but also the new market that became available in that period, e.g. due to adoption increase. In Figure 119, only 10% of the total market is available to churn each period.

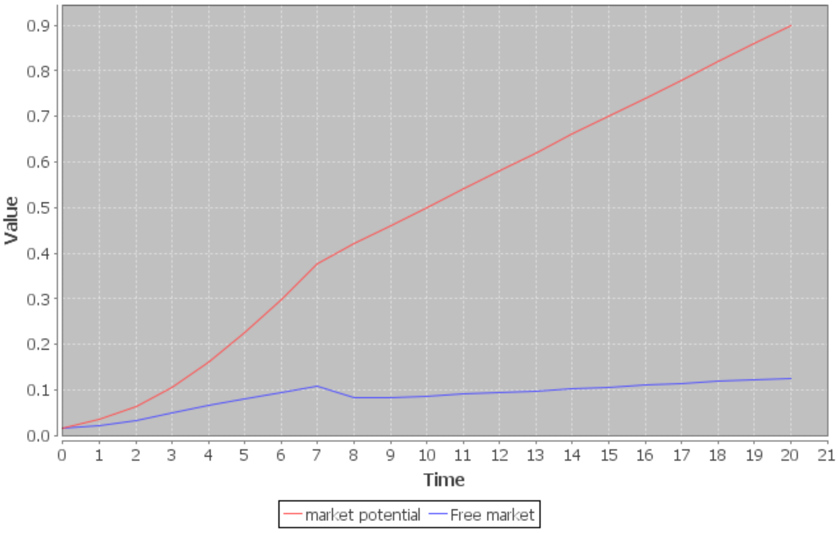


Figure 119: Determining the free market

It is this free market that can be divided between the different players. Based on the strategy of each player, a distribution parameter is calculated. Different models exist to determine these parameters. As was already indicated in the introduction, price difference might influence the distribution of customers. The lowest offer captures the largest part of the free market, but other offers till have some adoption. With the price difference between different offers increasing, the cheapest offer captures increasingly more of the free market. This is typically referred to as cross-elasticity. Other models exist, where the offer with the best price or quality captures all of the free market, a Winner-Takes-All model. An example of each distribution model can be found in Figure 120 and Figure 121.

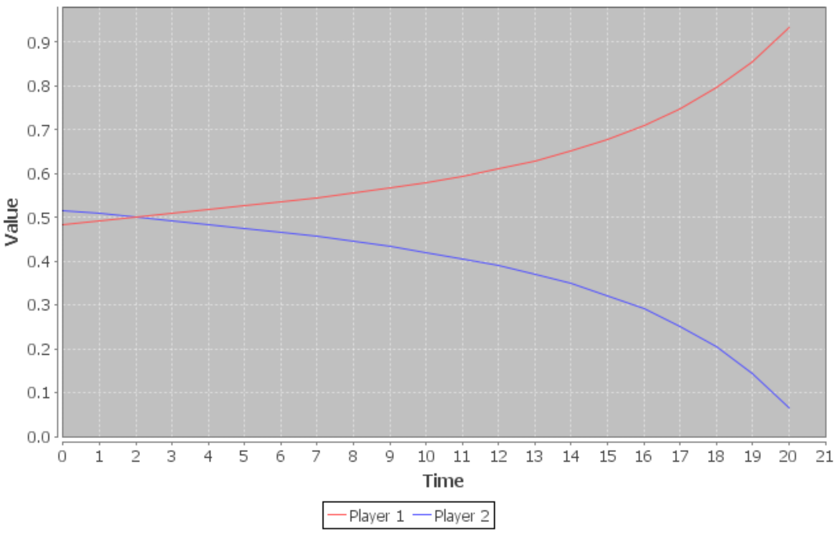


Figure 120: Distribution based on churn

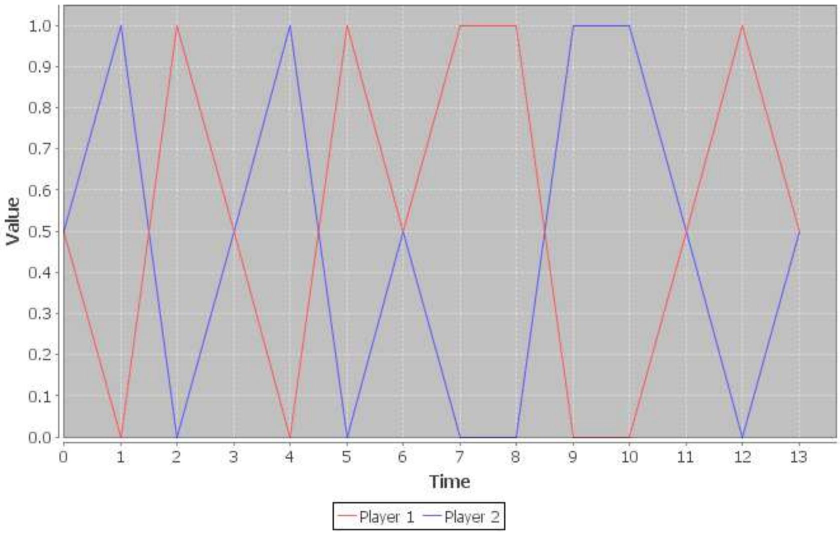


Figure 121: Distribution based on Winner-Takes-All

Combining these four aspects, Elasticity, Market, Free Market and Market Division allows to model the market shares of all players in the market Figure 122. It should be noted that the module can work with initial market shares, where the market evolution is determined from a given starting position.

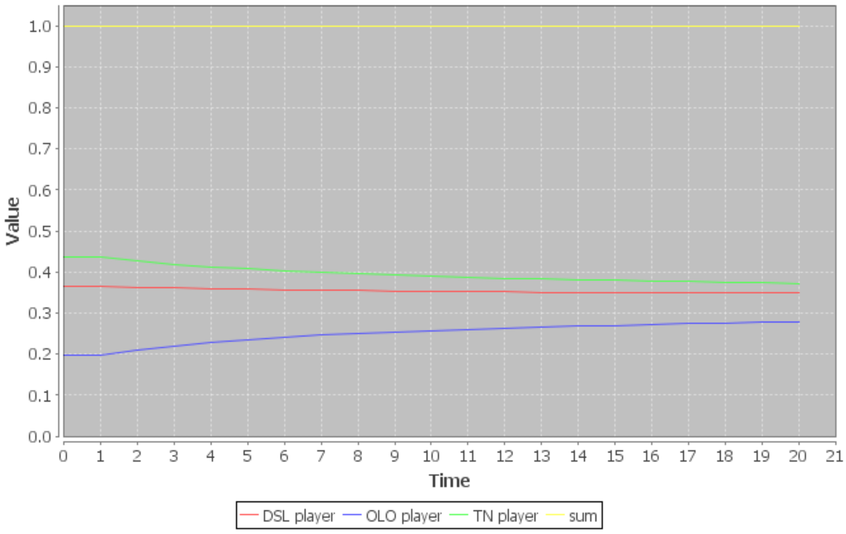
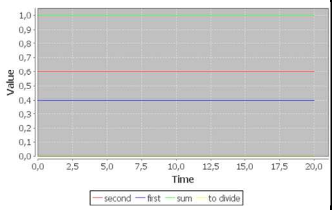
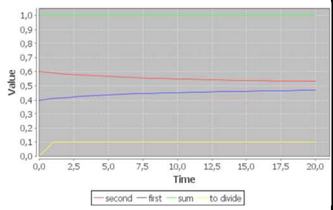
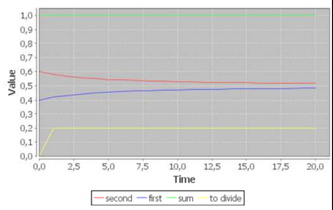
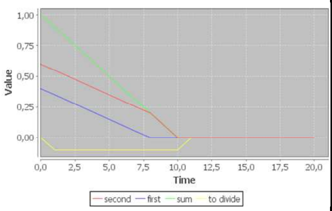
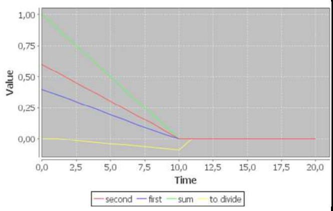
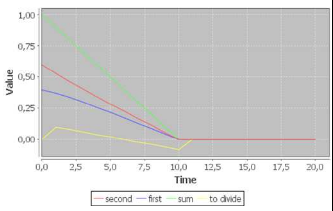
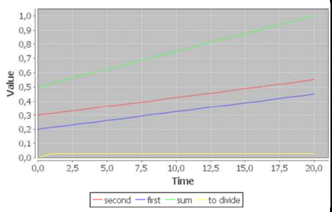
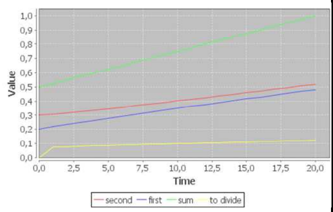
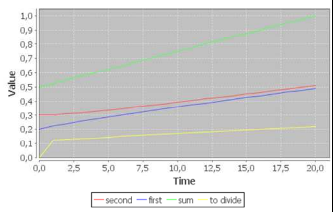


Figure 122: Estimating the adoption per player

Some more stylized examples of the usage of the market model can be found below. Note that these are not realistic values as they typically go out of reach of typical elasticity and inter product price discrimination factor. These examples are only intended to see the influence of changing one parameter at a time and how this will change the market shares of 2 different players. Throughout the remainder of the example is built around two offers which can have the same price – taking out the inter product price discrimination factor influence. The second subsection shows stylized examples when the two offers have a different pricing but where one offer stays constant and the lowest priced offer – taking out the broadband elasticity influence.

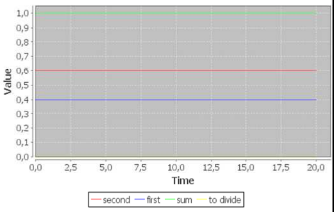
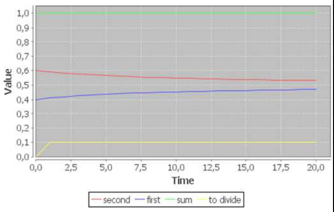
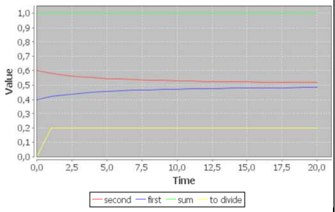
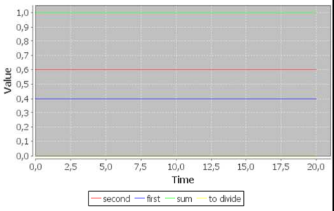
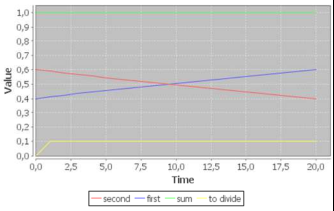
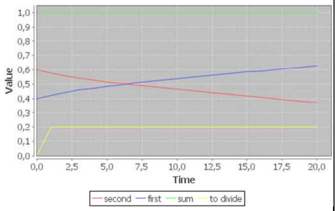
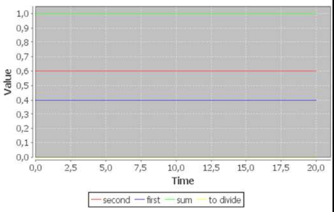
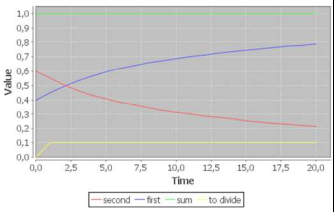
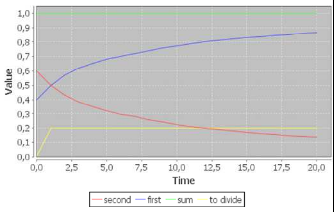
2 offers with the same price

	No Yearly Churn	*10% yearly churn*	20% yearly churn
constant equal prices			
Increasing equal prices, full elasticity			
decreasing equal prices, full elasticity			

When two offers have the same price, the market shares will remain the same even when the churn is high and the market is growing or shrinking. In the case the initial market is (unjustly) not evenly divided, the market shares will grow to each other with a speed depending on the churn. This is shown in the figures below. All examples start from an initial market split of 40%/60%. We left out the cross-elasticity as this will have no influence when prices are equal in each year and the distribution between the two offers is 50%/50%. In the cases of increasing/decreasing prices, full elasticity is considered, leading to an increase or depletion of the customer base. Finally in the case of decreasing prices, the initial market potential is only set at 50% of the total theoretical 100% market potential leading to an increase in market potential with gradually decreasing prices.

2 offers with different price

When the pricing of both offers is not the same, the lower price offer will gain a larger share with the extra gain depending on the difference in price and the cross elasticity between the different offers. Additionally the larger the churn the more customers will be divided between the different offers per year and the higher the influence of the move of customers to the lowest priced offer. The following table gives an overview of offers with different prices in which the pricing of the first is constant and the pricing of the second is increasing. This means that the influence of normal elasticity is non-existing.

	No Yearly Churn	*10% yearly churn*	20% yearly churn
No cross elasticity			
Low cross-elasticity			
High cross-elasticity			

C. Potential value range of discount rate for PIP

The valuation of the PIP project was set on a fixed discount rate (5%) without any analysis of the parameter as such. The discussion about the important input parameters and the potential range of values for the discount rate based on the weighted average cost of capital (WACC) can be found in the following. An analysis of the impact of the WACC range is given in section 4.3.4.

Before the evaluation of the WACC formula and its parameters is assumed, the business case under analysis must be more precise. It should be noted that the discussion about business cases of about a twenty-forty year time frame is rather difficult for "normal" companies. Nonetheless, the analysis here takes always this time frame into account and assumes that a company is willing to go for such projects / funding of new companies.

First of all, there is a need for understanding the relationship to the parent company. If the company is founded as a separate legal entity with no affiliation (beside ownership limited liability), it has to organise its financial aspects by its own. This could result in a lower level of negotiation power, especially in financial aspects. In contrast, if the PIP is organised as an integrated entity in the parent company, it has to comply with all parent company obligations like fulfilling cost of equity.

Second, the situation of negotiation power for equity and debt must be taken into account. Here the parent company can give (a) equity to the newly founded PIP company, (b) provide no cash but an indirect effect on the level of cost of debt for negotiation (some debt negotiation power) or (c) a mixture of (a) and (b). Case (a) is reasonable for situations where the parent company's WACC is expected to be lower than cost of debt of the new company. The case (b) depends on the ownership or perception and the associated risk assessment by the lending company, but with the "name" of the parent company or a legal relationship in the background, it could be cheaper for the PIP company to lend money.

Third, it is important to acknowledge the potential players being the parent company for a new player. In D6.1 four roles are identified for taking the PIP role: Private and Public Municipal Infrastructure Provider, Municipal Network and Infrastructure Provider and Telecommunication Operator. The latter identifies an industry directly, where the others are a mixture of different industries. For the Private Municipal Infrastructure Provider, Reggefiber is mentioned as an example. Lately, Reggefiber was sold to KPN (which is in the group of Telecommunication Operators), but before it was owned by Reggeborgh Glasvezelinvesteringen BV, a subsidy of the investment and construction company Reggeborgh groep. The public companies could be owned by either a city or a utility company which is owned by a city. To conclude, the following industries should be taken into account in the analysis (and therefore their respective financial ambitions and situations):

- Public authorities like cities
- Telecommunication operators, excluding mobile
- Utility companies
- Investment and financial service companies

Fourth, the desired target of the project will play an important role for the analysis of appropriate financial parameters. For example, a telecommunication operator will potentially use the deployed network for his own services (NP + SP) and will not grant access rights without sufficient risk premium. Whether the regulator will be able to force openness or not is not important at all, but in any case a certain risk premium should be granted. Otherwise, an infrastructure project with an unclear level of risk will not be done in the future (or only riskless projects, but this could end up in higher digital divide and is excluded in this section).

Overall, it is not possible to calculate all scenarios. In contrast, the target is to analyse the most important input factor, its parameters space and to conclude on the overall business case.

One, potentially the most, important parameter in the evaluation of the projects is the WACC. The respective formula is given below.

$$WACC = r_D \times (1 - T_c) \times \frac{D}{V} + r_E \frac{E}{V}$$

The meaning of the different parameters is as follows:

- r_D is the company's cost of debt
- T_c is the company's marginal tax rate
- D is the company's debt
- V is the company's market value and calculate as $V = D + E$
- r_E os the company's cost of equity
- E is the company's equity

Going into detail of the parameters, it is difficult to find detailed and reliable values, especially statistical significant ones. Some indications are available and detailed in the paragraphs below.

Wikiwealth collaborative research analysis of industries uses a database of 3200 publicly listed companies from all over the world [89]. It calculates ten industry values using the largest 30 companies. Four different industry groups could be identified with a WACC varying between 6% and 13%.

Table 42: WACC parameters for various industries based on Wikiwealth [89]

Industry	Equity risk free rate	Equity risk premium	Required return of equity	Debt-equity ratio	Cost of debt	Debt required return of debt	$WACC$
Telecom industry	4%	5%	9%	6%	7%	5%	10%
Utility	4%	5%	7%	96%	7%	5%	6%
Energy	4%	5%	9%	22%	7%	4%	8%
Financial	4%	5%	9%	5%	7%	5%	13%

Another source is the database of Prof. Aswath Damodaran [21] (based on Value Line database with 5891 firms), which calculates values for the WACC. Unfortunately, they are available for companies from the US only. With respect to the scope of this project, one could argue that global companies are converging in terms of financial performance or are measured with a similar performance. Here a WACC could be observed with a level between 3.91% and 10.78%.

Table 43: WACC parameters for various industries based on Prof. Damodaran [21][24]

Industry	Cost of equity	Equity-market value ratio	Cost of debt	Marginal Tax Rate	Debt-market value ratio	$WACC$
Cable TV	10.15%	59.50%	3.37%	27.35%	40.50%	7.03%
Electric Util.	6.41%	53.72%	2.37%	31.82%	46.28%	4.19%

(Central)						
Electric Utility (East)	6.08%	60.18%	2.37%	33.14%	39.82%	4.29%
Electric Utility (West)	6.40%	54.19%	2.37%	31.30%	45.81%	4.21%
Public/Private Equity	15.01%	62.55%	3.87%	3.79%	37.45%	10.78%
Telecom. Services	7.78%	74.58%	3.87%	14.22%	25.42%	6.65%
Utility (Foreign)	7.68%	39.21%	2.87%	26.07%	60.79%	4.30%
Water Utility	5.85%	55.12%	2.37%	35.22%	44.88%	3.91%

Assuming that a company is fully owned or backed by governmental organisations, one could argue that the cost of capital is the same as for the governmental organisation itself. Therefore one could simplify the formula for the WACC down to the cost of debt without any tax related part. For reference the governmental bond rates with a maturity of close to ten years are presented below [24], other information for bond, e.g. with maturity in 20 years, was not available at a comparable level. One can see that the levels of costs for debt vary significantly between 1.29% and 17.96%. In the light of the current economic or debt crisis, the levels reflect to some extent the current situation in the different countries.

Table 44: Interest rates for government issued bonds with 10 year duration [21][24]

Euro area	Oct 12	Non-euro area	Oct 12
Belgium	2.44%	Bulgaria	3.39%
Germany	1.47%	Czech Republic	2.24%
Estonia	-	Denmark	1.29%
Ireland	4.77%	Latvia	3.52%
Greece	17.96%	Lithuania	4.32%
Spain	5.64%	Hungary	6.94%
France	2.19%	Poland	4.57%
Italy	4.95%	Romania	6.85%
Cyprus	7.00%	Sweden	1.54%
Luxembourg	1.62%	United Kingdom	1.54%
Malta	3.99%		
Netherlands	1.77%		
Austria	2.02%		
Portugal	8.17%		
Slovenia	5.74%		
Slovakia	4.20%		
Finland	1.78%		

Some critical remarks have to be noted. First, the presented data reflect companies with a business scope much broader than the discussions in this document. A number of parameters in the calculation vary among the companies significantly (e.g. level of debt, cost of refinancing, etc.). In addition numerous parameters depend on other parameters and company strategies as well like dividend policy, negotiation power with lenders, and concrete situation of lender. Second, the key assumption of using the governmental bond yield for publicly financed projects does reflect the concrete project only in the case that the government will provide the financing of the FTTH project. Otherwise e.g. a federal state, a city or even a village is project leader; the financing costs depend on the same parameters and situation dependent parameters as a company. In addition, the government bonds are based on a ten year maturity, but FTTH infrastructure part requires even longer investment time frames (20 years or more) which will be reflected by higher yield rates. Unfortunately, this information was not available and is open for future analysis. For companies a similar discussion on risk is valid. Third, the financial details vary over time, too. For example, the long-term interest rates of Ireland decreased from 8.10% to 4.77% in a one year time frame. Another issue on the analysis of the risk is the argument that the investment into infrastructure (like FTTH infrastructure layer) has only limited risk. Again, this is case sensitive and needs to be investigated in detail for a concrete project. Based on the analysis before, the WACC was varied from between 0% to 15%. The result based on the complete cost including CPE is shown in section 4.3.4.

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