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Fiber to the Home with an Emphasis on Greenfield Developments

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Problem Description

In this assignment shall FTTH in greenfield developments be thoroughly evaluated in terms of technological, economical and strategic aspects. A case study shall also be elaborated with the above discussed aspects as foundation, and where the following results shall be presented.

As an additional requirement, the assignment can also include considerations about opportunities for using the communication infrastructure that will be established for realization of following additional functions:

• City Wide Wi-Fi outdoor coverage
• Feeder network for 3GPP base stations (with e.g. HSPDA stations that have to be located close to each other in order to obtain high bit rates)

Assignment given: 15. January 2008
Supervisor: Steinar Andresen, ITEM

Abstract

Fibre-to-the-home (FTTH) is experiencing great public acceptance throughout the world, as well as in Norway. This thesis investigates the technological, economical and strategic aspects of FTTH with an emphasis on greenfield deployment.

The thesis claims that the Active Optical Network (AON) and Gigabit Passive Optical Network (G-PON) are similar to some extent when compared to cost, while non-cost comparison shows that these two models have different qualities. Wavelength Division Multiplexing Passive Optical Network (WDM-PON) is commercially unavailable to a large degree for the time being, but would satisfy future needs better when it becomes standardised. The established passive infrastructure could also be considered for Wi-Fi services, and as feeder network for base stations for mobile broadband.

Further, the report claims that the property developer should consider the opportunity to be the network owner in greenfield FTTH deployments in order to reduce the civil work costs. However, the ownership would vary with context for a particular FTTH deployment. Both open and closed business models are investigated and it is argued that both have advantages as well as disadvantages. Two different finance models are also briefly introduced in this thesis; two-part tariff pricing model and a price discriminating model, respectively. These are suggested as alternative ways of thinking, in order to address the various economic capabilities possessed by different customer groupings.

The final part of the thesis is based on a case study of Lundåsen area in Trondheim, where a hypothetical greenfield FTTH deployment is evaluated. The cost expenditures (CAPEX) for each user were calculated to be almost 65% less than the norm for brownfield deployments in Norway. It is also estimated that the home price premium (the extra amount of money value added to price of a house) would be around 1% of the house price due to the fact that FTTH is implemented in the residence. Thus, this is a large contributor to the total revenues from a greenfield FTTH roll-out. The profitability analysis also showed a positive end result, thus indicating that FTTH roll-out in an analogous project like the case study should strongly be considered.

Education, love and peace for all.

Preface

This master thesis is my final work done at Department of Telematics, Norwegian University of Science and Technology (NTNU), in order to receive my Master of Technology degree. This work also concludes my indescribable journey as a student in Trondheim.

Working on the thesis has not been without its' challenges. However, at the end, I would have to admit that it has been quite educational and personally rewarding. Among other things, I participated in a broadband conference in Oslo, where I had the opportunity to meet with motivated and talented individuals who have inspired and guided me in my work for this thesis. Several actors whom I networked on a personal level have also shown keen interest on this topic for the report and are eagerly looking forward to the final result of my work. To me, this is evidence that my chosen topic of study shows considerable significance to the industry, while motivating me to acquire more knowledge about FTTH in Norway.

I would not have been able to pursue work on this thesis had it not been for those individuals who rendered their support and guidance. I would like to take this opportunity to acknowledge those. My supervisor Steinar Andresen has been helpful with defining the problem of this thesis and guiding me through my work. Next, I would like to thank Hallvard Berg and Per Alnes (Greenfield AS) who have both voluntarily helped me. Berg has given me feedback and comments on the thesis, and thus enhancing the quality of it. Alnes have also given me invaluable help, especially for the case study part. Special thanks to Bjørn Rønning (Greenfield AS & NetNordic AS) who assisted me in networking with the right people.

I would also like to convey my gratitude to Martin Nord (Telenor), Kaj Kangeman (PacketFront), Tom Solberg and Geir Weum (NetNordic AS), and Daniel Hegland (NPT).

I kindly welcome and encourage any comments, feedback or questions with regards to the thesis, and I hope that this thesis serves its purpose of educating oneself on the chosen subject matter and convey its necessity to those interested in FTTH.

Rushanth Vathanagopalan
Trondheim, 17.06.2008

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Abbreviations

ADSL	Asymmetric Digital Subscriber Line
APAC	Asia & Pacific
B-PON	Broadband Passive Optical Network
BSS	Billing Support Systems
CAPEX	Capital Expenditures
CO	Central Office
CPE	Customer Premises Equipment
EFM	Ethernet in the First Mile
EMEA	Europe, Middle East & Africa
E-PON	Ethernet Passive Optical Network
FTTC	Fibre-to-the-curb
FTTH	Fibre-to-the-home
Gbps	Gigabit per second
G-PON	Gigabit Passive Optical Network
GSM	Global System for Mobile communications
HD	High Definition
HPP	Home Price Premium
HSPDA	High-Speed Downlink Packet Access
ISP	Internet Service Provider
LAN	Local Area Network
LLUB	Local Loop UnBundling
Mbps	Megabit per second
NGN	Next Generation Network
NMT	Nordic Mobile Telephony
NOK	Norwegian Kroner (currency)
NPT	Norwegian Post and Telecommunication Authority
NPV	Net Present Value
OBMO	Osterwalder’s Business Model Ontology
OCDM	Optical Code Division Multiplexing
OLT	Optical Line Termination
ONT	Optical Network Termination
ONU	Optical Network Unit
OPEX	Operational Expenditures
ORN	Optical Remote Node
OSS	Operations Support Systems
P2MP	Point-to-multipoint

P2P	Point-to-point
PON	Passive active network
ROR	Rate of Interest
SCM	SubCarrier Multiplexing
SLA	Service Level Agreement
SMP	Strong Market Position
TDM	Time Division Multiplexing
TTM	Time to Market
UMTS	Universal Mobile Telecommunications System
USD	American Dollar
WDM	Wavelength Division Multiplexing
WDM-PON	Wavelength Division Multiplexing Passive Optical Network
WECA	Wireless Ethernet Compatibility Alliance
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WISP	Wireless Internet Service Provider
WLAN	Wireless Local Area Network

1 Introduction

This chapter explains the background and motivation of this master thesis. Hereunder are also the problem domain, limitations and research approach for the thesis outlined. The last subchapter explains how the remainder of this document is organised.

1.1 Background and Motivation

Fibre-to-the-home, or shortly known as FTTH, is an access network which is based on fibre optics. FTTH is emerging as the most promising fixed broadband access. Due to the higher bandwidth demands in the future, FTTH would undoubtedly surpass other access technologies like xDSL and coax sooner or later. It is estimated that there would be a bandwidth demand of 1 Gbps or more, around year 2020, and over 10 Gbps in year 2030. The bandwidth need is shown in *Figure 1*.

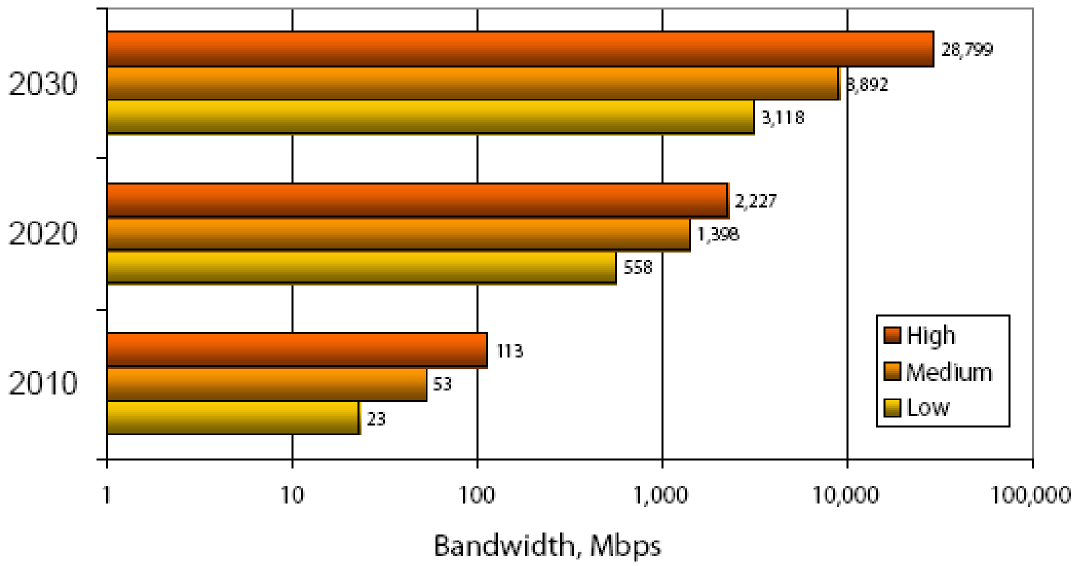


Figure 1: Projections of needed bandwidth in the future. Extracted from [1]

Different services call for different bandwidth levels. For instance, several High Definition TV (HD-TV) streams would demand for bandwidth at Gbps level. Since fibre is the only candidate able to cover these kinds of demands, there is no doubt that FTTH deployments will increase. In theory, the fibre cable could actually provide unlimited bandwidth, so long as the active network components manage to accompany.

Fibre cables have for a long time been used in the backbone network, but not until recent years was it considered for the access network. As the cost of FTTH deployment has decreased, there are several actors who have started to build and offer FTTH for the commercial market.

The main influences of the fibre infrastructure deployment costs can roughly be divided into these groups [2]:

- FTTH environment (city, open residential or rural)
- Size of the FTTH network
- Initial deployment cost of the infrastructure elements (CAPEX)
- Ongoing costs for network operation and maintenance (OPEX)
- Type of FTTH area e.g. Greenfield, Brownfield, or Overbuild.

As one can observe from the list, the deployment costs are dependent on several factors. The final point is an interesting one. Many of the fibre rundowns are on already built developments, what is often denoted as *brownfield*[1]. This means that there are already building structures or houses in that area, and appurtenant infrastructure like cables, sewer system etc. Most likely there are also other access technologies represented. The opposite situation which is referred to as *greenfield* is when one has untouched area with no established houses or buildings, and also when there are no infrastructures built. In this thesis, the main focus is on the latter situation, i.e. FTTH with an emphasis on greenfield developments. “New developments” is also used as an alternative term for “greenfield developments”, and both are used to denote the same meaning in this report.

[1] Brownfield is in the construction environment also used to denote contaminated land or industry area. Here I use it only to denote land where there are already established developments and infrastructure.

1.2 Problem Description

The problem description that is given at the beginning of the chapter is the prevailing surroundings for this master thesis. Thus, the main objective is to evaluate and elaborate the FTTH in greenfield developments in terms of constraints and opportunities within aspects like technology selection, economy and business model. The thesis further consists of a case study analysis consisting of a practical example with the necessary calculations.

To answer the problem description in a satisfactory manner, it would be helpful to institute some concretised *problem statements*. Therefore, important problem statements for this thesis have are:

PS1: What is the current status of the FTTH market, and where does greenfield FTTH deployment fit in this market?

PS2: How does FTTH for greenfield developments differ from brownfield developments?

PS3: What are the different FTTH architectures, and how do they affect the cost picture?

PS4: What aspects are significant in terms of FTTH, value chain and business models?

PS5: Who are the potential network builders and owners of greenfield FTTH network?

PS6: What economic decisions would make the financing feasible for both customers and the network owner?

PS7: What is the main conclusion of the case study that can be used as guideline for future greenfield developments?

These seven problem statements therefore outline the framework for the rest of this thesis, and are to be tried answered at the end of this report (the conclusion chapter).

1.3 Limitations

Greenfield development can include everything from building private houses, industrial and public buildings etc. In this thesis the greenfield FTTH development is limited to embrace mainly private houses.

1.4 Research Approach

The first research approach would be a literature study that would be performed in order to get the overview and necessary background about FTTH and the related topics.

This theory background would then be supported by collecting information and additional data from the FTTH industry when appropriate. Both existing theory and industrial experience would be utilised so as to make my own contributions.

The final case study would then include reflections and the findings from theory, industrial data/experience and my own contributions in an attempt to create a holistic case scenario analysis.

1.5 Thesis Outline

The remainder of the thesis consists of four main parts.

The first part includes *chapter 2* - *chapter 4*. The first two of these chapters offer a theoretic introduction to FTTH architectures, value chain and business models. Chapter 4 describes the trends and forecast of the FTTH market. Majority of the theory presented in this part is collected and based on other sources, i.e. a literature study.

Chapter 5 to *chapter 9* makes up the second part. *Chapter 5* outlines the meaning of greenfield developments in terms of FTTH, while *chapter 6* views the activities in the value chain and the different network owners. *Chapter 7* further evaluates the business models presented in part one. *Chapter 8* consists of economic, technological and regulatory considerations. Further in *chapter 9*, I look at some additional ways the established fibre infrastructure can be used. Common for whole part two of the thesis is that known theory and industrial knowledge is used to make my own contributions.

The third part of the thesis is composed of *chapter 10* and *chapter 11*. This is the case study part, where the first chapter gives the background and main business model choices for the case study. *Chapter 11* is an investment and profitability analysis, where the associated economic results are presented, along with the discussion of the case study findings.

The final part is *chapter 12*. This chapter comprises of the thesis conclusion, where the answers to the problem statements that were defined in *chapter 1.2* are stated. This chapter also includes suggestions for future work. Following the conclusion chapter, are the bibliography and the appendices.

All chapters also include a chapter summary where the key points of the particular chapter are briefly discussed.

2 FTTH Architectures

When building a FTTH network, it would certainly be important to evaluate what FTTH architectures may be appropriate to adopt. This is important even if it is not related to new developments. However, new developments provide a good opportunity to evaluate and implement the optimal system that is cost effective and satisfies future demands from a FTTH network.

This chapter will focus on different architectures that are adopted by the FTTH industry. There are mainly three FTTH architectures that are of current interest, which are namely point-to-point architecture (P2P), and the two point-to-multipoint (P2MP) architectures Active Optical Network (AON), and Passive Optical Network (PON).

2.1 Point-to-Point (P2P) Architecture

In this architecture, as the name suggests, individual fibres run from the Optical Line Termination (OLT) to each Optical User Unit (ONU)[2]. In other words, individual fibre pairs are run to each home (therefore also often just called "home-run fibre") [3]. *Figure 2* is an illustration of the P2P architecture, where a separate fibre-pair is laid from the OLT to an ONU.

P2P architecture has its advantages as well as certain major drawbacks. One advantage is the opportunity to provide the ultimate capacity, and satisfy each customer's requirements completely. Individual fibre pair also means greater flexibility in providing services to customers [3]. There are however some major drawbacks with the P2P architecture. At the OLT, the need for hub equipment will scale with number of ONUs (i.e. homes or subscribers). Besides the cost of acquisition, these equipments may also cause problems in connection with space

[2] OLT is the element which sends and receives the optical signals, placed in the Central Office (CO)/Local Exchange. The ONU is placed at the customers' premises where the optical signals are converted to electrical signals, and provides an interface (usually Ethernet) so that appropriate equipment for voice, video and data can be connected.

and power consumption. P2P solution also requires many fibre pairs, and with these all the installation and maintenance [3], [4].

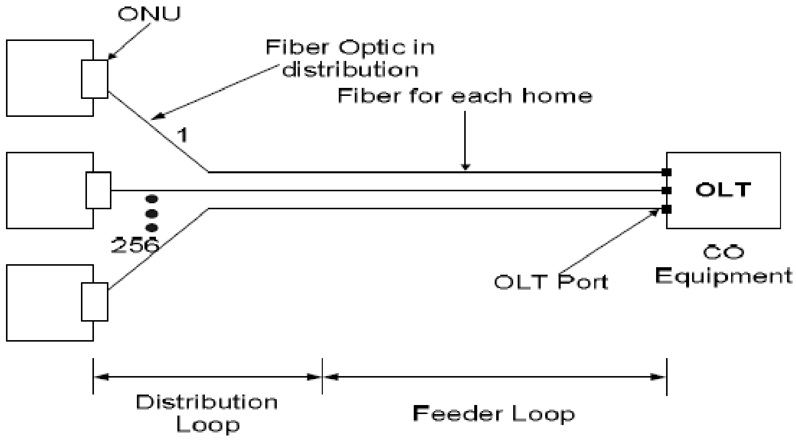


Figure 2: Point-to-point (P2P) architecture. Extracted from [5]

2.2 Active Optical Network (AON)

AON is characterised by a single fibre which carries all traffic to a remote node (ORN) close to the end users from the central office [3]. AON is also often denoted as Active Ethernet Network, since equipment needed to provide TV, telephony and Internet are connected through the common Ethernet standard.

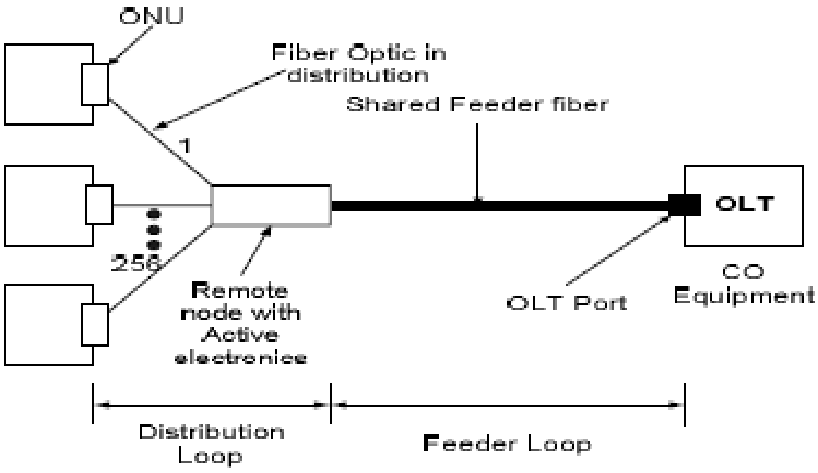


Figure 3: Active Optical Network (AON). Extracted from [5]

The remote node contains an active element, which processes the data frames that are sent from the central office (OLT) to the remote node, and forwards only frames to the respective network units (ONUs). From the remote node to network units, individual fibres are run to each cabinet/curb, home, building etc, based on the type of solution that is implemented. The feeder fibre is shared from four and up to thousand customers. *Figure 3* shows the main components and functions of the AON architecture.

Compared to the P2P architecture, the AON architecture's main advantage is that it is only used a single shared fibre to cover a certain area, thus reducing the fibre cost. It also scales better than the P2P model. Challenges are that the ORN with its active elements require powering, maintenance, and cabinets that can withstand temperature variations so as to protect the electronics [3].

2.3 Passive Optical Network (PON)

In this architecture, the active node from AON is replaced with a passive optical power splitter/combiner (only noted as *splitter* from here on); see *Figure 4.* The splitter is denoted as passive since it just *broadcasts* all the data that it receives. Like the AON, there is a single shared feeder fibre from the OLT to the splitter. The task of sorting out the right packets that belongs to each subscriber lies within the network units (ONTs) in the PON model. Because of the additional data processing task, ONUs in a PON model are usually costlier than in AON [6].

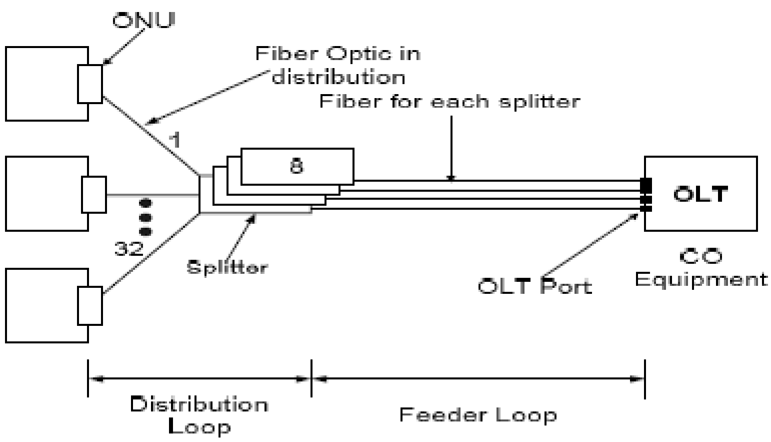


Figure 4: Passive Optical Network (PON). Extracted from [5]

Within the PON architecture, there exist three different main standards. These are Broadband PON (B-PON), Ethernet PON (E-PON) and Gigabit PON (G-PON). B-PON (also termed ATM PON) is an ITU (International Telecommunication Union) standard. E-PON is a standard promoted by the IEEE 802.3 Ethernet in the First Mile (EFM) group. These are however considered as legacy standards and are recently being replaced by other standards that are somewhat recent and offer higher bandwidth [7].

The third commonly known standard is G-PON. ITU elaborated this standard with the purpose of extending the capacity of PONs into Gbps arena. It is also a further development based on B-PON. GPON is much alike the B-PON standard, but has in addition higher downstream bitrates, lower overhead and the possibility to carry Ethernet packets, ATM packets as well as a mixed mode of these two transmission types[8]. G-PON has a download rate of 2.5 Gbps and an upload rate of 1.25 Gbps. It is estimated that the next generation G-PON would support up to 10 Gbps bit rate [9].

Upstream from the different users to the OLT must be allocated by some kind of multiple access technique to avoid collision between the different streams (recall that that it is used as a shared feeder fibre between OLT and splitter). All the PON standards mentioned above use Time Division Multiplexing (TDM) techniques, which means that the upstream packets are interleaved on a time basis, through the shared fibre.

In addition to TDM, there are three major multiplexing techniques for fibre access networks[8]: *Wavelength Division Multiplexing* (WDM), *SubCarrier Multiplexing* (SCM) and *Optical Code Division Multiplexing* (OCDM).

In WDM-PONs, each ONU uses a different wavelength channel to send its packets to the OLT. The same wavelength channel can be used for both upstream and downstream communication. In a SCM-based PON, each ONU modulates its packet stream on a different electrical carrier frequency, which subsequently modulates the light intensity of the ONU's laser diode. This means that the packet streams are placed into different frequency bands. In an OCDM-based PON each ONU uses a different signal sequence of optical pulses. This signal sequence is on-off modulated with the data to be transmitted [8].

TDM is currently the most popular multiplexing method for building a PON infrastructure. This is associated with the fact that the TDM technology has a moderate technical complexity, and costs less to implement than the other techniques [7]. On the other hand, while TMD-based PONs at present moment appear to be satisfactory for current bandwidth demands, future bandwidth projections and other trends in the broadband domain shows that other multiplexing techniques could be more favourable for a more future proof fibre-based access network [7]. Especially WDM-PON is an attractive candidate in this context. The next subchapter therefore explains WDM-PON in depth before passing on to the next chapter.

2.3.1 WDM-PON

The main difference between the TDM based PON and WDM-PON is that in the former all subscribers connected to the PON share a single pair of wavelengths, while in the latter scheme, each subscriber is assigned a pair of dedicated wavelengths. This makes all the end users independent from each other; allowing them to send data to OLT at anytime without worrying about collisions with other users' data [3]. The dedicated wavelengths to each ONT, creates in reality a virtual P2P topology. *Figure 5* depicts the generic WDM-PON scheme.

The WDM scheme originally requires each ONT to operate on a specific wavelength[3]. However this clearly boosts up the operational costs and would be quite impractical, since it must be manufactured unique ONTs for each particular PON. To this reason, the WDM-PON is considered to be the most expensive PON variant, hence been a key bottleneck in the commercialisation of WDM-PON [10]. However, there exist ways of reducing the costs. These solutions aim at making the ONTs "colourless", which is a general term used to denote all the solutions. Hence, the main point of implementing these solutions is to make the ONTs identical (lower operational costs and easier maintenance) while insuring that they can work in accordance to the wavelength plan [11].

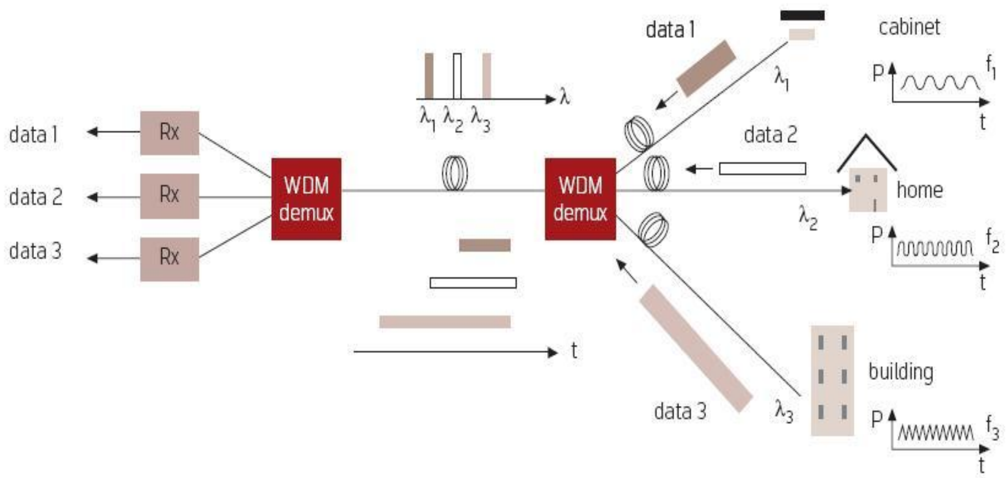


Figure 5: WDM-PON architecture. Extracted from [8]

It is claimed that WDM-PON can offer high bandwidth numbers, for instance 100 Gbps for each user [12]. Indeed, in theory the bandwidth could be virtually unlimited in WDM-PON [13]. But as WDM-PON standards are gradually worked out, it would be reasonable to assume a lower bandwidth level, around

[3] Actually, it is a laser diode within the ONT which operates on a fixed wavelength

100 Mbps or so. However, there is a consensus that WDM-PON has the greatest potential to provide very high bandwidths required in the future, compared to cost versus bandwidth.

2.4 Chapter Summary

The three main FTTH architectures are P2P (home-run fibre), Active Optical Network (AON), and Passive Optical Network (AON). The last two architectures have P2MP topology. All these architectures are not without its advantages and disadvantages.

P2P network provides the highest opportunity for satisfying any future bandwidth demands, but also proves to be too costly. AON architecture is a better option in terms of cost than home-run fibre. G-PON, based on time division multiplexing (TDM), is one of the standards within PON architecture that is widely acknowledged. WDM-PON which is based on wave division multiplexing (WDM) is still not standardised, but demonstrates capabilities to be the successor of G-PON in the future. With WDM-PON, bitrates up to 100 Gbps or more is a possibility in the future.

Important decisive factors are cost, satisfaction of future bandwidth demands and scalable architecture. The adopted technology should also allow for improvements and replacements with future network components. Hence, it is advisable for one to concentrate on the P2MP architectures. Therefore, the main focus of the preceding chapters will be on G-PON and AON.

3 Business Model Overview

This chapter presents an introduction to the building blocks of the business domain for FTTH. Briefly outlined in this chapter is the value chain and required business roles. Furthermore, this chapter delves into a topic of current interest, namely closed versus open access networks. Basic definitions and theory around closed and open access networks are stated, while discussions around these models are further continued in *chapter 7*. Thus, this chapter serves as foundation for later evaluation of business models.

3.1 Value Chain and Business Roles

Prior to the analysis of different business models, it would be useful to outline the business roles and the value chain for broadband access, i.e. for fibre access network in this setting.

Roughly, there are three main business roles that can be identified. These are the *network owner*, *network operator* and *service provider*. Network owners have control and ownership of the physical infrastructure. They usually use external or partner contractors to build the infrastructure, i.e. digs, ducts and lay fibre cables etc.

The network operator is usually in charge of management of the infrastructure, such as installation, monitoring and maintenance etc. Often this also means that network operator has to provide for necessary equipment related to the aforementioned tasks. Network owner and network operator can be the same actor or two different actors.

Service providers are those who offer various services to the customers, and are in charge of all tasks from management to support of their services. All of the above business roles are combined to serve the customers. *Figure 6* depicts a general overview of the business roles involved in a fibre access network.

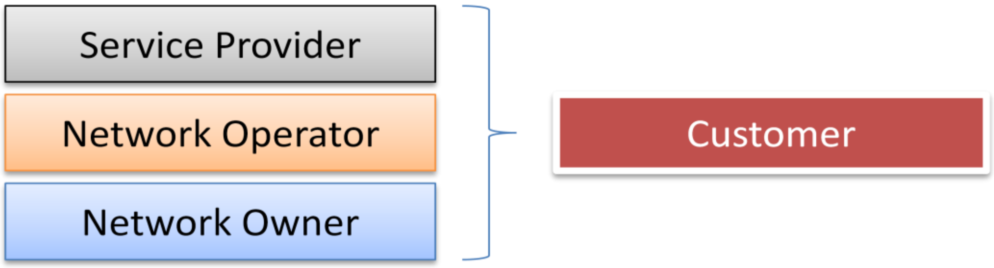


Figure 6: Business roles for broadband

In addition to business roles, one can also outline the value chain. Value chains create value by transforming inputs into products [14]. This is illustrated in *Figure 7* which depicts the typical parts of the value chain for a broadband market [15]. In the bottom are the *ducts*, *canals* or *poles* that are needed for the cables. The second element is the fibre cables, i.e. the *physical infrastructure* which have to be laid. Above this is the *active network* which comprises of the equipment and nodes needed for establishing communication on the physical infrastructure. This may also include components for billing and provisioning. Then there is *content and service production*. This is delivered over the network. Tied to this, is the *monitoring and management* of the network and services provided. Above this is *customer handling*.

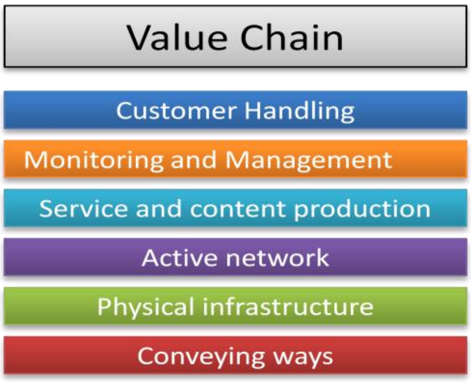


Figure 7: General value chain for broadband. Based on [15]

The two lowest activities in the value chain are often performed by the network owner, with necessary partnership. While service providers take care of providing services and the needed support to the offered services, network owner may do customer handling, or place a network operator in charge of these tasks. Installation, monitoring and management of the active network and the passive infrastructure are also typical activities tied to the network operator.

3.2 Other Value Creating Models

In addition to value chain, there are two other types of value creating models which are *value shops* and *value networks*, respectively. Value shops schedule activities and utilise available resources in a manner that is especially suited and dimensioned for a special task in order to solve a customer problem [14]. Value networks provide a networking function between customers, typically through some form of infrastructure [14]. Characteristics for value shop, value network plus value chain is given in *Table 1*.

As explained in the previous subchapter, the value creation for FTTH can be explained using a value chain. However, it may also have different value creating models presented within the different parts of the value chain. For instance, the passive and active network for which the responsibility falls under the network owner and operator, can be denoted as a value network since it is an infrastructure that connects different customers, as well as customers and service providers. Customer handling, on the other hand, could be seen as value shop (available resources are directed toward a customer to solve a particular problem).

Table 1: Overview of value chain, shop and network. Extracted from [14]

	Chain	Shop	Network
Value creation logic	Transformation of inputs into products	(Re)solving customer problems	Linking customers
Primary technology	Long-linked	Intensive	Mediating
Primary activity categories	• Inbound logistics • Operations • Outbound logistics • Marketing • Service	• Problem-finding and acquisition • Problem-solving • Choice • Execution • Control/evaluation	• Network promotion and contract management • Service provisioning • Infrastructure operation
Main interactivity relationship logic	Sequential	Cyclical, spiralling	Simultaneous, parallel
Primary activity interdependence	• Pooled • Sequential	• Pooled • Sequential • Reciprocal	• Pooled • Reciprocal
Key cost drivers	• Scale • Capacity utilization		• Scale • Capacity utilization
Key value drivers		• Reputation	• Scale • Capacity utilization
Business value system structure	• Interlinked chains	• Referred shops	• Layered and interconnected networks

3.3 Closed Access Network Model

Closed access networks are also known as vertically integrated networks, since one operator controls the whole value chain. In a closed access network model, one particular player has monopoly on providing services to the customers. This is the traditional model of implementing an access network. One player builds and runs the network infrastructure, while being the only service provider on that network [15]. There could be some other service providers than the owner, but these are usually strictly regulated by the network owner.

The main point here is that customers do not have opportunity to choose which service provider they want to get their services from. This also implies that in an entirely closed access network, the telecom operator hold a monopolistic power. This has been the typical model for already existing national telecom operators, which are often referred to as incumbents (e.g. Telenor in Norway).

In the FTTH market however, the utility company Lyse is an example for company which has closed access network in Norway. In September 2002 [15], Lyse, was the first to offer broadband over fibre in Norway. The company also has other partners throughout Norway (typically municipalities and regional actors) who resell Lyse's closed access concept Altibox[4].

3.4 Open Access Network Model

While closed access network gives total or majority of the power to a single player, an open access network encourages the opposite. This means that in an ideal open access network, the network owner arranges so that any service provider is free to provide their services on that network [15].

An open access network can thus be considered as the opposite business model to a closed access network in terms of how an operator chooses to settle in a market. In an open access network, a single network owner builds the network infrastructure while another network operator may be used for managing and maintaining the network [15]. These lower level tasks can also just be performed by the network owner. In addition, there are several independent service providers who provide various services on top the physical access network. Open access network is also known as *horisontal integrated* networks, because the

[4] Lyse: www.lyse.no
Altibox: www.altibox.no

various layers in the value chain can be realised by different players in that particular market.

Examples of the open access network model can be found in the Swedish FTTH market. These FTTH networks are called city networks ("Bynett") and have experienced big success in Sweden. City networks are also starting to get foothold in Norway. "Troms Bynett", owned by Pronea, is an example of FTTH provider that follows the open business model[5].

It should also be noted that the open access network model principally creates value by following the "Value Network" model, since the network owner mainly facilitates the process, whereby allowing the service providers to connect with customers, and vice versa.

3.5 Chapter Summary

The value chain for FTTH can, as for other broadband access, be roughly divided in this manner: conveying ways, physical infrastructure, service network, service and content production, monitoring and management, and at the top, customer handling. These activities are provided by actors like network owner, network operator and service providers. This is a coarse classification, since one may find actors that operate in between the mentioned business roles. In addition to the value chain, there are other value creating models like value shops and value networks.

There are essentially two ways of characterising the access network structure, namely open and closed network access model, respectively. While the open model opens up the value chain for other actors in a non-discriminative fashion, the closed model gives a single player, usually the network owner, control over the whole value chain. Both models have their advantages and disadvantages in different settings. This will be subject for further evaluation in *chapter 7*.

[5] Troms Bynett: www.tromsbynett.no.
Swedish city network: http://www.malarenergistadsnat.se/

4 Trends and Forecast in the FTTH Market

Trends are important to observe in a market situation. This also includes the FTTH market. This will provide for a better understanding on the decisions to be made, for instance on the type of technology and business model. Experiences from various countries that are implementing FTTH can be used as guideline to avoid major miscalculations in the study. This chapter will mainly focus on the general overview of how FTTH is adopted throughout the world, and also more specifically in Norway.

4.1 FTTH Market: Overview

FTTH has gained an enormous commercial breakthrough in the world lately, and the number of households with FTTH continues to grow. Approximately 22 million households worldwide have already FTTH by start of 2008 [16], [17]. Figure 8 shows how this total number is broken down for North America, EMEA (Europe, Middle East & Africa), and APAC (Asia & Pacific). Clearly, the highest penetration of fibre access network is to be found in Asia. In Asia and Italy, Fibre to the building (FTTB) is the most common fibre structure. FTTH is common in the rest of the world.

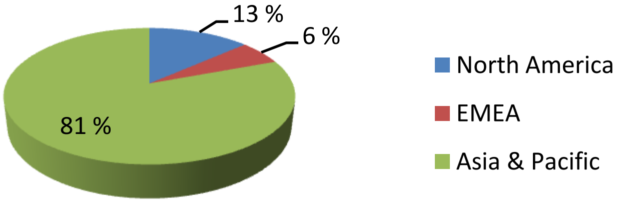


Figure 8: FTTH distribution throughout the world

Figure 9, derived from a recent press release from the FTTH Council [18], show the countries with the highest FTTH penetration in the world. While the three countries with highest penetration are in Asia (South Korea, Hong Kong and Japan), half of the countries on the chart are European countries. Scandinavia also has a high penetration level compared to rest of the world, with Sweden, Norway and Denmark on 4th, 6th and 7th place, respectively.

In Norway around 97.8 % of the households have some kind of fixed broadband per March 2008 (ADSL, coax or fibre) and this number is estimated to be 98.8 % in end of 2008 [19]. Approximately 10 % of this is through fibre. There has been an enormous growth in FTTH penetration the last few years in Norway. The figure rose from zero customers before 2002 (the year when Lyse started up), to around 110 000 customers as of February 2008 [20]. The majority of the customers (around 97,000) are customers at Lyse and its partners [21]. The numbers for "homes passed[6]" are around 181 000 for Norway [20].

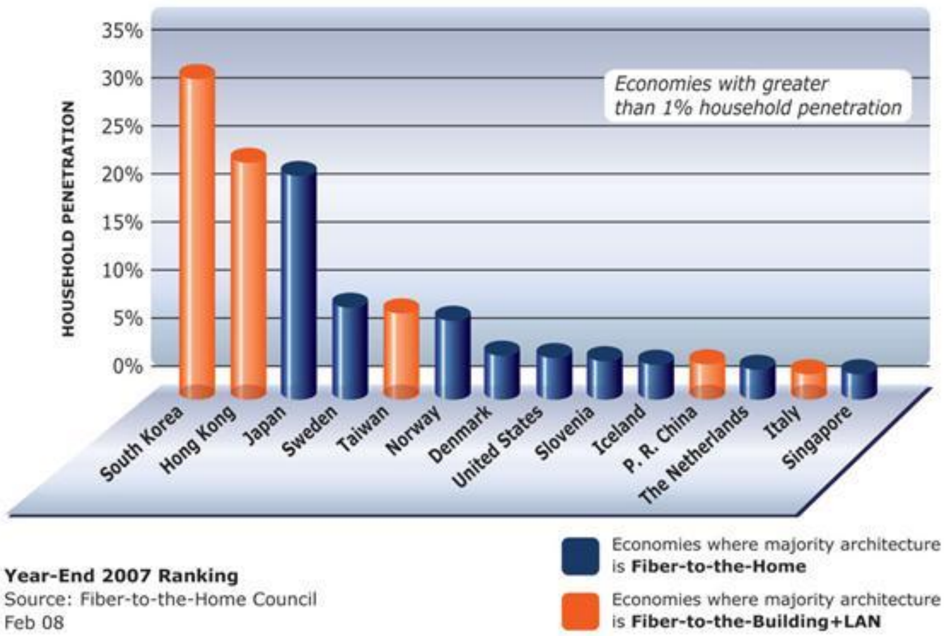


Figure 9: Economies with the highest penetration of FTTH/FTTB

4.2 Adopted FTTH Architectures

Different areas in the world have adopted various FTTH architectures till today. In Europe, both AON and PON architectures are widespread. The city networks in Norway and Sweden, along with utility companies and municipalities, have

[6] "Homes passed" denotes that the houses *can* easily be connected to the network, since the main fibre cables (i.e. feeder cables) are in place.

mainly chosen AON solutions. Many of the city networks acquire their main technology solution from PacketFront, while Lyse uses Cisco-based technology [22]. However, AON is not widespread as the PON architecture around the world. North America and Asia have mainly adopted the B-PON and GE-PON (the latter is a Gbps variant of the E-PON, used mainly in Asia), respectively.

Of the PON variants, the G-PON is acquiring more popularity. When it comes to Norway, there are currently no prominent actors who have implemented PON solutions. However, Telenor have announced that they will use the G-PON variant in their FTTH network which they are gradually building up these days. In fact, many incumbents worldwide seem to choose G-PON as their FTTH architecture, among them France Telecom [23]. Telenor is yet to be represented in the FTTH market, and is expected to enter the market in 2008-2009. It is also predicted that G-PON that supports up to 10 Gbps will be common in the near future (Currently supports 2.5 Gbps).

4.3 FTTH Owners and Business Model

FTTH networks have many different types of owners. Here one can roughly divide into incumbents, alternative actors (e.g. “Bynett”), greenfield and property developers (real estate) and regional actors like municipality and utility companies. *Figure 10* shows the customer shares different actors are predicted to take on a world basis [24]. In terms of greenfield FTTH deployment, the trends and forecasts are promising, even though incumbents are predicted to grow most.

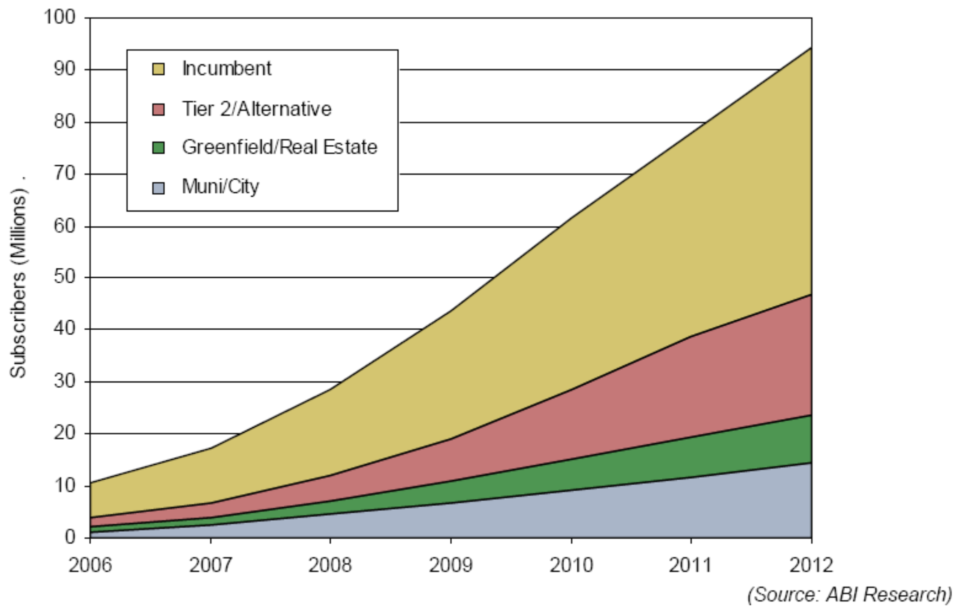


Figure 10: FTTH owners and subscribers for 2006-2012. Extracted from [24]

For Norway, it is estimated that between years 2008 and 2012, there would approximately be 100% increase in greenfield deployments, leading the number of customers to rise from below 10 000 and up to the double [20]. This also implies that several actors could take advantage of this positive change to implement FTTH in greenfield situation in the coming years. *Chapter 6* presents an in depth elaboration of different network owners.

4.4 Chapter Summary

Trends and forecast shows that FTTH is becoming more prominent as access network throughout the world. According to the market research organisation Heavy Reading, it is estimated that in 2012, it would be connected around 90 million households connected [25], as illustrated in *Figure 11*. Norway is one of the leading countries in the world in terms of FTTH, and experiences a considerably growth.

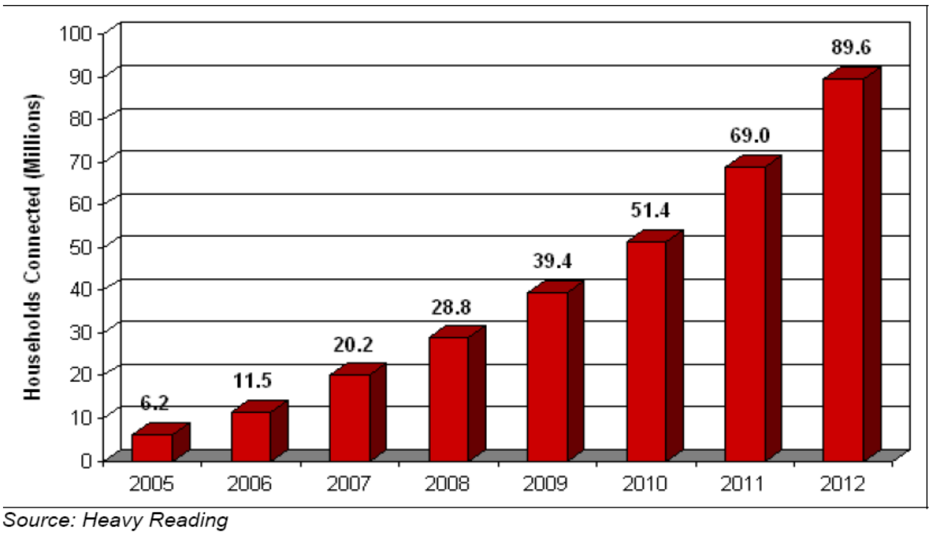


Figure 11: Forecast for number of households with FTTH. Extracted from [25]

Adoption of various FTTH architectures, and owners of the FTTH networks, varies throughout the world. In Norway it has primarily been AON, deployed and owned by utility companies and municipalities, and other alternative actors. Telenor on the other hand, have announced that they have chosen G-PON when they enter the FTTH market later this year or the next. With the entry of incumbents in the FTTH market, it is also estimated that they will grab a big share of the FTTH market. Nevertheless, greenfield FTTH deployments are predicted to become more common, which gives different actors opportunity to become network owners.

5 FTTH for Greenfield Developments

The principal difference between a brownfield and greenfield situation is obvious. In the former there are buildings and infrastructures already deployed, in the latter there are not. But what are the consequences of such a difference in terms of FTTH? This chapter will try to answer these questions by identifying the dissimilarities between the two cases, and the possibilities greenfield FTTH deployments have to offer.

5.1 Infrastructure

One of the leading differences between the two cases is based on the infrastructure in the area of the new developments. While several cables, ducts or canals can be found beneath the ground in already built land, there are none of this in an ideal greenfield situation. In brownfield areas these underground cables and ducts are often laid in different periods and it may not be any thought-through solutions for this infrastructure.

It is a common consensus that when a fibre infrastructure is laid, the largest part of the cost is mainly connected to the digging and ducting, i.e. civil works. One often assumes that around 70% - 80% of the cost is related to labour [3][7]. Another problem is that the same areas are dug up by different actors, and therefore considerably large sums of money and time is wasted on several ducts, digging and labour.

A recent report composed by various Norwegian organisations, argues that co-ordination may reduce risk and the social economic costs [26]. Many power companies have reported about electric current cables that are damaged during

[7] For instance: Cutting in asphalt costs around NOK 100 each meter while re-asphalting comes up to 200 NOK/m^2 in average[26]. This cost would vary with location (rural, city etc).

digging, causing injuries. In the same manner, plenty of resources are used on ruptured communication cables caused by digging work. For instance, rupture on a fibre cable can cost between NOK 50 000 – 100 000 to fix. Sometimes the whole fibre cable must be replaced when they are damaged, implying that cables up to 700 meters may have to be replaced in such a situation (this is for avoiding unacceptable signal attenuation) [26]. Those who are affected by the down time of the network would also experience negative consequences, often in form of economic loss. The digger may then be held responsible for this loss, and be required to pay compensation.

For these reasons, one great advantage is that one can co-ordinate the digging between different parties who must lay various infrastructures, in such a way that it minimises the number of diggings and thereby the costs related to that. This hereby also includes the infrastructure for fibre cables in the context of FTTH.

5.2 First Mover Advantages

In an ideal greenfield area, one may assume that there is no other access technology presented. This implies several things. Firstly, since there are no other access technologies available in that area, there should be reasonably simple to implement and recommend an access network based on fibre as the best option. After all, FTTH has the best potentialities when it comes to new and bandwidth demanding services[8]. If fibre is laid, there will most likely not be established any other fixed access technologies in the same area. This is because FTTH opens up for higher speed and bandwidth, i.e. a better bit price. Other fixed access technologies probably cannot compete on that feature, at least not for a longer period. It should also be noted that since the civil works can be reduced considerably in a greenfield deployment as mentioned in chapter 5.1, FTTH is not any costlier than other access network alternatives, e.g. xDSL [23].

5.3 Fibre as An Integrated Part of the House

By deploying FTTH in simultaneously with the development of the houses, additional advantages can be identified. The FTTH network would from the beginning be a natural part of the house or apartment, which minimises the demand for effort from the customers (or the new tenants). They do not need to

[8] Assuming that this is not a rural area, where there will not be any economically justifiable reason to lay fibre. Then there may be other better options, like for instance WiMAX.

be bothered with installations after they have bought the new house, or have the need for effort in terms of digging or other related activities etc.

Greenfield developments also make it more convenient to build so called Smart Homes[9], with FTTH as foundation. “Smart Home” is a term used for houses with ICT implemented to monitor, warn and carry out various functions in the residence, where the communication goes through the local network [27]. Smart Homes can also communicate with the surroundings through Internet for instance.

So by implementing FTTH in a greenfield development, one can erect houses that are entirely integrated in terms of combining different components in the house and the communication network. This new trend has already started to flourish (e.g. alarm and monitoring services through FTTH), but in future developments, it may evolve services that use the FTTH to interact with the power grid and other infrastructures tied to the house. Greenfield FTTH deployments would also be well-suited for pilot projects for testing new services for instance. So shortly put, FTTH in greenfield developments gives a great opportunity to build future-oriented houses where cost saving and convenience can be addressed.

FTTH in new development also have other benefits. Normally in brownfield deployments, it is required a penetration level of around 60% before fibre companies roll-out FTTH in that area [6]. The penetration level will likely be more when one offers FTTH as the access technology option *before* people move into their new houses. It would be easier to accept a technology from the beginning than to e.g. adapt to the technology on an ongoing basis.

Moreover, in the marketing of the house, there will probably be a higher value for it when it is offered with FTTH as standard access technology. This topic is discussed later in chapter 6.2.4, where the size of this value increase is evaluated.

5.4 Designing A Optimal Access Network

Another issue that is of importance is that FTTH for new developments does not have so many restrictions as it may be when there is a FTTH roll-out in a brownfield area.

Due to this fact, one may consider other innovative or novel approaches for the access network and the business domain that it creates. One can for instance

[9] The term “Smart Homes” is often used in relation with houses that are accommodated for the elderly or physically disabled. Here, I use this term to denote an ICT integrated house on a *general* basis.

evaluate other FTTH architectures or state of the art components, a different business model, or enter into effective partnerships to create what one could denote as an optimal FTTH network. Certainly, there is nothing in the way for implementing new FTTH technologies in brownfield areas either, but a greenfield situation would seem to give a higher opportunity to design a optimal system where all the different pieces (technology, business model, ownership etc) accommodate each other.

There is also cost related advantage when deploying FTTH in new developments compared to already existing residential areas. The access network could be included as an important part of the house in the initial stages itself, thus planning and deploying a network that minimises the cost of network parts and topology. In brownfield areas, this may not be possible due already exist physical buildings and houses, and sub-optimal choices may have to be made when deploying the fibre access network.

5.5 Contribution To A Greener and Sustainable ICT Development

In a time when environment problems and future challenges are placed on the agenda, there is a major focus on how ICT can contribute to a sustainable evolution and minimise the environmental problems. Within this context, FTTH deployment considered as such a significant effort. This is further strengthened in considering the deployments in new developments, as it grants an opportunity to implement a "greener" system, i.e. a network structure that optimises the environmental gain.

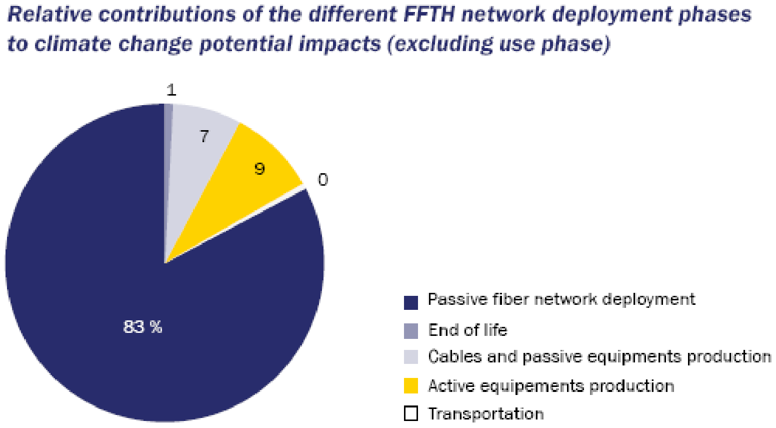


Figure 12: FTTH deployment and climate change

According to a recent report from The FTTH Council Europe, the deployment phase is the most critical one due to it's the potentiality for environmental drawbacks, like greenhouse gas emissions [28]. This is illustrated in *Figure 12*. Furthermore, the report states that the length on new ducts is the most essential factor in affecting the carbon gas emissions.

Therefore should co-ordination and the possibility of evaluation of all the aspects in the deployment of FTTH in new developments be an appropriate situation to contribute positively towards the environmental issues. Indeed, it should be a crucial aspect when planning a FTTH deployment in new developments.

It should also be noted that FTTH itself would prove to be an environmental friendly broadband technology in the future. An appurtenant press release from the council states the following [29 p. 1]:

> “ *Maximising the opportunity for new services whilst minimising the materials and maintenance required, FTTH contributes to reduced road travel, less transport infrastructure, and the introduction of innovative social and government services.*

So there are clearly other incentives present than just the economic gain when evaluating FTTH implementation, especially in new developments where the environmental aspects can be addressed well.

5.6 Challenges With Greenfield Developments

All of the above mentioned arguments lead to plenty of opportunities in considering FTTH deployment in greenfield, but this is not equivalent to an easy task.

The network owner, i.e. the actor who wants to deploy a FTTH network, must from the beginning include all actors who are involved in the development. This means that there is a need for simultaneous interaction, rather than a streamline implementation of the various infrastructures essential in the new development. For instance, it is a general trend that almost 90 % of the network itself is not planned until the actual roll-out [30]. This may result in poor design. Also, in greenfield situations this problem may be amplified, as the property developer, and perhaps another FTTH actor, may postpone the network planning until late development phase.

Scalability is also an aspect that is dissimilar for greenfield and brownfield situations. Currently, the FTTH deployments in a particular area is often carried out with the penetration level known in advance, i.e. the network owner has information about potential number of customers in that area. For instance, around 60%of Lyse's customers in an area sign up for FTTH *before* the deployment. In a greenfield situation, however, is the picture somewhat different. Even though the initial size of a greenfield development is known, and the FTTH actor can design the network according to that, need for network scalability is higher. The reason for this is that there are more likely to come more future developments and expansions in the same area, allowing room for more settlements. To make the move first into future developments area, FTTH actors would be dependent on a scalable FTTH architecture and technology as well.

Finally, even though you often will get a first mover advantage, it may be possible that others will also build out parallel fibre infrastructures, making it less profitable and thus disappointing the initial thought. This challenge is further discussed in next subchapter, since it seems to be a valid and actual question in the future.

5.7 Are There Possibilities for Several FTTH Actors in the Same Area?

An interesting and valid question is whether there is any room for several fibre infrastructures (built by different actors), or whether first comer gets a natural monopoly, since it is commonly assumed that more than one FTTH network would be less profitable for the actors who enter after the first had set foot.

Generally, fibre deployment in brownfield is more costly due to the civil works which comprises of up to 80 % of the CAPEX. And FTTH actors do not start deploying fibre access network until they acquire a desired penetration level; around 60 % in a particular area as mentioned previously. In theory, this would not leave room for a second FTTH provider or at least make it very difficult for the second FTTH actor. Hence, this combination would most likely result in only one FTTH provider in a certain area and thus giving a local monopoly for that actor[10].

However, the picture seems to be different for greenfield situations. As the major part is related to civil work, co-ordination among actors during the development significantly reduces the CAPEX. This could offer opportunities for more than one actor to establish a FTTH infrastructure in a particular area.

One can characterize FTTH networks as a *market with positive feedback*. In terms of FTTH networks, the number of customers likely to adopt this technology also depends on how many customers that have already said accepted this technology [31]. For instance, more FTTH customers would yield a lower price on services which again attract more customers to that provider (*positive feedback*). Readers who are unfamiliar with market with feedback and the related topics are referred to Jan Audestad's paper about this subject [31]. The remainder of this subchapter will use theory from there.

To get a picture of how two or more FTTH providers will manage in the FTTH market (in a particular area) the theory for market with positive feedback may be used. The simplest example would be to evaluate two providers. For this example let us assume that the FTTH builders have the same offer and functionality, and that the customers can churn[11] between the providers. There are no regulations for either providers, and both have a similar market coupling.

In a situation like this, [31] explains how the competition will evolve. This is illustrated also in *Figure 13*. Let us assume that S_A and S_B denotes FTTH provider A's and B's market share. From the initial point (0, 0), customers will start choosing FTTH from one provider. They will move towards either A or B. One may think that both providers will get 50 % of the market share each (point 0.5, 0.5) and then settle the competition. But this would not be the case since this middle point is unstable. This means that small perturbations will make customers go away from the middle point to one of the providers. This kind of market is denoted as "winner-takes-all market" [31].

In the long run this implies that one FTTH provider will get all the market shares, and the other would go out of business. This however is not a satisfying situation for a business actor who has invested in fibre infrastructure.

[10] This may however be different for various area types, i.e. if town, suburban or rural. In a densely populated town it may be less change for monopoly, while rural areas would be more suited for monopoly for the first mover.
[11] Churn/churning rate refer to the net numbers of customers that one provider looses to or captures from the other provider.

But as theory predicts this kind of outcome, it also assumes a situation where certain criteria must be met; churning, providers are similar etc. This may indicate that it may be possible for other actors to compete in the same area, by altering these factors.

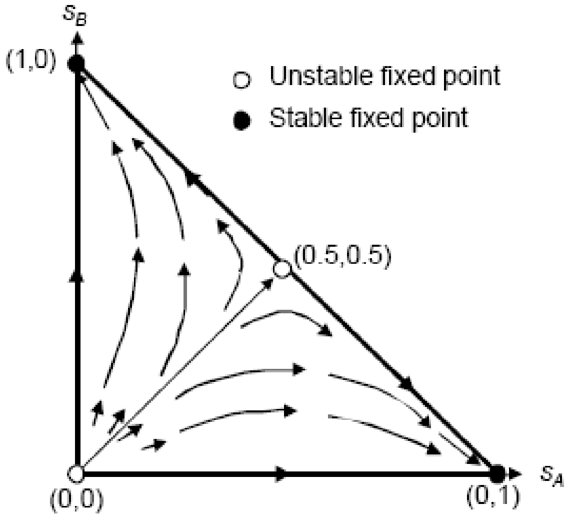


Figure 13: Winner-takes-all market. Extracted from [31]

For instance, if we consider market without churning, there are more stable equilibrium points (if N competitors, then there are N-1 stable equilibriums) [31]. This means that each competitor could get an initial market share. There may be a need for control of the churn, e.g. by having a lock-in period. The FTTH providers may also offer different conditions aimed at different kinds of customer groupings, which enable more than one actor to be present in the FTTH market in a particular area.

For new developments in *rural areas*, there is most likely no point in establishing several FTTH networks even though it is relatively cheap. Telenor has for instance most likely monopoly on access infrastructure in rural areas [22]. But in more densely populated areas or within cities, there are opportunities for several actors. Size of the new development is probably also another important factor in deciding whether there is room for more than one actor. Small scale developments would not seem to be attractive for more than the first mover. But if new developments include a higher number of potential customers, it may be profitable for more than one FTTH developer to enter also [22], [23].

Furthermore, the conveying ways should provide room for parallel fibre networks, e.g. in same or separate ducts. While the competition may be viewed isolated, it could also be that different FTTH builders can cooperate when establishing the infrastructure, and then compete on the other parts in value chain. In France, this kind of cooperation is already observable in brownfield, but may be implemented in greenfield situations as well. Several actors share the ducts into buildings, and coupling cabinets/splitters in basement provide the opportunity for the customers to switch between operators. Internal cabling for collective use is administrated by regulations [23].

Based on these observations, possibilities for several fibre networks in the same area seem to present as long as aforementioned conditions are fulfilled. But it is also logical to assume that more than two or maximum of three FTTH infrastructure builders will not be necessary or profitable in any areas. Each of them would probably only manage to seize a minor market share, making it less profitable.

Summed up, this observation suggests that a single actor may not necessarily get natural monopoly in the future, particularly in the case of FTTH infrastructure in large scale new developments. Competitive actors should therefore not dismiss the thought of building out in greenfield areas just because others have already planned to build a fibre infrastructure. But the market size, i.e. number of customers, would be one decisive factor. The opportunity to enter into agreements between other FTTH builders as well as other infrastructure builders could create room for several FTTH networks. However, there may also be need for regulations in the FTTH market. This issue is addressed in *chapter 8.4*.

5.8 Chapter Summary

Greenfield FTTH deployments offer some advantages other than brownfield deployments of FTTH. The advantages include co-ordination of different infrastructures, first mover advantages in terms of access technology, fibre as an integrated part of the house, designing of an optimal access network structure and positive contribution to environmental challenges.

The possibilities for several FTTH actors with parallel fibre network are also considered in this chapter. There seems to be a higher chance of getting several FTTH actors in the same area, if certain conditions are present. For instance, the size of the development, i.e. number of potential customers, is an important factor.

6 Value Chain and Network Owners in Greenfield Developments

This chapter aims at evaluating the value chain and network owners in terms of FTTH deployment in greenfield developments. The analysis includes outline on the areas of value chain cost reductions and the strategic decisions can made when rolling out FTTH in greenfield areas. Different network owners hold different qualities, which is also thoroughly investigated in this chapter.

6.1 Value Chain Considerations

The different parts of value chain may be investigated with the intention of making various strategic decisions when planning and deploying FTTH network in greenfield developments. This part of the chapter will examine each part of the value chain with aim of identifying factors that may create more successful greenfield FTTH deployments.

6.1.1 Conveying Ways

Conveying ways is an activity in the value chain that is very vital, especially in terms of greenfield deployment. This is undoubtedly due to the high costs of civil work related to digging, laying ducts, cables and tubes. This phase presents a very good prospect for cost reductions. Co-ordination of digging and all infrastructure deployment is crucial for attaining an efficient and cost-effective FTTH deployment in greenfield areas. There would be need for cooperation as well as co-ordination among different actors who build the different infrastructures such as water pipes, electricity grid etc. and fibre developers. Proper agreements should be set in place, where distribution of responsibility and financial aspects are divided among the involved parties before the development starts.

6.1.2 Physical Fibre Infrastructure

In terms of the fibre cables, it is believed that there should be laid fibre cables if one already needs to dig. In new developments, there are clearly some diggings to be done, so one should utilise the possibility to lay fibre as well. It can also be argued that fibre should be laid even though there are no plans for an immediate implementation of a *functioning* FTTH network in the new development. This means that it should be laid *dark fibre* just so the opportunity to use it or sell capacity in the future, is present.

6.1.3 Active Network

An essential aspect for greenfield development would be to have a scalable active network to also cover future developments in the same area. In addition, it would also be crucial not to enter into agreements with vendors that create lock-in. Active networks could also contribute to a key part of the CAPEX, so that it would be beneficial for the network owner if they manage to obtain discounts. Discounts may e.g. be based on numbers of potential customers in the area [32], so greenfield FTTH owners should look forward and include future developments when negotiating for better prices.

6.1.4 Service and Content Production

Developer or the network owner could provide some innovative services with the purpose of enhancing the attractiveness of the new development. For instance, there could be demand for a service where janitor services could be ordered through interactive TV. These kinds of extra services, offered with new built houses, could possibly attract more customers, in addition to increasing economic return on the development.

6.1.5 Monitoring and Managing

This is an activity that may cause high OPEX. Therefore, it should be a specific thought-through plan on the holding of the lowest possible OPEX. Network owners often pay less attention to the OPEX than CAPEX. In greenfield developments, it would be significant to calculate and implement ways of reducing the OPEX. Why is this important? New developments are giant investments as it is, and FTTH would be an additional investment. Network owners who invest money in FTTH clearly expect the highest revenue achievable (within certain viable conditions). Even though the CAPEX is immense initially, the OPEX would in a high degree influence how fast the cash flow transfers from negative to positive, i.e. it may quicker yield profit for the investors. (More about CAPEX and OPEX will be outlined and discussed in *chapter 8*)

6.1.6 Customer Handling

This activity directly influences the customers. An advantage in a new development deployment could be that the required technical components are already in place, when customer moves in or takes over the residence. This concerns especially Customer Premises Equipment (CPE). There is no need for the customer to perform any installation, leading to a seamless adoption of FTTH. The challenge in new developments would be to have sufficient resources so as to provide good customer service, especially at the stage when the development is completed, and many customers move in at once.

It also makes it easier for the customers by including the payments for the services and the network in the monthly assessment of the house. This would demand extra effort from the network owner and perhaps the developer (i.e. *if* network owner is someone other than the developer), but offers a greater satisfaction for the customer.

Customer handling would be an important activity that also needs to be mapped early in the development phase. Even though the FTTH network itself is outstanding, thought-through customer relations would be very essential to achieve a successful FTTH business. One needs to consider if a single particular actor should provide customer handling, or if this task should be outsourced to an external actor. The latter would imply that the customer may have to deal with two (or even more) independent instances, which may be perceived as troublesome. This must be evaluated in terms of cost versus convenience factor and which business model one wishes to carry through (for instance open versus closed model).

6.2 Network Owners

When building a fibre access network for new developments, there are possibilities for several business actors to own that network. With the entry of the horisontal integration, it allows for several business actors to enter the value chain. This includes players like utility companies, municipalities and incumbents (e.g. Telenor). In this context, private investors and (property) developers can be deemed to be a possible owner in the future when building a fibre access network. A combination and collaboration among these aforementioned actors is also feasible.

Who is capable of managing the network, and who should do this? Owners of the network would look for economic return; there might also be other incentives for being a network owner in the fibre market. It is also vital to identify the different advantages and disadvantages of the causes of the different ownership models.

6.2.1 Utility Companies

In contrast to access networks like ADSL or coax which are mainly owned by incumbents, several fibre access networks are developed and partially or wholly owned by utility companies. In Norway, Lyse is an example of such a utility company.

Utility companies have numerous advantages that make them suited for the task. They have an already established infrastructure that they can utilise. This also implies that they have a long experience and knowledge in ducting and regulations that is connected to that, since these companies have laid e.g. power cables before. So there is scope for a significant level of corporation synergies within planning, developing, installing, management, maintenance etc.

Furthermore, utility companies often have an already established customer base from previous, related to other subscriptions (power, natural gas etc). This means that they encompass an extensive experience with handling customers, and possess systems to support such features.

In terms of a residential area, there is a need for a power grid from one provider or another. Since a utility company has to lay down a power grid, it also sets them in a good position to lay the fibre cables (the infrastructure) simultaneously, and exploit co-ordination advantages as well. Ownership by utility companies also present opportunities for establishments of new services as well as more interaction between different services like electricity, fibre, gas and so on.

Utility companies are also more apt for ownership if we consider their investment horizon. They operate in a time horizon of 30 - 40 years (may even go up to around 50), which makes them very suitable for being the owner in areas where the investment amount is very high.

6.2.2 Municipalities

Municipalities make the second group of actors who may be network owners. Normally, municipalities are co-owners with other actors, like for instance utility companies. Initiative from several municipalities in Norway has brought fibre to the communities that live in the appurtenant areas. What are the prospects of municipalities being the owner in new developments?

Municipal ownership may seem feasible when there are new developments that have some link to municipal interests. If it is for instance municipal residents, schools, office buildings etc. that are built, then there is certainty that the municipality would consider ownership. Municipalities have a different approach to value creation. Beyond pure economic profit, it is a higher degree of social-economic value creation involved with municipal ownership. This is true because a municipality is an authority with responsibility for the whole community in that area. Hence, there are more ideological aspects that will be enclosed when municipality becomes the owner.

Other advantage is that in many areas, especially in Norway, there must be obtained a digging permit from the municipality before anyone can start to dig. So in the case it is the municipality itself which is going to own the fibre, there could be easier to co-ordinate since the planning and permit is gathered at one actor.

It is also easier for municipalities to obtain funding from authorities. Høykom is such a Norwegian body that provides economic support to different projects initiated by municipalities in the country[12]. The funding may not necessarily be reserved for only municipalities in the future, but they are at least assured a good position to get it also in the upcoming years as well.

One other advantage that may lead to good prospects if municipalities became owners in new developments, is that there will undoubtedly be new services that would benefit the public in a unique new way, for instance the emergence of e-Health and telemedicine (e.g. as part of the Smart Homes that I discussed in

[12] From the start of Høykom in 1999, over 400 million NOK has been given to over 400 projects in more than 100 municipalities in Norway [67]

chapter 5.3). As an example: It may become a standard service to offer a health check-up through a high definition video conference in the future. Since it is public health service in Norway, it could be profitable for the municipalities to own the fibre them self. By adopting such a strategy, they can offer services using their own network making it cheap, instead of needing to make agreements and be a service provider on others' network. The latter may be more expensive. So already by entering as a network owner in new developments, the municipality can ensure of having a network they own and can use as they wish for future public services. This is of course a long-time scenario, but not unlikely to happen.

There are some disadvantages with municipal ownership though. One often experiences much bureaucracy with public bodies, and this could be true here as well. One surely does not want to slow down a building process because of bureaucracy. There is also a potential possibility for the municipality having a longer time-to-market (TTM) since they are not involved in a major risk as private investors.

It may also be that municipalities are not always suitable for ownership of new developments. For instance if the new developments are not considered as a beneficial or within municipal interests, there may not be any point in municipal ownership. It is also not guaranteed that the municipality will always have economic resources to become the owner, while other actors as private investors or utility companies have the economical strength to do so a shorter time period.

6.2.3 Incumbents

Incumbents are defined as established firms within a market segment [33]. In Norway, Telenor is typical Norwegian example of incumbent in the telecom sector. Telenor has been absent in the FTTH market in Norway, until now. This can probably be explained by different reasons. This can probably be explained by the fact that the incumbents often try to delay the "sunset", i.e. they try long enough to profit from an already existing technology. This is done by several ways. Telenor and the GSM Association did e.g. make "emerging markets[13]" as their strategic area, when it became clear that the mobile telephony in developed countries was approaching its saturation points [34].

So it is logical to state that incumbents enter the market late as they do not want to introduce a new technology while the old access network is still profitable. Replacement of network (and different technologies) is indeed a costly affair.

[13] Emerging markets are for instance in developing country like Bangladesh.

The transition from a currently good access network (like ADSL) to a better one (i.e. FTTH) may not yield a significant difference in profits, since customers may not recognise the need for the change in access technology at the given time.

However, this does not mean that incumbents are not aware of FTTH. For instance, Telenor has rolled out hybrid cables to all of the houses they have laid copper access for, both new developments and other areas since 2005 [23], [35]. They have just recently announced that they want to enter the FTTH market. So being incumbent gives them a solid advantage in that they have already rolled out fibre when they laid infrastructure for another access network, here ADSL. In the same way as a utility company had laid other kind of ducts, incumbents have also exploited the opportunity to co-ordinate digging and ducting.

The other advantage of an incumbent being the owner is that they also often have a big customer base like utility companies. For Telenor, the number of their broadband customers is around 1.7 million in the Nordic region, whereas around 1.4 million are xDSL customers [36]. This means that they are likely to reach out to a larger crowd when they intend to introduce FTTH, and receive a profitable penetration level. Another advantage for incumbents like Telenor is that they are likely to have a well-established infrastructure in most parts of the *country*. Telenor also has several Central Offices (CO) spread throughout Norway. This will reduce the costs related to housing for the network components.

So an observation of incumbents, especially through the use of Telenor as an example, is that they are somewhat late to enter the FTTH-market. They do not seem to be in a "rush" to make use of their fibre infrastructure, probably because they have a market position in several access technologies. It is mentioned in [36] that FTTH should be a part of Telenor's access portfolio, and they pursue a *balanced* strategy. In other words, they seem to combine different access technologies, among them are FTTH based solutions. It is also understood as FTTH is not their only access technology in the coming years. This is a difference from e.g. utility companies that do not own other access technologies, and hence goes totally in for fibre roll-out.

6.2.4 Property Developers

Lately, property developers are also opening up their eyes for FTTH. Developers' main intention for owning and deploying a fibre infrastructure is for increasing the value of their property. While this seems to be a well known fact in e.g. North America, in Norway one may wonder if real estate developers are aware of this to the same degree.

RVA & Associates estimated that FTTH adds in average about USD 5000[14] to the price of home in USA, which is a considerably excessive large sum [1]. This is shown in Figure 14. In Norway, it is generally estimated around 4% increase in the residence value if FTTH is implemented [37]. Even though a home price premium of 4% of the house price could appear to be unrealistic high for a property developer, any percentage increase that gives profit would be considered a good economic argument to roll out FTTH.

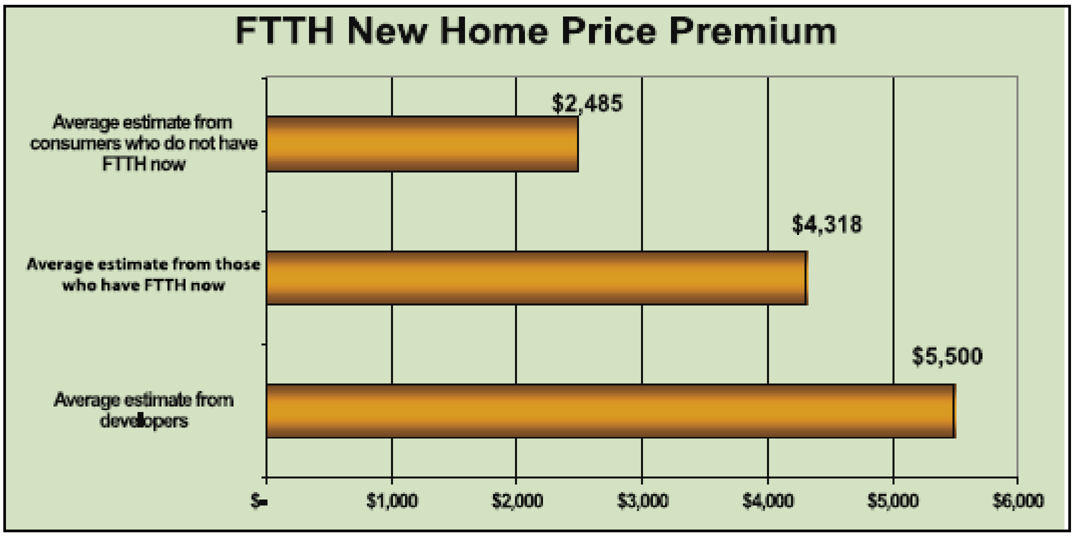


Figure 14: Value increase for a new house with FTTH. Extracted from [1]

It seems like it would be more sensible to assume a home price premium of NOK 30 000 – 35 000 for a house that costs NOK 3 million. Discussion with Norwegian FTTH actors indicates that this is a more realistic value. According to Tom Solberg, Manager of Business Development at NetNordic, 1-2 % would indeed be a more reasonable percentage than 4% [38]. The value increase of the house is however dependent on the knowledge house buyers have about FTTH and how they appreciate it [38]. So with increasing knowledge and acceptance of FTTH, it would also be fairly to assume that home price premium could increase.

For property developers, new developments therefore present a good opportunity to deploy FTTH, and increase the revenues as they sell the houses. This is also strongly connected to the rate of return (ROR); a question of how much they will be able to earn on deploying FTTH in the new development. It is mentioned that around 100 houses may be enough to deploy an economic viable FTTH deployment [1], but it is reasonable to believe that the more potential customers,

[14] With an exchange rate around 1 USD = 5 NOK when writing this thesis, this amount is equal to around NOK 25 000.

the cheaper will CAPEX per user be. As for property owners, the profitability has to be considered for each development, and it is strongly connected to the size of the development.

Based on these observations, property developers would most likely be involved as owners in greenfield development, given that the number of houses or potential customers are high enough.

6.2.5 Private Investors

Private investors are in this context used to denote those who invest their money in FTTH and remain passive, until certain profitability is achieved. It is a known fact that private investors expect high returns in a shorter time period than other actors like e.g. municipality or utility companies. They may also be interested in early exit, when they have made satisfactory earnings.

Value of the networks depends on their size, i.e. number of customers [31]. This implies that when private investors want to sell out, profitability will be higher for each additional customer in that network. Thus, it is reasonable to assume that private investors would not be interested in owning and investing in a FTTH network that have a low number of potential customers. High number of customers also yields bigger return from service providers who wish to use this access network.

It is safe to assume that private investors do not place top priority on social-economic value. It does not mean that they are just profit oriented, but usually means that this is a not their first priority. However, investors may have different characteristics and there may be some who manage to combine both profit making and social value creation.

So in what situations would ownership be advantageous by private investors? Certainly, if it exist a potential for high number of users in the FTTH network, this could be of interest for private investors. In new developments, where emphasis on large scale investments is high, private investors may be the right actors to throw in money.

Private investors may also be more interested in investing in fibre access network if the new development is a bigger area which includes business life as well. If new and effective services accommodated enterprises and firms are delivered by service providers (e.g. 3D-video conferences) on the network, they may take more in provision from the service providers as well as getting good income from the firms for use of the fibre. This could therefore be a lucrative business for private investors if they become owners at the correct situation in the future.

For new developments that need instant funding, private investors also may be well-suited, given that they see profitability in the upcoming years. They may for instance build the network and provide for the economic expenses at the start, and have an agreement with e.g. municipality that they can take over in certain years when the ROR is satisfying for the investors.

In conclusion, one can claim that due to the short-term focus on return, private investors may not be an appropriate owner. But in the upcoming years however, private investors may in a larger degree see the profitability in FTTH investments. Indeed, during the course of my study in the thesis, I got a stronger confirmation of private investors as emerging owner group of FTTH in the future. In the conference "Bredbåndsdagen 2008", there was pointed out that private investors are beginning to see big possibilities in the FTTH market [20], [39][15].

6.3 Chapter Summary

The different activities in the value chain can be evaluated in order to identify important key factors that can give a successful FTTH deployment in greenfield situations. Co-ordination and scalable active networks are two examples of greenfield related aspects that should be considered.

Evaluation of networks owners like municipalities, utility companies, property developers and private investors shows that there are possibilities for different owners with dissimilar qualities. While utility companies and municipalities have a much longer investment horizon, private investors would probably wish for a much quicker return on the investment. For greenfield FTTH, the property developers also shows advantageous qualities for being the owner, and there are reasons to believe that they will increase in the coming years in Norway.

[15] An example of this is Asker and Bærum Fibernett, a company owned by private investors. Their goal is to establish fibre in the Asker and Bærum area in Norway.

7 Evaluation of Business Models

An overview of the open and closed business model was given in chapter 3. The open access network model seems to be a favourite of many alternative network owners nowadays, while incumbents and utility companies like Lyse follow the closed model mentality. Based on the type of access model that is chosen to deploy FTTH, the pick will undoubtedly produce different outcomes. Thus, important questions are what advantages and disadvantages these models impose, and what kind of business models that may be suited for various greenfield developments.

In this chapter I will first evaluate these two main business models, and try to identify their associated advantages and disadvantages. Finally, I attempt to give some conclusive words about the business models, both in general terms and more specifically in relation to greenfield FTTH deployments.

7.1 Evaluation of the Closed Network Access Model

Closed access network is the traditional way of organising the network and accompanying services. Even though it is outlined that closed access network may give monopolistic power to the one network owner, which often is considered not to be the optimal market situation, one may find justice for this model.

We can take Lyse as example. When they started up as a FTTH actor in 2002, ADSL from Telenor was the most widespread option when it came to broadband. So when Lyse wanted to establish itself as a disruptive company in the broadband market, they had to make some economical and strategic choices[16]. FTTH requires big scale investments, and especially when one is the first player to build up as a new challenger against incumbents, the company would try its hardest to reduce the risk and uncertainty around the investment. Therefore, Lyse felt they could operate most successfully by controlling every activity in the value chain, all the way from building the physical fibre infrastructure to be service provider. In other words, this vertical network model gives early disrupters more control – both in terms of cash flow and the strategic way to manage a FTTH network.

In a Høykom report from 2007, Erik Gundegjerde, the Managing Director of Lyse, gives their perspective and response on the common accuses about the company offering the customers a closed access network [40]. According to him, many underestimate Lyse Tele's solution. He says that in Lyse's business model, the high penetration level of their commercially available products gives them possibility to build a fibre-optic infrastructure on solid business grounds, while in open networks you are dependent on the customer to finance a large part of the infrastructure. This seems to be the prevailing situation for e.g. Troms Bynett where customers must pay a big amount upfront.

However, opponents against the closed access network model in the telecommunication sector point out several drawbacks with this model. One is of course the problem with a single business actor keeping control of the whole value chain, and in theory, retaining power with monopoly tendencies. Since it is only one or some few service providers who are regulated by the network owner present in the access network, opponents often argue that the closed model hinder variety in services and further innovation. Customers then do not have the freedom to choose who they want to use as their service provider, and are often offered a so-called triple play packet instead. The closed model therefore is often regarded as a static business model.

7.2 Evaluation of the Open Access Network Model

Open access networks make it possible for many service providers to present on the same network. Instead of one actor controlling the whole value chain, the roles are given to appropriate business actors. This shall in turn give the

[16] Disruptive company can be described as a company that either creates a new market, or enters an existing market, with new features or changes that address different aspects like technology, product, regulations, customer behavior and etc [33]. Ergo, disruptive companies challenges already existing standards imposed by incumbents.

customers freedom to choose from a variety of services, as well as switch between service providers as they please without any constraints. As the open business model promotes competition between the service providers, supporters of this model argue that the customers will get cheaper prices on the services, i.e. market price, while the quality of these services are high (so they can attract the most customers).

The open model would also seem to encourage formation of new service providers in the market, meaning that smaller and niche service providers could also offer interesting and innovative services on the network. So long as the new service providers can pay the provision or fee set by network owner, they would also get an equal chance to compete in one the network for customers' favour.

The open model contributes in another positive way for the customers as well. Service providers would, as a result of the "open market place", try to differentiate themselves in order to attract the customers. This would benefit the customers as more individual preferences could be satisfied by one of the many service providers.

So are there any drawbacks related to the open network model? One may claim that the open network model is not mature enough to harvest all of the mentioned advantages, because it is considered to be relatively a new way of organising the value chain in the telecommunication business. And even though the model encourages diversity among service providers, in practice there are not so many yet. This is illustrated in *Figure 15*. While one often depicts the open access network model as a *free economic market* (or competitive market), I would rather portray it as *oligopolistic market*, at least for the time being. This is for instance the situation for Troms Bynett, who is pursuing an open business model.

The openness of the access network may be really beneficial for the customers since the service prices are pushed down, but this may also affect many of the established *service providers* in a negative way. Some will be squeezed out as they fail to keep up in a potential price war. In this context, one interesting example can be emphasized from the Troms Bynett. Most of the Internet Service Providers (ISPs) are Norwegian in this network, and all have a similar price level. But recently, a Swedish ISP also entered the market. Figure 16 shows the monthly price for Internet access with 6–10 Mbps bandwidth. Compared to the Norwegian actors, the Swedish actor (Bahnhof) has a remarkably low rate. Sweden is long known for the much cheaper Internet rates compared to Norway. But as the open business model arrange for a non-discriminative service offers in the access network, foreign service providers do also have the opportunity to enter the Norwegian FTTH market.

While such a price competition comes as pleasure for the customers, Norwegian ISPs in the market could be forced to lower their prices and in worst case, forced out of the market. This challenge is somewhat new for the time being since such city networks ("Bynett") and open models are more a recent phenomena in Norway. However, in the coming years this would need a higher attention. Too much "openness" would maybe result in need of some kind of regulations, e.g. through Norwegian Post and Telecommunication Authority (NPT). This discussion about regulatory aspects is continued in *chapter 8.4*.

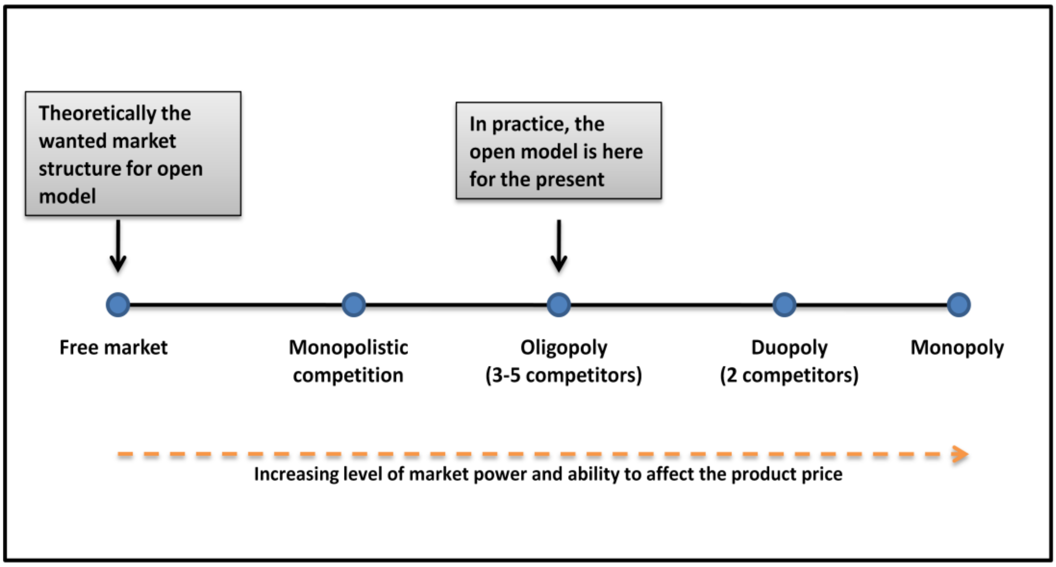


Figure 15: Different market structures and open business model's position

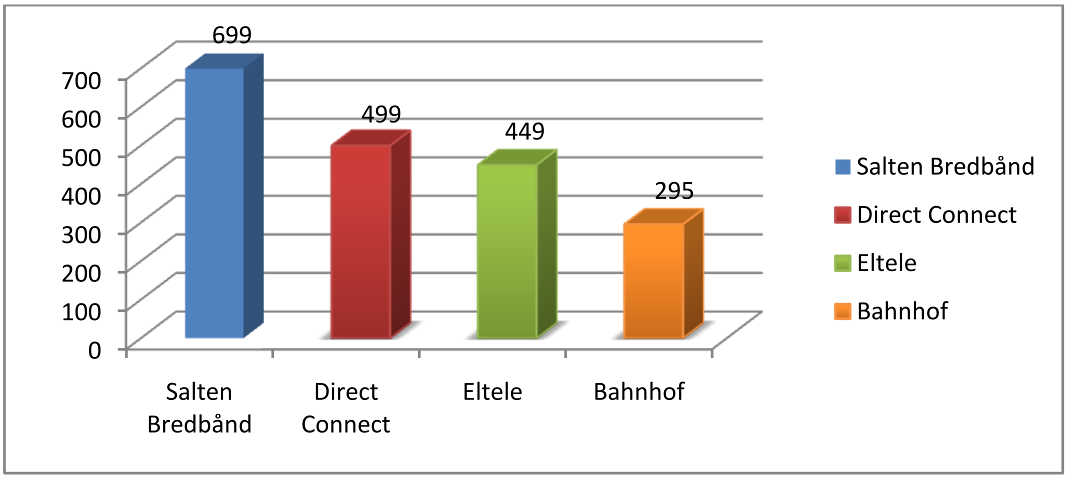


Figure 16: Internet prices in Troms Bynett

7.3 What Is Best For Greenfield Developments?

By looking at arguments for and against open and closed access model, one may not strongly advice one model in preference to the other, at least not without looking at the circumstances of the FTTH deployment. When the open and closed business models are outlined, they seem to be the opposite of each other. They theoretically represent two extreme points; the open business model on one side, and the closed model on the other side. The reality may not be so black and white. The above defence from both camps for which model is the superior may seem to have gone out of hand. It may therefore be need of a more objective reasoning.

For instance, even though the practicing of closed model by Lyse (and its partners) is criticised, Lyses customer base continues to grow. Lyse also persists on getting several new partners in Norway, and currently also in Denmark. What does this tell? Obviously, the closed model works.

It is given a good illustration of this in [6]. In year 2005, roughly when the open model was introduced, it was estimated that around year 2008 it would be around 60 000 customers within the closed model. The corresponding number for open model was estimated to be around 40 000 customers. These numbers proved to be incorrect. Now it is over 100 000 households in the closed model, while the open model has around 10 000 customers.

Hence, it seems like even though the closed model in theory creates local monopolies, this does not create too much problems, or more precisely put, this have not created any problems until now. It gives for instance small municipalities in Norway the opportunity to enter the FTTH area without too much trouble, and the service prices are not noticeably higher than in an open access network. In the same way, the open model is having its success in Sweden with high penetration level and many service providers. So this business model certainly has the potential as well.

Through the discussion above, it should be clear that both open and closed model has advantages and disadvantages. One must consider the different circumstances before choosing. So how is the decision taking influenced when we consider what kind of business model to use in new developments?

By looking at the different business models, that is open versus closed, it seems like each model are good for different time perspectives. For the short-run, and initially, it would make sense to implement a vertical model for new developments. How so? There may be a need to have a ready and thought out plan for what services one should offer for those who move into the new residents. One can give a concrete list of what services that would be provided, without any need for the customer to pick out self. It would be a more convenient agreement for the customer to be to when there are well-defined and precise network services.

In the long run however, it seems like the open access network model presents most opportunities as well as freedom of choice. By introducing the open model, one can argue that one add an extra value to the FTTH in the new development, and at same time providing for a future proof business model. Recall that in *chapter 5.4* I outlined how greenfield deployment of FTTH opens up for creating an optimal FTTH solution. For that purpose open access network model appears to be well-suited in the future.

Furthermore, the open model would satisfy the *customers* most. While one may argue that customers in a closed access network get all the services they need, they do not have the opportunity to choose from the beginning. One argument that favours the open model is: How can one say that the customers are really satisfied in closed access networks, when they never get the chance to pick out the service provider themselves? To put it another way, are the customers just pleased to get FTTH in first place so they forget that they never get the chance to choose what service provider they want? Therefore, customers seem to benefit more from an open business model than the closed one.

In addition, I would claim that new niche services would not flourish in a closed business model. Since the open business model actors are mainly interested in providing services that many of their customers are willing to buy, niche services would not be prioritised. I believe that niche actors and services would be important for satisfaction of customers and source for further evolution of new services that become commercial.

However, one important point is that the network developer would wish to choose the most *economic profitable* business model. The closed model would provide a uniform and somewhat predictable income compared to the open model, since the network owner controls and composes in advance a service portfolio that is to be provided on the network.

The open model is more unpredictable in terms of cash flow, by not knowing how the income would degenerate. For instance, the network owner would most likely not know in advance the number of service providers in the network for a future time period. This would therefore affect the income. This gives the network owner two possible scenarios [41]. One is that the revenues can exceed the expectations, thus giving higher profitability. The other is the opposite where the network owner suffers economic loss. Thus, one could say that the economic risk is different for the open and closed model. This risk must therefore be evaluated by the network owner *before* the investment and implementing an overall business model.

As this discussion shows, there would be difficult to nominate one “winner” among these two business models. If the network owner is willing to risk a bit in order to increase the profitability, and at the same time sees the benefits of giving customers the opportunity to choose between service providers, the open model would be the most fitted. The closed model would be preferable for network owners who want a predictable outcome, and believe that they would meet the customers’ demands without opening up the network for all service providers.

Greenfield FTTH could therefore follow any of these models. A good alternative could be to operate as a closed network model initially, by providing only one service provider for each service type. Then, when the time is right (solid economy, enough customers, new type of services on the market etc.), the network owner could open up the value chain, and follow the open access network policy.

7.4 Chapter Summary

This chapter discussed the main advantages and disadvantages of the open and closed access network model. These are summarised in *Table 2*.

Supporters of each model argue that the one model is better than the other, but the picture is a bit more nuanced. Comparing the benefits and the disadvantages for each model, the open business model seems to the most promising for the future in terms of customer satisfaction and optimal market structure. But the market trends also shows that the closed model has a solid and functioning place in the FTTH market.

Each model also appears to have different qualities when it comes to profitability and risk. The open model may have a higher risk, with potentiality for higher earnings. The closed model has a lower risk, but also a moderate possibility to yield a higher rate of return than expected.

This indicates that each model would have to be considered before the FTTH deployment, in terms of risk and profitability as well as where one want to settle in the discussion about innovation, niche services and customers.

Table 2: Advantages and disadvantages with open and closed access networks

	Open Access Network	Closed Access Network
Advantages	• Abundance of service providers • Freedom of choice for customer • Theoretically optimal market structure • Encourage niche services and innovation • Possibility for higher earnings than expected	• All support is performed by one actor • Gives small municipalities change to easily and quickly deploy FTTH • Have a solid financial ground already before deploying FTTH in an area • Less risk, somewhat predictable earnings
Disadvantages	• Still immature as business model in Norway • Some service providers may be squeezed out • Foreign service providers may force national service providers out of the market • A bit greater risk than the closed model	• Customers cannot choose which service provider they want • More power to the network owner, and less to customer • Creates local monopolies • May hinder niche services and further innovation compared to open access network

8 Economic, Technological and Regulatory Considerations

The economic aspects are essential in all FTTH deployments. Large amounts of money are involved both in terms of CAPEX and OPEX. Many natural questions arise in connection with this. For instance: How does the cost picture differ from a brownfield deployment to greenfield development? What does the architecture selection have to say for revenue and the different expenditures? And from the customer's point of view, what kind of finance models would be well-suited? This chapter will try to indicate some key points for these questions, seen in relationship with FTTH in greenfield developments. In addition, regulatory aspects are also discussed in the end this chapter.

8.1 Cost Picture for Greenfield Deployment

The cost picture for greenfield FTTH deployment is not radically different from a brownfield deployment. However, there are certain points that differ. Some of these points have already been mentioned, but here I will look a little bit closer at them. This chapter outlines some general observations.

As mentioned, co-ordination of civil works would be one of the cost factors that can be reduced considerably. The saving would be depended upon several factors, where one of them is which actors are involved in the civil works. For instance, property developer and a utility company could co-ordinate. This means that both parties could enter an agreement where they share the civil work costs. One could e.g. imagine that that the utility company would pay a certain percentage of the related civil work costs. Thus, partnerships between involved actors in new developments could give a substantial reduction in the CAPEX.

One simplified example can illustrate this. CAPEX each customer is estimated to be around NOK 20 000 in Norway [6]. Troms Bynett would for instance charge each customer this kind of amount before FTTH deployment in a particular area. Let us assume that the civil works make up 70% of the CAPEX and that a utility company is the FTTH owner. Co-ordination with the property developer could make it possible to share the civil works cost, for instance by 50-50. This would make the CAPEX per user to go down by 35 %, which is a remarkable amount (see Figure 17 for illustration). In the same way, if one assumes that the property developer is the network owner, the civil work costs could be set to zero because the property developer would need to pay for civil works not related to FTTH anyway.

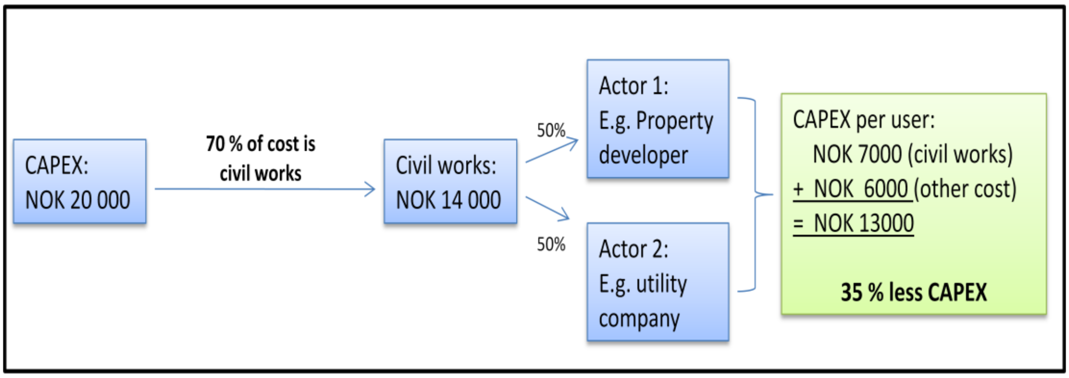


Figure 17: CAPEX savings by sharing the civil work costs

Surely, the above example is bit simplified from the reality, but is a good indicator for how coordination can cut the CAPEX. The point is anyway that there are positive economic impacts for both the network builder and the customer. Network builder can get a footing in the market, without an equal high penetration as brownfield deployments, thus getting customers that before were not within range. On the customer side, there are many more that can afford or consider FTTH, since the initial cost is much lower.

As aforementioned, penetration level is also an issue that is directly connected to cost. Penetration level in greenfield developments will most probably be different from FTTH deployments in brownfield. Multi-unit dwellings or other new houses are often sold *before* the development starts. In addition to this will FTTH be a better and maybe the only best access technology present. So customers would more or less be in at situation where there are no better choices than agreeing on a FTTH offer as well. One should not exclude the possibility for houses with FTTH being the most attractive houses to purchase in coming time. So many of these factors could actually give a near 100 % penetration level in new developments in the future, while it still may be profitable to also operate on a lower penetration level than what is necessary for brownfield developments.

8.2 Finance Models

One of the most crucial elements when deploying the FTTH network, from both the investors and the customers' point of view is how the financing is settled. Many open access network models may be the best option instead of closed ones, but they often fail in designing well financial model which is suitable for the customers. This was for instance true for potential customers for Troms Bynett. Their financing model called for around NOK 20 000 before the deployment, making it difficult for customers to pay, and thus giving them fewer customers [42]. It seems to be more concentration on how the network owner can finance the FTTH roll-out than how the cost looks from the customer's point of view.

Alternatively, the infrastructure owner could instead pay this onetime cost self and later get it back by adding a monthly sum to the other cost for services or by other means. This would on the other hand increase the economic risk for the network owner.

The financing seems more positive for greenfield deployments than brownfield deployment however. First of all, the possibility for cost reduction as a result of the co-ordination between actors is itself an encouraging point for the customer (and of course the other parties involved). This should give the customer a much cheaper establishment fee. Moreover, in a greenfield deployment it is more likely that the network owner (e.g. property developer) takes care of the initial costs for the fibre infrastructure. In brownfield, the customer is often the one who pays for this through high establishment fees.

Some actors would and must probably still continue to charge their customers a certain establishment fee, if that is necessary for their business model (e.g. they cannot take so much risk in a particular area, open network model etc). However, network owners could try another positioning when charging the customers than today's usual financing models. Below, I suggest two possible approaches that network owners can adopt to finance the FTTH expenditures.

8.2.1 Two-Part Tariff Model

In a greenfield development, one have the possibility to complete the network deployment in two phases. First, one could build the FTTH network with a 100 % penetration level, where all the houses have fibre sockets installed, but where these are not activated. In the second phase, when the customer wants to use the FTTH network, the network owner would activate the connection by installing the media converter which transforms the optical signal to electrical signal [43].

This kind of two-phase completion of the FTTH network gives opportunity to use a *two-part tariff financing model* for the network owner. A two-part tariff is a pricing method in which consumers are charged both an entry and usage fee for a product or service [44]. This pricing method is not unknown in the telecom business. Customers pay for instance a monthly access fee, and then per-minute fee for their telephone services.

This could be a financing alternative that may be used by the FTTH network owner, a bit differently. The customers, i.e. the buyers of the new houses, would in this model pay a little initial amount, hopefully much lower than today's amount for establishment. In Norway for instance, many houses are sold before they are developed, demanding a certain advance payment from the buyer. Likewise, customers would in advance be charged for a certain amount for the *opportunity to use* the FTTH network when the deployment is done. After this, the customers would have to pay a usage or activation fee when they move in or wish to become a FTTH customer at a later point. The concept is illustrated in Figure 18.

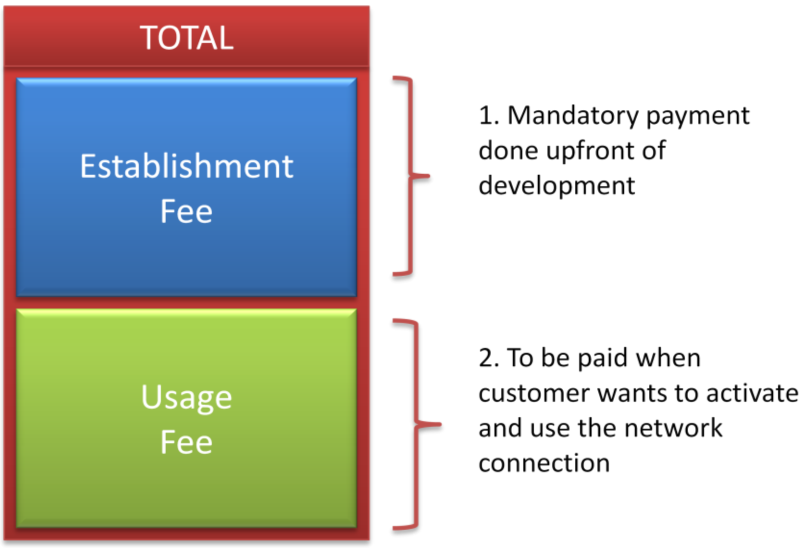


Figure 18: Two-part tariff pricing model

What are the advantages by adopting a two-part tariff model? One is the opportunity for the customer to go for FTTH at later point even though she is uncertain of this in early development phase. This also gives the opportunity to divide the amount the customers have to pay in two smaller parts for two different time periods. This could for many customers be economically feasible, in addition to give customers the feeling of not paying a big sum at once (a psychological effect).

Also for network owners would this model be advantageous. They reduce the risk, by getting a certain amount before the development phase. And it would be most likely that the customers would activate the FTTH network as the time goes and high bandwidth demanding services are only feasible through FTTH network. Thus, the network owner can count on a certain revenue flow after the customers move in.

This model does not come its without challenges though. The main problem with two-part tariff model is how to set the entrance and usage fee when there are many customers [44]. There is no simple formula to calculate the optimal entrance and usage fee. So there would be need for some trial-and-error experimentation to find the most optimal establishment and usage fee. The two-part tariff model is further explained in *Appendix A.2*.

8.2.2 Price Discriminating Model

Another type of financing model that the network owner could impose is charging different group of customers for different amount for the initial investment, i.e. the required CAPEX. In this context, different customer groups would for instance be customers who are willing to pay everything in upfront and customers who are not sure and may choose FTTH sometime in the future after they have moved in. This means that the first mentioned group could get a discount on the establishment fee, while those customers who wait will not get this discount. This is what in micro-economics is denoted as third-degree price discrimination [44] (see also *Appendix A.3* for a deeper note about price discrimination). This kind of price-discrimination would encourage the new house owner to choose FTTH from the beginning, simultaneously arrange an opportunity to choose FTTH later for a bit higher price for those who hesitate.

8.2.3 Some Final Remarks On the Financing Models

Both mentioned finance models could be combined to cover the decided part of the CAPEX. This means that for instance that one imposes a two-part tariff financing solution, but the usage fee might be reduced for those customers who sign up for FTTH from the beginning. And of course, there should be possibilities for getting a nice discount if customers pay everything upfront as well.

So there are two key points to think about in considering of financing models. One, the customers should feel that they will get the most lucrative deal if they manage to pay as much as possible initially, but still have the chance if their economic situation or other reasons make them wait. The second point, which indirectly follows from the first, is that network owners should put some effort in providing many different financing solutions so that most of the customer groupings can be satisfied[17]. Sure, this could be a challenge, but this would also provide a win-win situation for both customer and network owners.

8.3 Comparison of the FTTH schemes

This subchapter seeks to offer a cost and non-cost dependent comparison of the different FTTH schemes. The main focus is on AON, G-PON and WDM-PON, and my foremost aim here is to identify why diverse actors choose, and will choose, different FTTH schemes.

8.3.1 Cost Comparison (CAPEX and OPEX)

In *chapter 4.2*, the trends showed that the AON and G-PON structure are the most widespread architectures in Europe. G-PON seems to be the choice of incumbents, i.e. Telenor in Norway, while other actors like utility companies and municipalities goes for AON architecture. Followers of the respective architecture argue for the reasons why their choice is better than the other. Here one may want to consider both a cost and non-cost analysis to decide for what architecture to settle for in a particular situation, i.e. greenfield developments in this report.

Experience through the work of this thesis and personal discussions with several FTTH actors[18], indicates that the CAPEX for AON and G-PON is not considerably different nowadays. For WDM-PON however, the cost seems to be still too high to get a big commercial spreading. It is still not considered mature enough to be widely used. Nevertheless, WDM-PON deployments have begun to turn up. Novera Optics is for instance one WDM-PON technology supplier that

[17] Ideally, each customer should have an individual financing solution, but this may seem impossible and bit to idealistic.

[18] E.g. at the conference "Bredbåndsdagen 2008" [39].

aims at the FTTH market with their λ-PON™ technology [45]. During the master thesis, the company was unavailable when trying to obtain more information, but Novera Optics' technology illustrates that commercial WDM-PON deployment is completely feasible and around the corner.

One essential discussion then is how the OPEX cost would vary for PON and AON architectures. For instance, there would be a need for field engineers in AON for maintenance of the active components (this is actually the same situation for the copper based network). One also normally assumes that AON would demand more resources in form of powering because of the active components in the remote node, and it may further be necessary with indoor climate for the components to function. This would consequently increase the OPEX a bit. In addition, more errors could occur in AON (because of the active components) [23], which further could boost up the OPEX.

These OPEX increasing challenges have lately been addressed somewhat by the actors involved with AON. Troms Bynett, representing the AON model, reports that there their OPEX cost is actually not higher than for any PON models. As a matter of fact, their calculations show a *lower* OPEX than for a PON network. The reason for this is that the technology they have chosen (PacketFront) gives an automated control and provisioning system that reduces the OPEX, they claim [46]. AON actors who do not use this kind of provisioning system would therefore normally have a higher OPEX.

Telenor on the other hand, reports that their calculations for G-PON show that this is some percentage cheaper than AON, but these are not large numbers[23]. However, they have reached a conclusion for the time being that G-PON would yield the lowest CAPEX and OPEX for their concern, and will be the architecture they choose to adopt now.

Even though these above findings show that OPEX may be not so different when one compare the general FTTH architectures, the choice of vendors seems to be a significant cost issue. Proprietary FTTH components for instance, should be avoided, and it would be important for the network owner to choose a FTTH solution that has standardized components.

This situation is illustrated in *Figure 19* fetched from [47]. In a hypothetical FTTH build out, one wished to consider different architectures, vendors and network solutions. Six offers was collected, each having different composition of equipment, vendors and architectures. However, all of these solutions were supposed to manage the same tasks. For instance, both Bid A and Bid D are based on PON, but yields a different CAPEX and OPEX cost. This is also true for

Bid C and Bid D, which are based on AON. Different vendors, different ways of projecting etc. may give different CAPEX and OPEX cost which may not solely be concluded on the basis of FTTH architecture. It would be important for the network owner in the new developments to pay attention to these issues when deploying FTTH.

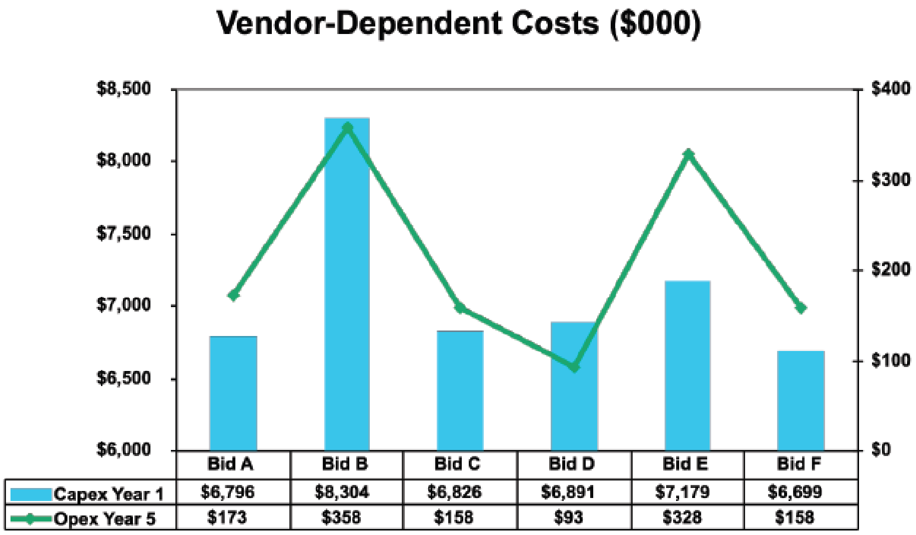


Figure 19: Cost variation with different vendors. Extracted from [47]

As seen until now, the discussion between AON and G-PON would not easily point out one winner in terms of costs. Vendors are mostly biased to their own chosen architecture. One must therefore be careful when making technology decisions. And with uncertain numbers from WDM-PON vendors, it would be very difficult to compare all of these technologies in terms of cost, i.e. CAPEX and OPEX. In Norway, for instance, WDM-PON is not commercially available yet. This makes it hard to get industry data. However, I have tried to collect some more cost comparisons between the different FTTH architectures in *Appendix B*: that could be interesting to note when one is in a position of comparing the different schemes.

8.3.2 Non-Cost Comparison

Beside the economic comparison, which may be said to be quite equal for AON and G-PON, there are other qualities for these two schemes that need to be evaluated. In fact, if the economic differences are not so significant, there must surely be some other factors that decide the architecture choice.

As outlined earlier, Telenor have chosen the G-PON architecture for their FTTH network, while Troms Bynett has gone for AON. A deeper evaluation of these architectures reveals that both have some different characteristics that are suited for different scenarios.

G-PON is most suited for a centralized traffic flow [48]. This indicates that the traffic in the network flows out of the local network. For network that does not have local content or services, this would be a good option. For Telenor, this is the case. In contrast to Troms Bynett, they have a more centralized structure on their network, making G-PON the best candidate. Telenor also mention that G-PON have good QoS handling. But a more important point is that they get an easier integration with existing xDSL management systems [23][19].

AON on the other hand, supports a distributed traffic flow, like what we find in the city networks [48]. This means that the traffic mainly flows between local nodes in that network, and do not "exit" the local network. If the network is going to support local services and content, the AON architecture gives the best performance and scalability. Since the city networks aim at connecting the local nodes and offering services for them, the AON is suited for this.

Another advantage for AON is that there are less geographic restrictions than PON. This is because a PON system has a distance limitation of 20 km, while AON can reach to the double of this. In fact, there are solutions available for up to 120 km or even more, but there has not been need for using this yet [46]. Even though 20 km range is enough now, further expansions in an area may derive advantage from the AON architecture.

Future expansion is indeed a point that needs consideration. PON demands careful planning, since the fibre is a shared medium that makes customers dependent on each other. AON removes this obstacle since new subscribers can easily be added to the network both without geographical restrictions [49] and technology that may scale better for greenfield deployments that comes is many phases.

Hence, unless you are an incumbent, the AON architecture may seem to be the best choice for the alternative FTTH owners. Greenfield FTTH deployments may also be best off with AON architecture to support future expansions in the same area.

[19] Note that this point is also discussed as one the advantages for incumbents being the network owner in chapter 6.2.3; they have existing systems and knowledge that can ease the transfer to FTTH.

8.3.3 Thoughts About Powering in AON

Power consumption for the network could also be an issue where most cost effective solutions should be evaluated. In this connection, there would for instance be some percentage of savings by using *solar panels* in CO and ORN. For instance, under Bredbåndsdagen 2008 conference, external housings for the active components and electronics were promoted by a Danish company called Intego[20]. It could for instance be a possibility for installing solar panels on the top, and thus try to reduce OPEX in the long run. Even though the utilisation level of current solar panels often is not satisfying enough, there are absolutely future opportunities presented. This semester a prize winning concept for third generation solar panels were introduced at NTNU [50]. This kind of technology innovations can make it feasible to invest in FTTH in smaller areas or reduce cost of the overall FTTH deployment in the coming time. In addition, it would contribute to a more environmental friendly solution.

8.4 Regulatory Aspects

The Norwegian Post and Telecommunication Authority (NPT) are responsible for the regulations in telecommunication sector in Norway. One of the most well-known regulations in Norway involves Telenor and their copper-based network[21]. This chapter considers the regulatory aspects for FTTH, especially in terms of future greenfield FTTH deployments. For instance, is there need for any new regulative laws to encourage or control FTTH deployments? And if so, in what degree is it needed?

Currently, there are no regulations on fibre access networks. This has not been necessary because the growth in FTTH has happened in the recent years.

As already mentioned, Telenor have quietly laid fibre cables in new estates. The possibility for two or more actor with their own fibre network was evaluated in *chapter 5.7*. Question that arises in this connection is whether there would be necessary for regulations of fibre roll-outs like Telenor's, so other actors are not squeezed out from the market. Personal communication with Martin Nord explains some of the confusion that is connected with the hybrid cable roll-out and in what extention this is done [23]. The hybrid cables are used just for the

[20] www.intego.dk

[21] Based on a legislative decree approved by EU (Local Loop UnBundling - LLUB), Telenor was identified as a monopolistic market actor, and further forced to open up its access network for all other actors who wanted to offer their services on it in 2003 [68].

final drop (i.e. the final distance from the end user to a remote node). Fibre cables between CO to the remote nodes have not been laid [23]. This means that Telenor still have to lay much more fibre cables to make the whole network fiber-based, just like other FTTH-actors.

NPT is actually observing Telenor and their actions with great interest, but have not planned any regulations in the near future [51]. This makes sense, since Telenor is currently not a big FTTH actor. NPT itself believes that Telenor would not get any monopolistic power within FTTH market as it did get with the copper based access [51]. Therefore, regulations on the passive infrastructure would most likely not be done by NPT [51]. This would imply that the authority trust the market to settle itself when it comes to competition on the passive fibre network level. In a more recent decree made by EU (December 2007), it is made suggestions that the regulations now also can be applied on other technologies than just the cobber based network. In other words, the LLUB market is stretched out to include also fibre (and other access technologies like coax etc). NPT emphasizes that there is room for introducing regulations if really needed, i.e. certain actors show significant market power (SMP). But even then, it would most likely be on a regional basis [52].

Regulations on the service level could however be relevant, similar to ADSL, if some actors get a strong market power in certain areas [51], [52]. Here Lyse could be a candidate, the same with Telenor. As Lyse, Telenor have also planned a closed access network model, i.e. they would not open up for other service providers on their FTTH network [53]. NPT is doubtful whether they want to intervene and regulate Telenor, because it could result in lower investment will from Telenor in FTTH [52].

The above findings show that FTTH could be regulated in the same way as the copper based access network, if one actor get SMP. Since regulations would be relevant on a regional basis in that case, independent FTTH owners could be hard to regulate, for instance greenfield FTTH deployments. The ownership of FTTH networks is much more varied than the original copper access network where Telenor had a near national monopoly. For FTTH networks with an open access network model, the regulation would not even have any considerable effect.

However, there may be need for regulations connected to conveying ways (ducts, poles) in a greenfield situation if many different actors are interested in building a FTTH network. Like the example in France (*chapter 5.7*), such regulations could be one of the key factors which make it feasible with parallel access networks, where smaller actors also are given a fair chance to be FTTH owners.

As it was mentioned at the end of *chapter 7.2*, where I discussed the open business model, there may also be need for some regulations based on who the service provider can be, and the price they charge. Especially when e.g. Swedish actors enter the Norwegian market, it would force out certain Norwegian service providers. If one want to let Norwegian operators to continue to exist, and not outstripped from the network, there may need for some kind of regulations. After all, it would not be beneficial for the open model, and the network owner and customers, if one service provider forces out everyone else. The service providers could be regulated by the network owner itself, but then it would sure be a discussion about the “openness” of that network.

8.5 Chapter Summary

Differences between brownfield and greenfield FTTH deployments are that co-ordination can lower the required CAPEX, and at the same time make it profitable even with a lower penetration model.

Financing models need to be more suited the customers. I have here suggested a two-part tariff model, and a price discriminating model to ease the financing for the customers, while they preserve the network owner’s interests.

AON and G-PON architectures do not vary too much in cost, but both have different qualities that need to be evaluated. I have argued that AON would probably be the best option for a greenfield FTTH deployment. WDM-PON is not commercially available in big scale yet, and is therefore difficult to evaluate.

This chapter has also taken regulatory aspects in account. In terms of greenfield development, it would be very difficult to create regulations that can be applied on owners of FTTH networks. However, it may need for regulations of the ducts or conveying ways in greenfield developments, to make room for competitive parallel fibre infrastructures. Also, especially in open networks, it may be need for some regulations; either from the network owner or an authority like NPT, to control foreign service providers entering the local FTTH market.

9 Additional Functions On the Established Infrastructure

Deployment of a fibre infrastructure in a greenfield situation gives opportunities for creating and offering new functions on the same infrastructure in addition to FTTH. In this chapter, I will briefly propose some additional ways the deployed fibre infrastructure can be utilised.

9.1 City Wide Wi-Fi Outdoor Coverage

Wi-Fi (Wireless Fidelity) is certification provided by the Wireless Ethernet Compatibility Alliance (WECA) for wireless LANs based on the 802.11 Standards [54]. Collection of Wi-Fi hotpots makes it possible to connect to the network wireless in a certain region. In Norway, “Wireless Trondheim” is such a project where one wishes to provide Wi-Fi access that covers most of the city Trondheim, i.e. a public WLAN [55].

When providing a Wi-Fi outdoor coverage, it is several options for the needed backbone network. It could be copper based network, licensed radio solutions (e.g. WiMAX), unlicensed radio solutions, and of course fibre backbone network. For WLAN operators (often denoted as WISPs for “Wireless Internet Service Providers”), the biggest cash outflow is the rental of wired backbone network [56]. Fibre backbone networks could be deployed by the WISPs themselves, but this would be somewhat expensive and not always justifiable in all areas.

With this in mind, a WISP who wishes to get the higher coverage and the lowest cost related to the backbone network, the fibre infrastructure that is established in greenfield situations could be a cost-effective alternative. The network owner of the FTTH and WISP could enter into agreements that give the WISPs possibility to use part of the infrastructure as their backbone network. This would be advantageous for both parts. FTTH network owner would get an additional income source, which could give a quicker positive cash flow or used to lower the establishment fees house buyers have to pay. The WISP on the other hand would reach a bigger potential market, with lower rent.

With an open business model, the WISP would not be so different from other service providers who operate in the FTTH network. In fact, the main thing that would differ is that there would be need for wireless access points to provide services. In other words, the FTTH network owner would in practical be offering one more service on the network for the customers. Revenue model can therefore be similar to what other service providers in the FTTH network agree to, i.e. yearly fee and a commission based on sales. As long as WISPs install the needed equipment in that area, they would get the same terms as the other service providers.

For WISPs these kinds of agreements with the FTTH owners could gradually give a higher coverage area for a much lower cost than other alternatives. Besides, bandwidth would not be a problem on a fibre network. Table 3 summaries the advantages for both FTTH network owner and WISP by using the established fibre infrastructure as a backbone network for Wi-Fi.

Table 3: Advantages for FFTH owner and WISP in using the fibre network as a backbone network

ADVANTAGES FTTH OWNER	ADVANTAGES WISP
• Additional service for the customers on the FTTH network • Increased revenues • Minimal effort is needed from the owner	• Larger coverage throughout the city • Cheaper rent of backbone network • “Unlimited bandwidth” can be provided

9.2 Feeder Network for Mobile Broadband

Mobile broadband is a description used for a set of different network standards like WiMAX (Worldwide Interoperability for Microwave Access), UMTS (Universal Mobile Telecommunications System), HSDPA (High-Speed

Downlink Packet Access) and Ice[22] which gives high bit rate Internet access through the mobile network.

Also for mobile broadband standards could an already deployed fibre infrastructure be favourable as the feeder network. Instead of deploying own dedicated fibre cables, mobile broadband operators can use the existing fibre to build out their coverage.

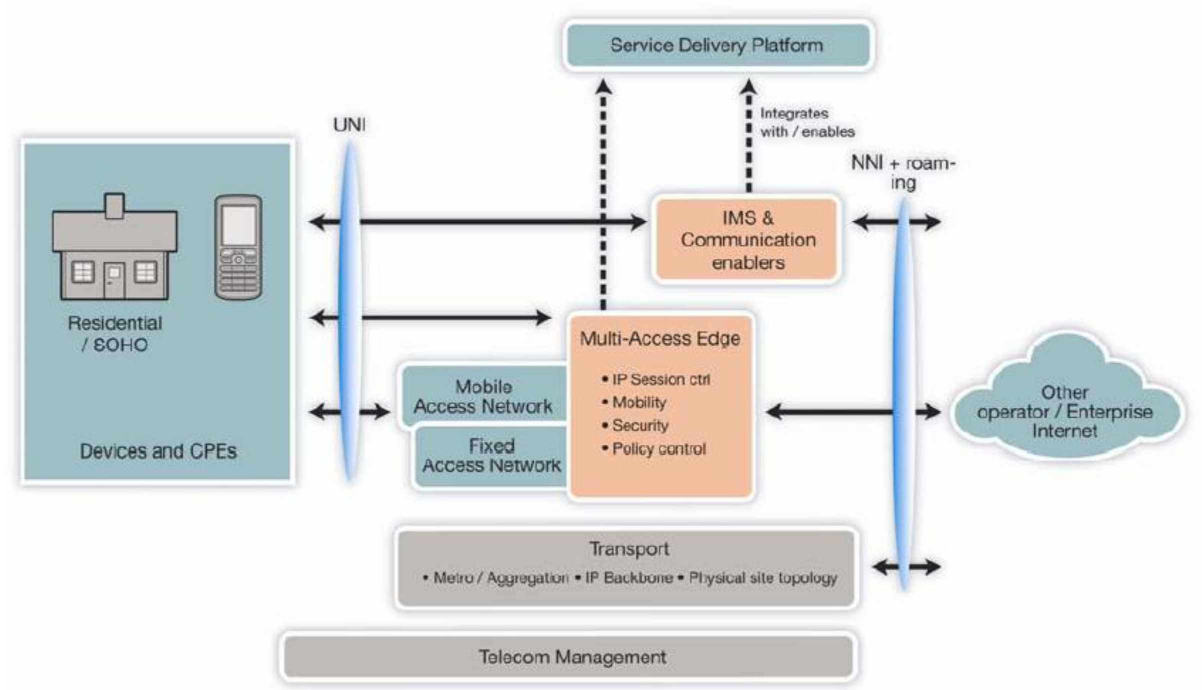


Figure 20: Full Service Broadband Architecture [57]

Full Service Broadband [57] is a term used for denoting network architecture that supports users with service connectivity from any device, anywhere; in a seamless fashion (i.e. network must support different types of mobility like terminal, user, session and service mobility). This would also imply switching between fixed and mobile broadband. In this scenario one wish to have a backbone that tackle high bandwidth demands and have high flexibility. For this purpose one could combine the already established FTTH network as backbone network to handle traffic from e.g. a base station [57]. Figure 20 illustrates the Full Broadband Service scenario, where the fibre infrastructure is relevant for the backbone/feeder network.

[22] Ice is a mobile broadband service offered on the old NMT450 network (i.e. operates in 450 MHz frequency). Ice is currently offered in Norway, Sweden and Denmark, at the time also being deployed in Poland. Ice offers a WLAN router in their product portfolio, as the only mobile broadband operator in Norway currently [69],[70].

This kind of utilization of the established fibre infrastructure would give a more cost effective solution for the next generation network (NGN). This would also save environmental costs related to additional digging, equipment and components for a parallel feeder network in the same area.

Anyhow, utilization of the already deployed fibre network requires interaction and cooperation between the different actors, i.e. FTTH owner and mobile broadband operator. Proper Service Level Agreements (SLAs) must be in place for instance.

However, one challenge is that the network owner would not be interested in this kind of co-operation if the mobile broadband is in direct competition with the FTTH network. But addressed properly, the possibilities for using different FTTH networks in a particular region as feeder networks for mobile broadband are definitely present.

9.3 Chapter Summary

This chapter has briefly outlined how the established passive fibre infrastructure in greenfield developments can be used in additional ways. The purpose here was to show that once the fibre is laid, it gives offers scope for providing new services on it, or integrate it with other network standards.

One way the fibre infrastructure can be employed, is as a feeder network for an area with Wi-Fi coverage. The fibre can also be utilised as feeder or backbone network for mobile broadband. This kind of combination of the established fibre infrastructure as feeder network, would give the greenfield FTTH networks a higher value on the network. At the same time, this also provides a foundation for providing services in that particular development area that ensures different kind of mobility. This concerns for instance seamless transfer between fixed network, Wi-Fi, mobile broadband and even mobile network like GSM.

10 Case Study: Lundåsen

The main purpose of this case study is to see how some of the different aspects of FTTH development that have been treated so far may be used in a real setting. By applying the discussed aspects in a case study one may also see what kind of practical problems that potentially could arise.

The case study consists of this chapter and *chapter 11*. Here is the background for case study as well as the overall business model outlined. In *chapter 11* is the economic part of the case study presented, where an investment and profitability analysis is presented.

10.1 Background

This case study is located in Trondheim Municipality (also a city), Norway. The population number here is 165 191[58]. In Trondheim it is estimated that around 1100 new homes are needed each year, and several areas are reserved for planned future developments [59]. Such areas are proposed by the Trondheim Municipality, and can be seen in *Figure 21*.

I have, in consultation with my supervisor, chosen an already developed area, and considered as it was a greenfield area. By doing this, I have access to the street design which would not be obtainable for planned developments. By knowing how the street pattern, I can estimate the needed length of the fibre cables as well as the topology for the network. This would also at the same time give a fairly alright picture of how to think in greenfield situations.

In the case study I wished to examine a defined area, in order of magnitude around 500 houses, with possibilities for more expansions in the future. It should also lie at the edge of the city, and not inside the city core. The development area mainly consists of private households. The house types should be single-unit dwellings, and/ or row houses (i.e. it is a FTTH case study and not FTTB).

With these requirements, the chosen area has situation in Lundåsen which lies south west in the municipality. This is marked with red circle in *Figure 21*. The area consists of two parts. One is a main area which already have settlements, but which I will threat as the main greenfield area. I will denote it as Lundåsen Vestre. The other part is the area called Lund Østre (see *Figure 22*), which is an actual area reserved for future developments by Trondheim Municipality. These two areas satisfy the above mentioned requirements more or less, and are therefore picked for the case study.

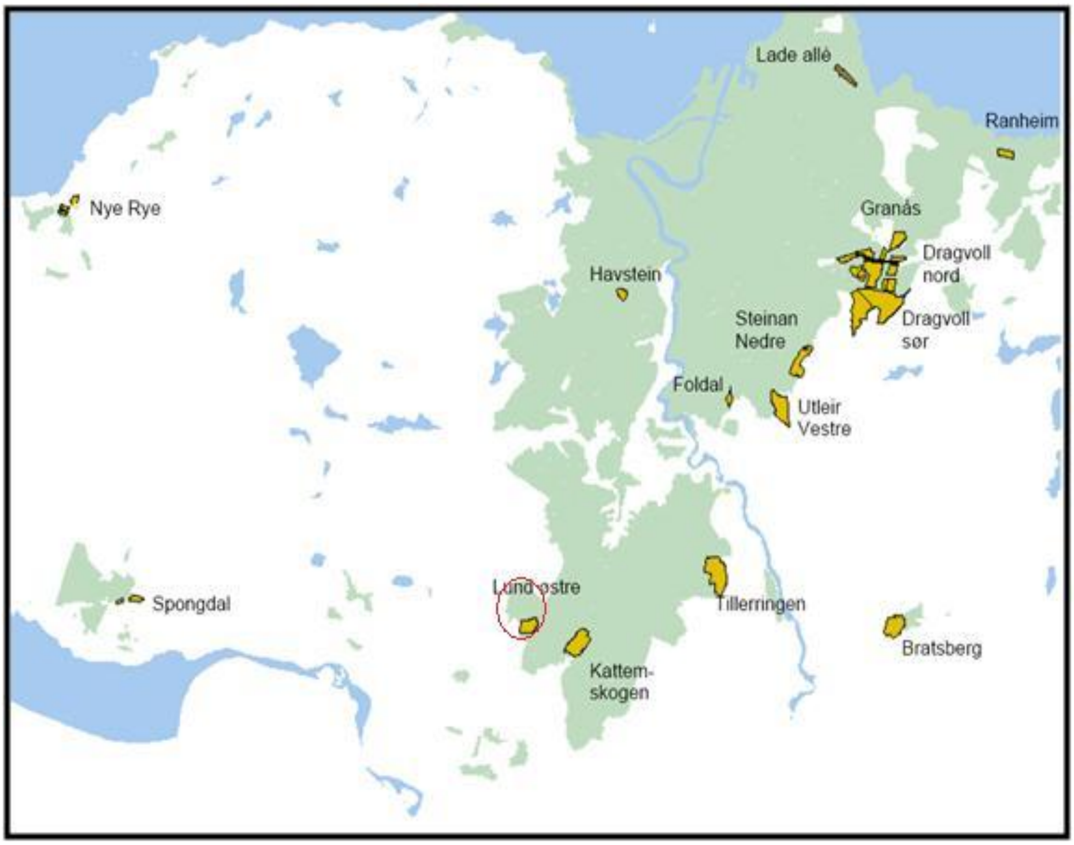


Figure 21: Future developments in Trondheim

The hypothetical development plan is to divide the FTTH deployment in Lundåsen in two phases. In the first phase Lundåsen Vestre will be completed in four years (year 0 – year 3), with 500 houses. Lundåsen Østre would then be erected in year 5 and 6, with a total of 150 houses. At the end of sixth year, the plan is to have 650 houses in total. The development plan will be further explained in *chapter 11*, where the economic calculations are made.

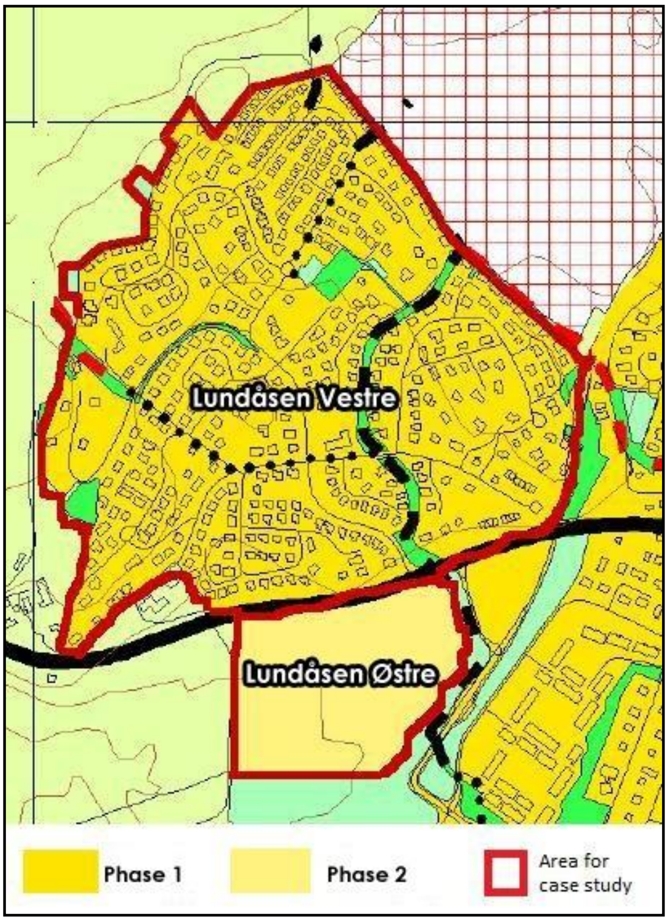


Figure 22: Close-up of Lundåsen area

10.2 Selection of FTTH Architecture, Business Model and Network Owner

For the Lundåsen case study, some factors must be decided in advance. This includes picking out the FTTH architecture, main business model (i.e. open or closed) and who the network owner could be. The next three subchapters would therefore shortly explain the choices I have made in relation with this. Notice that each of the choices affects the selection of the others.

10.2.1 Network Owner

Several options are possible for the network owner. A utility company could for instance be feasible. For Trondheim area, it seems like Nord-Trøndelag Elektrisitetsverk Bredbånd (NTE Bredbånd) would be a potential FTTH owner [37]. However, NTE Bredbånd is a partner with Lyse, thus offering their Altibox concept. This would collide with the choice of having an open network access model.

The best option for FTTH deployment in Lundåsen seems to be the property developer of that area. The reason for this is, among other things, the possibility for saving civil work cost for FTTH, since the most part of this will be covered by the civil works tied to the main development of the area anyway. So is the case study I will assume that the property developer is the network owner.

However, it should be noted that property developers should consider strategic partnerships with utility companies if their own resources are not adequate to deploy a FTTH network. They involved parties must then come to an agreement on key points like cost, revenue and responsibility sharing. NTE Bredbånd, for instance, mention that they among other instances, also co-operate with property developers [60].

10.2.2 FTTH architecture

In *chapter 8.3*, I looked at how the cost picture is for different FTTH architectures like PON and AON. One observation there is that the cost difference between both architectures may not vary so much as one usually expects, especially if one consider it in an isolated setting.

So the challenge is to adopt a FTTH architecture that would suit a greenfield development with several development phases. Therefore, based on arguments in *chapter 8.3.2*, I choose an AON implementation. This implies that there are active remote nodes with switches and need of powering.

10.2.3 Open or Closed Access Network Model?

As argued in *chapter 7*, both open and closed model have different capabilities. For this greenfield FTTH deployment, I have picked the open access network model. This assumes that the network owner, i.e. the property developer, is willing to take a little risk, but sees opportunities for better return.

10.3 Detailed Business Model

The overall business model is as mentioned above chosen to be the open access network model. However, this has to be considered as the high-level choice. Different parts *within* this business model have to be addressed in more detail.

For describing the detailed business model for Lundåsen project, one could use Osterwalder's business model ontology (OBMO) [61]. OBMO is convenient to use, as well as very relevant for describing e.g. a telecom business. Readers that are unfamiliar with the OBMO or wish to refresh this topic are referred to [61 pp. 42-101]. *Table 4* shows the main pillars in this ontology.

Table 4: The nine business model building blocks in OBMO. Extracted from [61]

Pillar	Building Block of Business Model	Description
Product	**Value Proposition**	A Value Proposition is an overall view of a company's bundle of products and services that are of value to the customer.
Customer Interface	**Target Customer**	The Target Customer is a segment of customers a company wants to offer value to.
	Distribution Channel	A Distribution Channel is a means of getting in touch with the customer.
	Relationship	The Relationship describes the kind of link a company establishes between itself and the customer.
Infrastructure Management	**Value Configuration**	The Value Configuration describes the arrangement of activities and resources that are necessary to create value for the customer.
	Capability	A capability is the ability to execute a repeatable pattern of actions that is necessary in order to create value for the customer.
	Partnership	A Partnership is a voluntarily initiated cooperative agreement between two or more companies in order to create value for the customer.
Financial Aspects	**Cost Structure**	The Cost Structure is the representation in money of all the means employed in the business model.
	Revenue Model	The Revenue Model describes the way a company makes money through a variety of revenue flows.

However, describing the whole Lundåsen project with OBMO in its full form would be out of scope for this thesis. So the following have been done: The nine building blocks described in *Table 4* will be used as guidelines to address the different aspects for the case in. Further, in this chapter I present only the last pillar which will be discussing the Cost Structure and Revenue Model as this is of importance for *chapter 11*. The first seven building blocks are each briefly discussed in *Appendix C*: and are to be considered as additional material.

10.3.1 Cost Structure

The cost structure describes what costs that are involved in the FTTH project. I have already talked about costs, i.e. CAPEX and OPEX. *Table 5* summaries the main costs associated with FTTH deployment in Lundåsen.

Table 5: Cost structure for FTTH

COST STRUCTURE	
Capital Expenditures (CAPEX)	**Operational Expenditures (OPEX)**
• Cable costs (fibre cables, joints, connectors) • Civil works (can in this case be excluded) • Costs related to OLT (real estate, housing, router/switches, electronics) • Costs related to ORN (real estate, chassis, router/switches, electronics) • Cost related to CPE (ONU, modems, installation) • System management (software, middleware, portals) • Marketing	• Network management and maintenance • Customer handling • Administrative tasks • Marketing and service promotion • Other (powering, CO-rent etc.)

Note that the selection of the AON architecture demands cost posts like chassis, real estate, switches in the ORN and powering.

10.3.2 Revenue Models

Through this block, the network owner would be interested in identifying by what means it can make money. Possible revenue models are outlined in more detail below:

Access revenues from customers (resident buyers):

- *Establishment fee:* New house buyers have to pay an establishment fee for the FTTH when they buy the house (before the development phase)
- *Remaining decided CAPEX each household:* Can be paid as the customers move in, either as one-time amount or as several monthly payments.

Note that I here assume use of the two-part tariff revenue model is used in the Lundåsen case study.

Access revenues from companies and public instances:

- *CAPEX:* The whole amount must be paid at once.
- *Special customer handling:* Can provide customer handling fitted the corporate market, and thus get revenue from that.

(This revenue source is however not included in the calculations in *chapter 11*)

Revenues from Service Providers (SPs):

- *Establishment fee:* May not be necessary, but one can charge a small amount for becoming a service provider on the network.
- *Yearly fee:* It is normal that the service providers pay a yearly fee for being service provider on the network.
- *Provision:* Payments from the service providers on a provision basis. A certain percentage has to be paid for each customer each month or year for instance.

Other revenue sources:

- *Value increase of house:* This is a quite prominent revenue post. As mentioned before there is estimated around 1% home price premium.
- *Niche services:* Network owner may provide niche services that are locally anchored.

Advertisement: It would be possible for service providers or other commercial actors to advertise on the portal.

Table 6 summarises the means of revenues.

Table 6: Revenue sources

REVENUE SOURCES			
Access Revenues (resident buyers)	**Access Revenues(companies and public instances)**	**Service Provider Revenues**	**Other sources**
• Establishment fee • Remaining decided CAPEX each household:	• CAPEX • Special customer handling	• Establishment fee • Yearly fee • Provision	• Value increase of house • Niche services • Advertisement

10.4 Chapter Summary

This chapter have introduced the Lundåsen case study. Selection of the network owner, the overall business model and the FTTH architecture has been made. The network owner is suggested to be the property developer, while the overall business model is chosen to be the open access network model. I have also chosen AON as the FTTH architecture for this greenfield case study.

Osterwalder's Business Model Ontology is further used to address different aspects within the business model. The most important part here is the cost and revenue blocks which are presented in this chapter. The rest of the building blocks for the Lundåsen case study are briefly discussed in *Appendix C*:.

11 Investment and Profitability Analysis

This part of the case study discusses the economic viability of the FTTH deployment in Lundåsen area, to illustrate and examine a greenfield scenario. The purpose of this chapter is to see if a greenfield FTTH deployment in a order of magnitude as Lundåsen is profitable, and if so, in what degree.

11.1 Introduction and Assumptions

It was a bit difficult to get definite prices from the contacted vendors, both because these were confidential and because it is often given discount on certain parameters. PacketFront would for instance give anything between 20 – 70 % discount, e.g. based on the size of deployment and possibilities for network expansion in the future [32]. Different unit costs that are necessary for the calculations are acquired from different sources, like [5], [32], [62], [63]. Some individual numbers are omitted, as well as some are roughly estimated because of the confidentiality criteria. However, the calculations aim at representing a realistic scenario.

The reason for choosing an already developed area (Lundåsen Vestre), and regard it as a greenfield area comes for use in this part. By looking at the streets and the infrastructure, one can measure the length between CO and ORN, and from ORN to CPE when calculating cost for fibre cables (the passive infrastructure). This information is further used for phase 2, development of Lundåsen Østre. Measuring has been done directly at Trondheim Municipality's Map Service[23].

Since the complete calculations and the analysis of this case are very comprehensive, it is not included here as a whole. However, for those who are

[23] http://webhotel.gisline.no/GISLINEWebInnsyn_Trondheim/

interested in getting a better understanding, I would refer to *Appendix D*: and *Appendix E*:. Here, one will find all the complete setups and calculations. In this chapter I will only provide the basic assumptions and key findings, illustrated with graphs for better understanding.

The following assumptions are laid for the calculations in the case study (justifications given in previous chapters for certain points):

- I assume 100 % monopoly on the access in the Lundåsen area for the owner, since it is of a minor magnitude. This would also simplify the calculations somewhat.
- Even though there are possibilities for companies/public instances to settle in Lundåsen area, I only assume that there are private households which are built.
- All the erected houses are sold the subsequent year (e.g. all houses built in year 0, are sold in year 1).
- AON architecture is chosen in preference to G-PON), implying *active* remote nodes with switches and need for powering.
- The owner is the property developer. Thus, civil work costs are put to zero since there must be digging anyway.
- The investment horizon is 11 years (year 0 – year 11) which would be a realistic time period.
- I have not included EBITDA[24] for simplicity.
- All the revenue sources suggested in *Table 6* (previous chapter) are included except: Niche services and revenues from companies/public instances (since I only consider private households).

Table 7: Hypothetical development plan for Lundåsen

	Phase 1					Phase 2					
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Lundåsen Vestre	150	150	100	100	0	0	0	0	0	0	0
Lundåsen Østre	0	0	0	0	0	100	50		0	0	0
Sum	150	150	100	100	0	100	50	0	0	0	0
Accrual sum	150	300	400	500	500	600	650	650	650	650	650

[24] Earnings Before Interest, Tax, Depreciation and Amortization

The hypothetical development plan is as follows by *Table 7*. Further it would be reasonable to assume that one ORN will cover between 100-200 houses [62]. I have therefore estimated that it will be needed 4 ORNs, covering the area like in *Figure 23*. ORN 1- 3 covers the phase one development, while the last covers the second development phase (Lundåsen Østre).

With this background and assumptions, I will in the remainder present the obtained results.

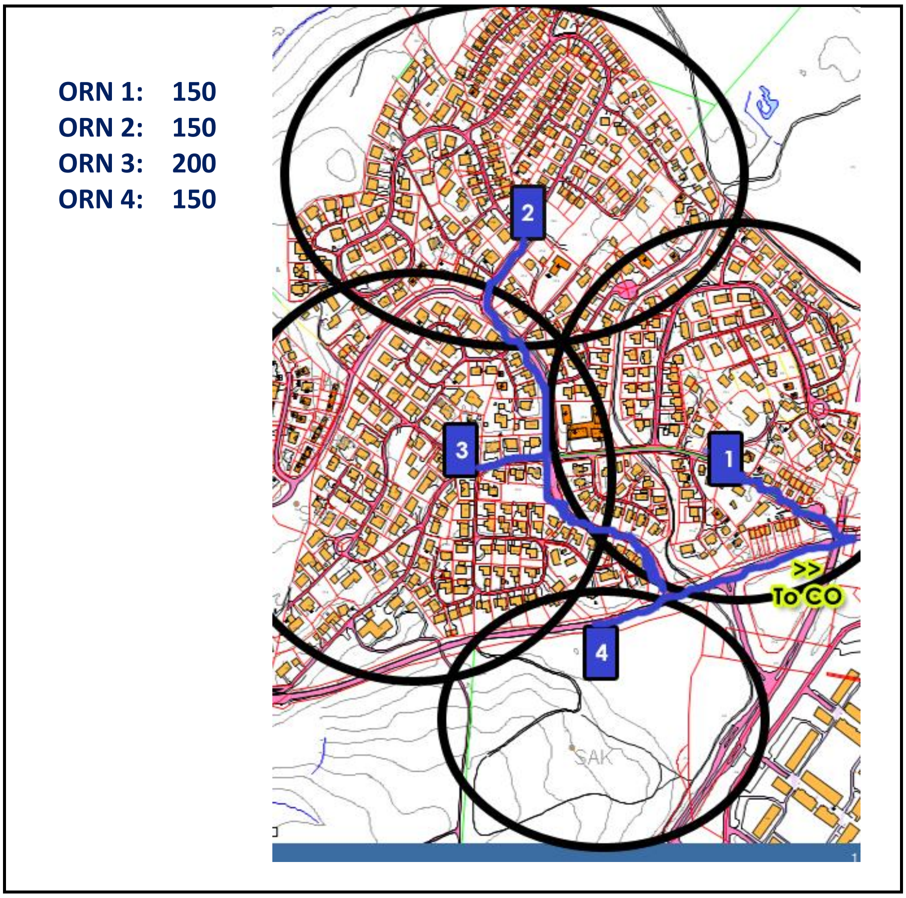


Figure 23: ORN coverage in Lundåsen

11.2 Cost Results (CAPEX and OPEX)

The CAPEX for FTTH in Lundåsen is estimated to be circa NOK 4.4 million for the total of 11 years. The different CAPEX posts are distributed as in *Figure 24*, where the passive infrastructure is the biggest post and makes up around 43 %. Notice that the civil work cost is not presented due to the assumption that civil work is covered anyway because of the new developments.

The total OPEX for 11 years sums up to circa NOK 5.8 million. The biggest cost is associated with the network management, as Figure 24 shows.

Figure 25 is also interesting to look at. It illustrates the percentage distribution of total CAPEX and OPEX costs per year. Here the CAPEX gradually decreases from year 0 to year 4, but increases in year 5 and 6 due to the development Phase 2. From year 8, all costs are OPEX.

Based on the numbers for CAPEX and OPEX, one gets approximately NOK 6800 and 7700 for CAPEX and OPEX per user, respectively. In total, it means that each customer costs around NOK 14500 for the 11 year period (it is 650 customers in total).

Notice that the CAPEX here appears to be really low compared to the standard assumption which is around NOK 20 000. This means a saving around 65%. One of the main reasons is of course that the civil works costs are not present.

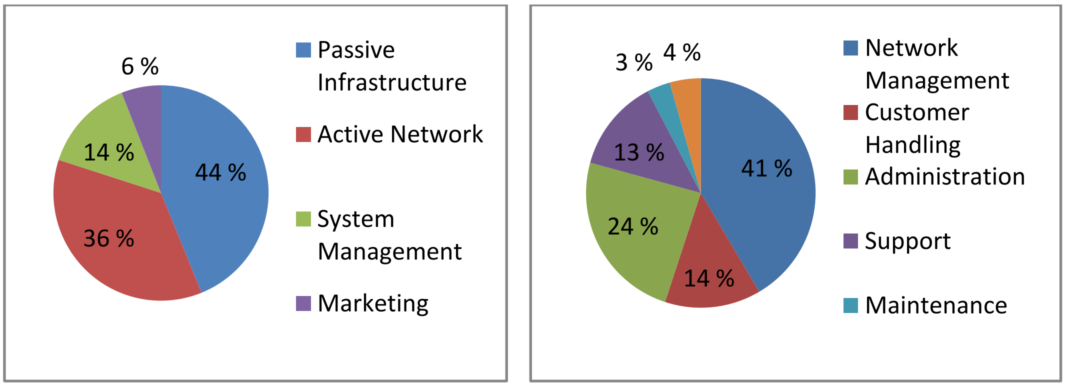


Figure 24: (a) Distribution of the different CAPEX posts (b) Distribution of the different OPEX posts

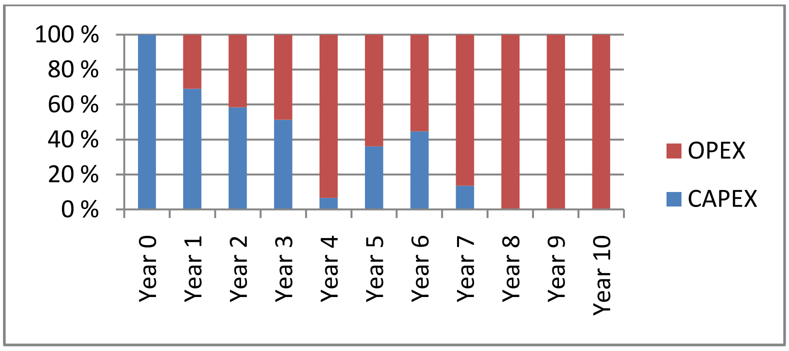


Figure 25: Percentage distribution of total CAPEX and OPEX costs each year

11.3 Revenue Calculations

As suggested in *chapter 8.2.1*, I have assumed that one would try to use the two-part tariff financing model. This means that the customer would pay a certain amount in upfront (i.e. before the houses are built) independent of whether the customer wishes to use the FTTH access or not. When the customer moves in, and wish to use the network, he or she will pay an additional sum.

I have chosen these two amounts based on the CAPEX per user, and then added a bit more, i.e. NOK 4000 upfront, and NOK 4000 to start using the FTTH network, in total NOK 8000. So, if 150 houses are built in year 0, one will get NOK 4000 upfront from each of those 150 customers, and NOK 4000 from each of them in year 1, when they move in. Setting these amounts to at least cover the CAPEX per user would often be crucial to cover the expenses in a FTTH deployment of this magnitude. But if the property developer is interested in increasing the profitability, there is possibility for insisting a higher upfront or usage cost. One good idea could be to include the upfront FTTH cost in the price of the house. Such an amount would not be outstanding, compared to the upfront price one pay for a house, and would easily be accepted by the buyer. These two payments are called "Access Revenues" in the remainder of the chapter.

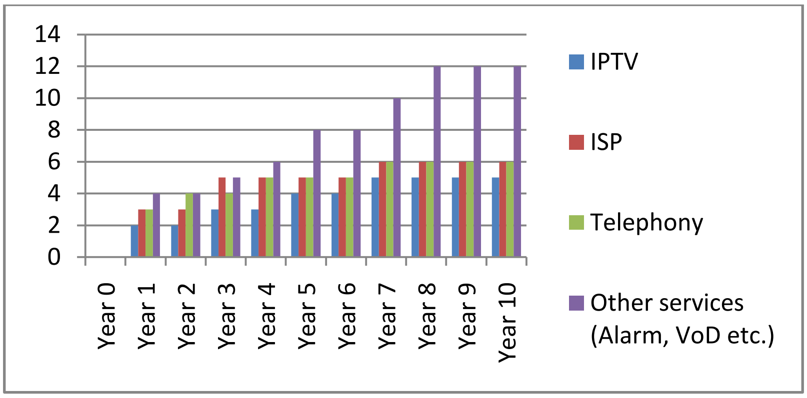


Figure 26: Services and Service Providers on yearly basis

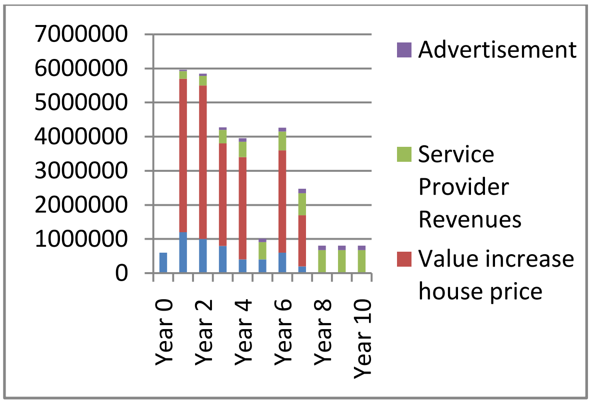
Further I have assumed a gradually increase of service providers offering services like TV, telephony, Internet and other services (Alarm, Video On Demand etc.), see *Figure 26*. Further, the service providers will pay a certain amount yearly and a provision based sum to the property developer, as mentioned in *chapter 10.3.2* about revenue sources. The details are outlined in *Table 8*. The yearly fee and provision rates used here are based on [62]. In addition to access and service provider revenues, I have also calculated advertisement revenues.

However, the biggest revenue source for the developer in Lundåsen would be the house price premium (HPP). I have in this case study used 1 % of the house price as the amount for HPP, based on the findings in *chapter 6.2.4*. The house price was set to NOK 3 million (average) giving NOK 30 000 in profit for each house. In the further calculations for the case study, I have looked at both how the revenues and final result would be if the HPP was included in the revenues, and omitted. This is done since it seems to be a certain doubt in the industry about how the FTTH is appraised by the customers, and how much the value increase shall be. This separation would make it possible for decision makers to evaluate both scenarios separate. The next two subchapters present both these scenarios.

Table 8: Yearly fee and provision from the service provider to the network owner

SERVICE	YEARLY FEE PER PROVIDER	AVG.PRICE SERVICE FOR CUSTOMER	NET OWNER PROVISION (%)	NET OWNER PROVISION (NOK)
IPTV	25 000	200	20 %	40
ISP	15 000	350	65 %	228
Telephony	5 000	150	50 %	75
Other services (Alarm, VoD etc.)	15 000	150	30 %	45

11.3.1 Revenue Results With Home Price Premium



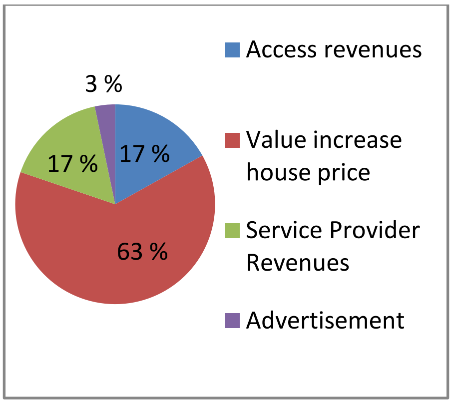


Figure 27: (a) Yearly revenues (b) Distribution of total revenues by source (with HPP)

With aforementioned background, *Figure 27 (a)* illustrates how the revenues distribute for the total investment horizon. The total revenue for 11 years is estimated to NOK 30.8 million. The main part of the revenue is from the HPP, which is around 63 %. This implies that over NOK 19 million is earned from the home price premium in Lundåsen. The further distribution of the income by revenue sources are shown in *Figure 27 (b)*.

11.3.2 Revenue Results Without Home Price Premium

Here the equivalent numbers as the previous subchapter presented, without inclusion of HPP.

The total revenues from year 0 to including year 10, gives in this scenario around NOK 11.3 million. Since the HPP is omitted, the access and service provider revenues stand for around 91 % of the total. *Figure 28* shows these numbers graphically.

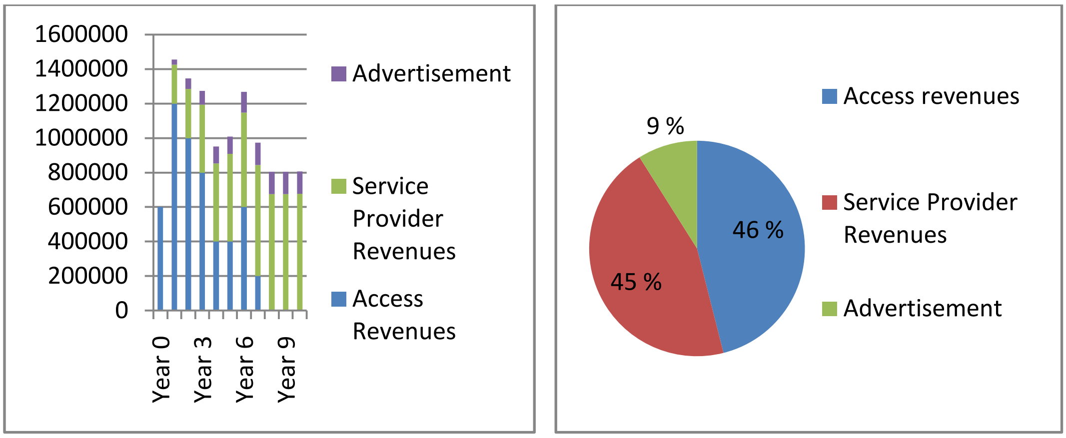


Figure 28: (a) Yearly revenues (b) Distribution of total revenues by source (without HPP)

11.4 The Result: Cash Flow and Net Present Value (NPV)

Like I have done for revenues, the results have been separated in terms of inclusion and not inclusion of revenues from HPP. Beyond this difference, other factors are equal for both of the scenarios.

The result gives the overall profitability for the greenfield FTTH deployment by the developer. Here the cash flow is calculated, as well as the Net Present Value (NPV). The NPV express what a future cash flow is worth today, and indicates therefore if the overall investment is profitable or not [44]. Calculation of NPV is based on number of periods for the cash flow, i.e. in the case study it this is 11, and a discount rate. If the NPV is positive (NPV> 0), one should invest. Thus, if

NPV is negative, the investment is not profitable. For deeper theory about NPV, readers are referred to *Appendix A.4*.

11.4.1 Results with Home Price Premium Revenues

Figure 29 show us the cash flow for the Lundåsen project from year 0 to year 10. The cash flow varies a lot because of the two phase development, and the way two-part tariff financing model functions. The cash flow never goes negative after the first year. Between year 1 and year 8 (apart from year 4) the high revenues from access and HPP give a very positive cash flow. From year 8 and further on, the cash flow is more stable and one can see a very small gradual increase on yearly basis.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Revenues	600000	5955238	5845588	4273450	3951975	1008475	4267520	2473544	805023	805510	805803
CAPEX	-1603500	-820000	-595000	-485000	-35000	-282500	-420000	-117500	0	0	0
OPEX	0	-366118	-423093	-461518	-497693	-499105	-521205	-747793	-755793	-755793	-755793
Cash Flow	**-1003500**	**4769120**	**4827495**	**3326933**	**3419283**	**226870**	**3326315**	**1608251**	**49230**	**49718**	**50010**

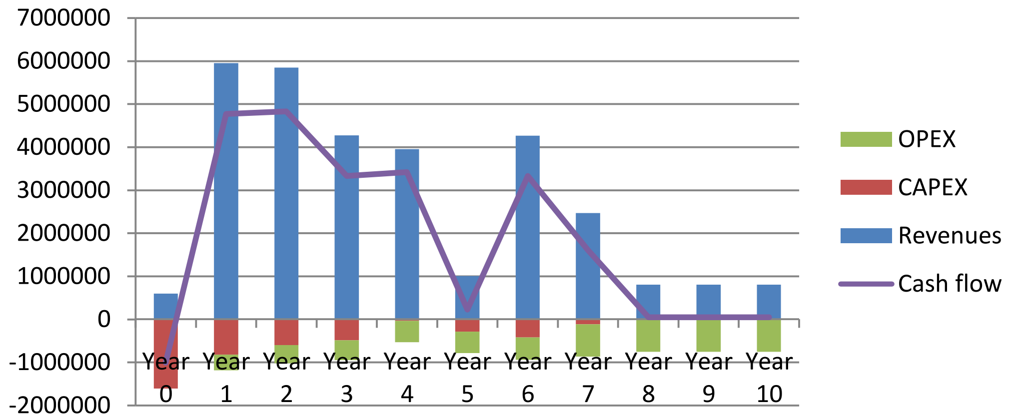


Figure 29: Cash flow for Lundåsen project (with house premium revenues)

However, estimation of the NVP is further needed to look at profitability. A realistic discount rate could be around 10 %. This would yield a positive NPV around NOK 13.7 million. For an optimistic, but still realistic discount rate at 20%, the NPV is still really good, almost NOK 10 million. Based on these numbers, the property developer should absolutely invest in FTTH for Lundåsen.

One thing what would be interesting to look at is how the NPV varies with different discount rates. This is graphically illustrated in *Figure 30*. Even for 70% discount rate, the NPV is still positive, yielding almost NOK 3 million. In fact, the NPV is not negative before a discount rate is around 472% (a very unrealistic discount rate however, but illustrates the point).

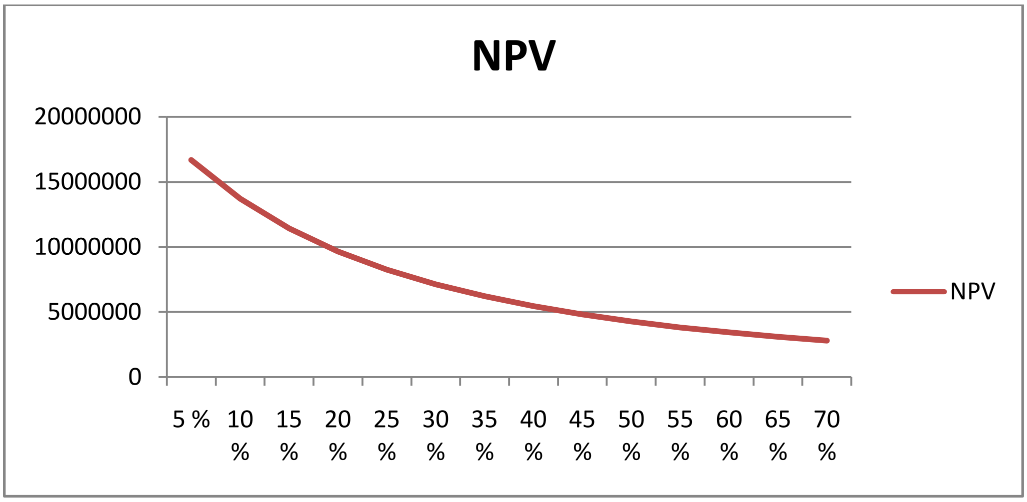


Figure 30: NVP for different discount rate (with house premium revenues)

In conclusion, results calculated with the HPP yield a NPV that clearly states that FTTH in Lundåsen should be done. The next subchapter looks at the scenario without the house premium revenues.

11.4.2 Results without Home Price Premium Revenues

The cash flow with the HPP omitted is shown in *Figure 31*. The main difference is that revenues for the years when customers move in have decreased with a constant. Year 8 to year 10 for instance, would not be affected by omitting the HPP, and are therefore exactly the same here.

However, in this case the NPV is much lower. With a discount rate of 10 %, the NPV is estimated to be just around NOK 0.44 million, but still positive. *Figure 32* shows the NPV for different discount rates. Here it is worth noticing that for a discount rate above 23.5%, the NPV turns negative, thus discouraging investment in FTTH if one demands a higher discount rate.

Since the NVP is still positive, the property developer should invest in FTTH in the Lundåsen area, even though HPP are omitted. But as the *Figure 32* indicates, if another investment for property developer would yield a higher return rate than the discount rate (e.g. above 15%), then deployment of FTTH in Lundåsen needs to be reconsidered.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Revenues	600000	1455238	1345588	1273450	951975	1008475	1267520	973544	805023	805510	805803
CAPEX	-1603500	-820000	-595000	-485000	-35000	-282500	-420000	-117500	0	0	0
OPEX	0	-366118	-423093	-461518	-497693	-499105	-521205	-747793	-755793	-755793	-755793
Cash flow	**-1003500**	**269120**	**327495**	**326933**	**419283**	**226870**	**326315**	**108251**	**49230**	**49718**	**50010**

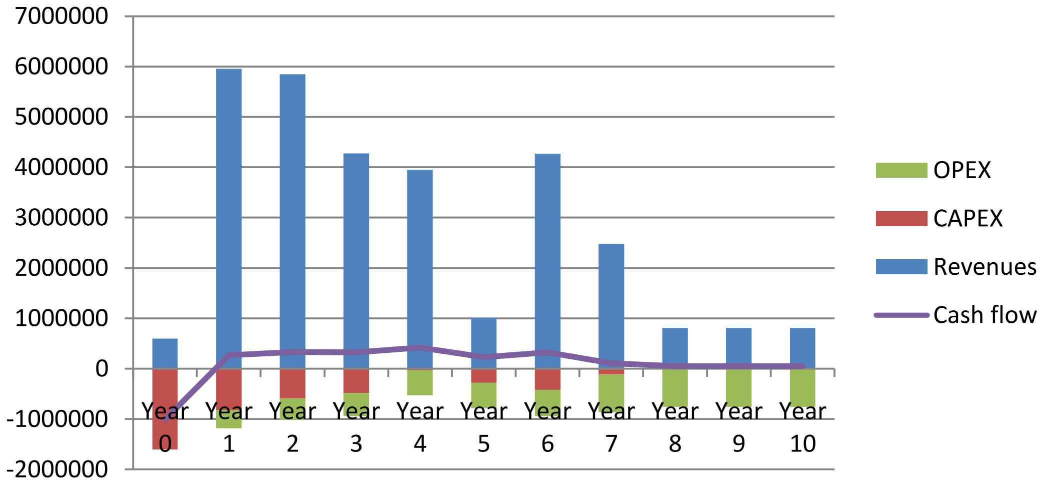


Figure 31: Cash flow for Lundåsen project (without HPP)

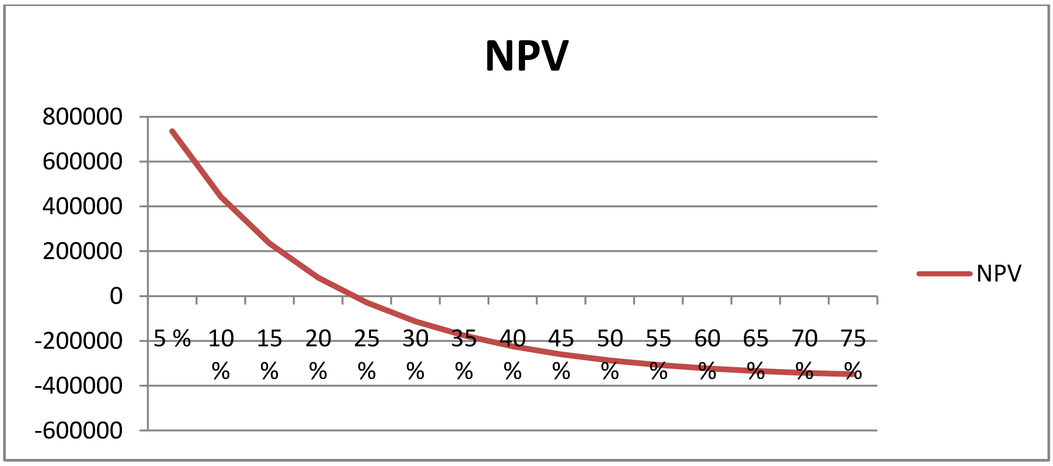


Figure 32: NVP for different discount rate (without house premium revenues)

11.5 Sensitivity Analysis

In this chapter, I perform some further analysis by altering different inputs to see how it affects the NVP. The calculation sheet that is composed for this case study (*Appendix E*:) gives the opportunity to perform different sensitivity analysis on practically all the inputs.

Some sensitivity analysis is in fact already performed above by calculation of the two different scenarios where HPP are included, and in the other not. This illustrated how the NPV varied with different cash flows due to the revenue difference. Investigating the NPV with different discount rates was also sensitivity analyses. Here I present some further analyses for some other input factors.

11.5.1 Passive Infrastructure

The passive infrastructure (i.e. fibre cables) make up as mentioned almost half of the CAPEX. It could therefore be important to see how the CAPEX per user varies if the Lundåsen project requires more fibre than estimated initially.

Figure 33 shows how the CAPEX per user evolves as a result of increase in the fibre length. In the case it is estimated 18 400 metres of fibre. If e.g. the needed fibre length appears to be 20 000 metres, CAPEX per user would go from NOK 6705 to NOK 6952, yielding a percentage increase of 3.7%. In an opposite situation, where the needed fibre length may be only 16 000 metres, the CAPEX per user would end up at 6336 NOK (5.5% decrease).

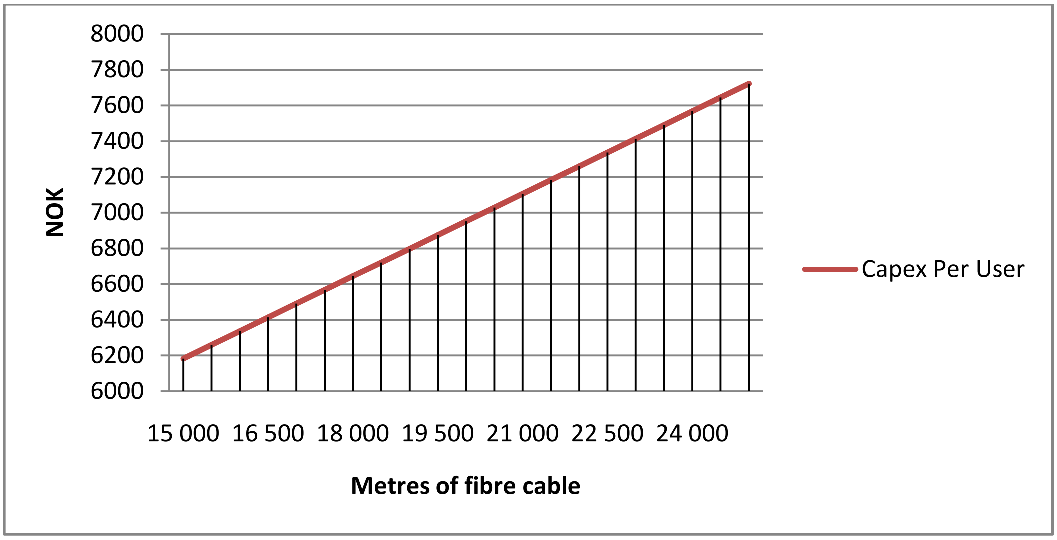


Figure 33: CAPEX per User vs. fibre cable length

11.5.2 System Management

As mentioned in the opening, it is quite normal to get discount from vendors, based on certain criteria. PacketFront operate with e.g. a discount rate between 20% and up to 70%. Even though the price for the system management components for this case is roughly estimated and acquired from several sources, it would be interesting to see what impact different discount rates would apply on the total. System management includes components needed for Automation, Provisioning, Portal and OSS and BSS. Various user licenses are not included here. In the case it was as default only used a 20% discount on the mentioned system components.

Figure 34 illustrates how the CAPEX per user changes for different discount rates. With no discount, the CAPEX per user is almost NOK 6900, while with 70% discount this amount is reduced to less than NOK 6300. Since Lundåsen project has a limited number of prospective customers, I would assume that one would not get a full discount rate. But around 30% could be achievable. Viewed isolated, the discount in CAPEX per user is not that much, even if one get full discount of 70%. But in combination with other cost reducing strategies, this could contribute positively.

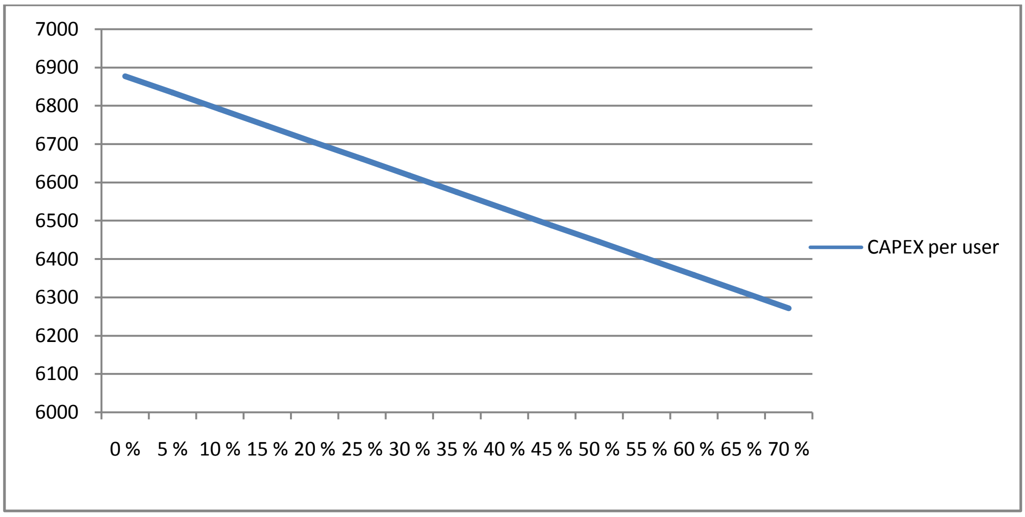


Figure 34: CAPEX per user vs. discount rate of system components

11.5.3 Two-Part Tariff Model

One challenge that I discussed earlier (*chapter 8.2.1*) was how to set the different amounts for the two-tariff model. In the case, these two amounts, the establishment fee, and the usage fee, respectively, were each set to NOK 4000. Here, the network owner could be interested in how the NPV changes if one for instance charges a higher establishment fee, and the same time reduces the same amount in the usage fee.

This is evaluated and graphically shown in *Figure 35*. Notice that the total amount that is paid by the customer is constant, i.e. NOK 8000. I have only varied the different fees, so that if customer e.g. pays NOK 2000 in establishment, then he shall pay NOK 6000 for the usage after he moves in. The discount rate is held on 10%, and HPP revenues are omitted in this analysis.

The result is that the more the network owner charges in establishment fee, i.e. in upfront, the higher profitability would the owner get in the end of year 11 (NPV increases).

The two extreme cases are that either the network owner chooses to charge the total amount upfront (NOK 8000 in establishment – NOK 0 in usage) or owner charges nothing in upfront (NOK 0 in establishment – NOK 8000 in usage). The first would yield a NPV of NOK 620101, while the latter gives NOK 266742 in NPV. This means that there is a 57 % better return for network owner by demanding the whole amount in upfront, theoretically.

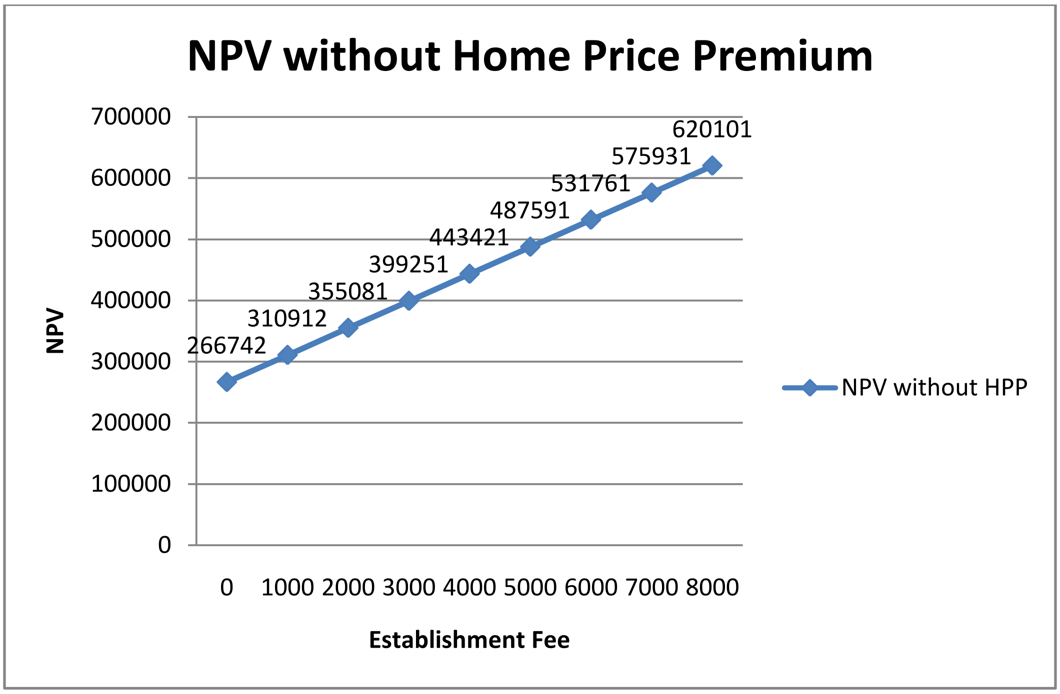


Figure 35: NVP for different establishment and usage fee

However, charging the whole amount before the development is done would not be a good idea if one wants to have the customer in focus. It also gives the customer no options around adopting the FTTH. In the opposite case, where nothing is charged before the customer moves in, the risk is much higher for the network owner. Both these extreme cases are in fact not a two-part tariff model either.

So it would be up to the network to choose two amounts that gives the desired NPV, and at the same time giving the customers a good and reasonable financing option.

11.6 Validity of the Case Study

The case study was carried out with an aim of investigating a realistic greenfield FTTH scenario. However, some considerations about the validity of the case study and the results would be appropriate to give here.

The case study has used available theory, and elements from what I regard as my own contributions in this thesis, as the starting point. One challenge is that theory and industrial practice often is not the same, and the latter is also more complex than the first mentioned.

The data that is used in the case study is also collected from several industrial sources as mentioned earlier. But these data has not been available in fullness because of the confidentiality and business critical details[25]. Based on this some statements and calculations had to be depicted in a simplified manner throughout the thesis. This means that that the claims and results presented in the case should be treated as guidelines, and not concrete advices.

11.7 Chapter Summary

This part of the case study consists of the economic considerations. Cost and revenue calculations have been performed, and used to further calculate the results and look at the profitability.

The results have been calculated with both the home price premium included, and without. This is due to the uncertainty about how the value increase for the house is appraised by the customers in the Norwegian market. But it is clear that if the revenues from the home price premium are as big as it is estimated for this case study, it would yield a considerable large profit for the network owner.

Anyway, both scenarios give a positive NPV for 11 year period with 10% discount, indicating that this kind of greenfield FTTH deployment should be considered by the property developer. Some sensitivity analyses have been performed because of possible error in estimations and assumptions.

The validity of the case study is also discussed, and I suggest that the findings in these calculations should be user as guidelines rather than concrete advices. This is due to that the numbers are collected from several actors from the real FTTH

[25] This is especially because of the nature of this thesis. One, it is unrestricted, meaning that it is accessible by all. The other is also of course that there would be difficult for companies to let go of crucial details to a student.

market and had to be modified or roughly estimated for the case study to protect of business critical details. Theoretic assumptions are also not always in accordance with practical implementations.

12 Conclusion

This thesis has looked at technological, strategic and economical aspects that are related to FTTH, with emphasis on greenfield developments. This was done by studying available theory, communication with FTTH actors in the industry and by making my own contributions based on these resources. Finally, a case study has also been done in relation with this thesis to investigate the discussed topics in a realistic scenario.

Table 9: Problem statements for the thesis

PROBLEM STATEMENTS	
PS1:	What is the current status of the FTTH market, and where does greenfield FTTH deployment fit in this market?
PS2:	How does FTTH for greenfield developments differ from brownfield developments?
PS3:	What are the different FTTH architectures, and how do they affect the cost picture?
PS4:	What aspects are significant in terms of FTTH, value chain and business models?
PS5:	Who are the potential network builders and owners of greenfield FTTH network?
PS6:	What economic decisions would make the financing feasible for both customers and the network owner?
PS7:	What is the main conclusion of the case study that can be used as guideline for future greenfield developments?

Seven problem statements were instituted in the beginning of this report in order to cover the key aspects in the original problem domain for this thesis. Thus, these problem statements serve as foundation for the conclusion given in the remainder of this chapter. The problem statements are recalled in *Table 9* for convenience.

The overall trends show that the FTTH is growing as an access network throughout the world. This also includes Norway, which is in fact one of the leading countries within FTTH. The FTTH market also appears to be diverse when it comes to network owners, technological architectures and business models, especially when considering with other access networks like ADSL or coax. In this context, greenfield FTTH deployments are also expected to increase in the coming years.

FTTH for greenfield developments differs from brownfield developments in certain areas. Throughout the thesis, it has been argued that the civil work costs could be considerably lower than for brownfield areas, yielding a lower CAPEX per user. Greenfield FTTH deployments also give the possibility to design an optimal network, integrate the network as a proper part of the house from the beginning, and contribute positively for reducing environmental challenges. In addition, greenfield development does not make FTTH costlier than other access technologies like ADSL.

Furthermore, the most promising FTTH architectures have been surveyed, with the intention of identifying cost and qualitative differences. This survey includes the AON, G-PON and WDM-PON architecture. WDM-PON would be the best option in regards of bandwidth satisfaction, but it is not commercially available as the other options yet. In a decade or so, the WDM-PON would be more mature and may prove to be the best alternative of the FTTH models. The cost difference isolated does not seem to differ significantly between the two other FTTH architectures, namely AON and G-PON.

However, a qualitative exploration showed that G-PON is suited for centralised traffic flow, while AON would be the best option for a distributed traffic flow. Moreover, I have argued that for a greenfield FTTH deployment with possibilities for future expansions, AON seems to be the best candidate in terms of qualitative characteristics. This also depends on the type of the network owner. For an incumbent like Telenor for instance, G-PON would be more suited as it better fits their present managing systems.

Investigation of the value chain shows that co-ordination in the early phase with ducting and trenching is an important cost reducing factor. Scalable active network without lock-in agreements with vendors are also crucial in the long-run. Both open and closed access network model are present in the Norwegian market. It is argued that the open business model would be the most satisfactory one for the *customers* compared to the closed model. The open model also seems slightly more advantageous in terms of innovation and niche services. But it would also be essential to emphasise that the closed model also serves it purpose in the Norwegian FTTH market, and still keeps growing. The risk, and thus the profitability, also seems different for both models. The open model gives the impression of having a higher risk, but also a larger potential for return. The closed model appears to be less risky, but with a moderate earning capability compared to the open model.

The FTTH networks also have the opportunity for being owned by many different owners. This thesis has outlined owners like utility companies, municipalities, incumbents, property developers and private owners. Different owners possess dissimilar qualities. The property developer demonstrates the largest potential for being the network owner for greenfield FTTH since the civil works would be covered by the main development anyway. However, the property developer should seek assistance or partnership with other regional instances, for instance a utility company, if the technical knowledge is not sufficient.

The Norwegian FTTH market indicates that the financing model may need to be reconsidered to satisfy both the customers' and the network owners' economic criteria. In this thesis, I have suggested two alternative financing models, namely two-part tariff model and price discrimination model. The main conclusion when it comes to financing models is that FTTH actors need to provide several financing solutions that would fit different customer groupings. Greenfield deployments make it feasible to also include a part of the cost within the advance payment of the house, thus making it possible for a higher acceptance for FTTH among the customers.

The report has also briefly discussed the opportunities for using the established fibre infrastructure for additional functions. For instance, the infrastructure could be used as a feeder network for Wi-Fi or mobile broadband. Making room for these kinds of functions on the infrastructure gives the greenfield FTTH networks additional income sources, as well as providing excellent capacity for the Wi-Fi or mobile broadband operator.

Finally, I have carried out a case study in the Lundåsen area in Trondheim to see how the different aspects discussed earlier in the thesis can be addressed in a realistic setting. Property developer was chosen as owner, while AON was selected as the FTTH architecture. The open network access model was also chosen to be the overall business model.

With these assumptions, the calculations showed that CAPEX per user can be reduced significantly if the property developer is the owner, and thus being able to ignore the civil works cost for FTTH (almost 65% saving). The property developer would at the same time obtain a large profit through home price premiums due to FTTH. The amount of the home price premium is however still uncertain for the Norwegian market, but 1% value increase of the house price have been used in the case study. This is based on American reports, as well as personal communication with Norwegian FTTH actors. The home price premium is assumed to be dependent on the knowledge house buyers possess about FTTH.

However, because of the uncertainty, I have chosen to separate the final result in two parts. One includes the home price premium (HPP) revenues, while the other does not. Nevertheless, the results for both scenarios showed positive NPV. This indicates that this kind of greenfield FTTH deployment should be considered for future greenfield FTTH projects with similar qualities like the Lundåsen case study. . The validity of the case was also briefly discussed, and it was stated that the findings should serve as guidelines, rather than concrete claims.

12.1 Future Work

The scope and time limit of this thesis have kept the overall business model for the case study at a low-detail level, but it would be an interesting area of future work. Therefore, one suggestion for is a further elaboration of a complete and more detailed business model for a greenfield FTTH case. This could be done by applying a business model ontology, for instance Osterwalder's, in its complete form. This could in greater detail reveal other factors for a successful greenfield FTTH deployment.

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Appendix

A: Microeconomic Topics

This chapter aims at elaborating the economics topics used in the thesis. Some basic definitions are given first, and then are two-part tariff, price discrimination and Net Present Value (NPV) elaborated in more detail. Remainder of this chapter is mostly based on [44].

A.1 Basic Definitions

Marginal Cost (MC): Is the cost of producing one additional unit of a product.

Reservation Price: Reservation price is the maximum price that a customer is willing to pay for a product.

Demand Curve: A curve that shows how much of a product consumer is willing to buy as the price per unit changes.

Marginal Revenue (MR): Is the change in revenue resulting from a one-unit increase in the output

A.2 Two-part tariff model

A two-part tariff is a pricing method in which consumers are charged both an entry and usage fee for a product or service. The challenge with the two-part tariff is to set the entry and usage fee, so the total revenue is maximised.

While this can be mathematically calculated for one or two customers, a system with several customers cannot be easily calculated. Here one would need to perform trial-and-error experiments to discover the best solution. Simplified, one could start with a price for the product, here the fibre access. Then one calculates the optimum entry fee and finish with estimation the resulting profit. Then one does the whole process again, with a new price, a certain times to approach the optimal two-part tariff. This is illustrated in *Figure 36*. T* is the profit-maximizing entry fee, given P.

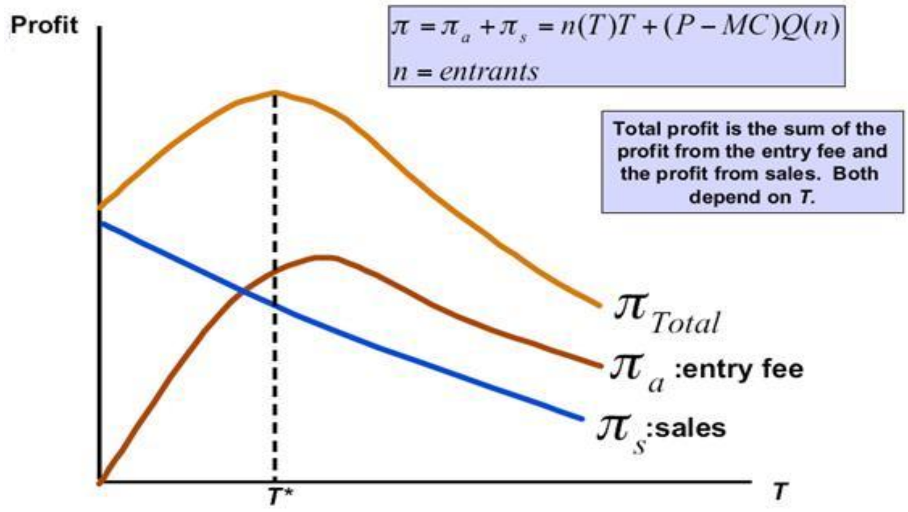

Figure 36: Two-part tariff model. Extracted from [44]

This may seem easy enough but the problem is that we only consider the price here, and not taking other parameters in consideration. For instance could customers' different demand for the fibre access, make it hard to set the price.

A.3 Price Discrimination

Price discrimination is often separated in three forms: First-, second- and third-degree discrimination.

First-degree price discrimination is when we have enough information to charge each customer his or her reservation price. Second-degree price discrimination is charging different price per unit for different quantities of the same good or service. This is for instance done when customers pay less for each Mbps the more overall bandwidth they buy.

In the thesis, third-degree price discrimination is suggested. This means dividing consumers into two or more groups with separate demands curves and charging different prices to each group.

Figure 37 shows the third-degree price discrimination graphically, shown for two different groups. The optimal prices (P_x) and quantities (Q_x) are such that the MR from each group is the same and equal to MC. In the figure, the first customer group has a demand curve D_1, and charged P_1. Customer group 2 has the demand curve D_2, and charged a lower price P_2. The MC depends on the total quantity produced (Q_T). The Q_1 and Q_2 are chosen so that $MR_1 = MR_2 = MC$

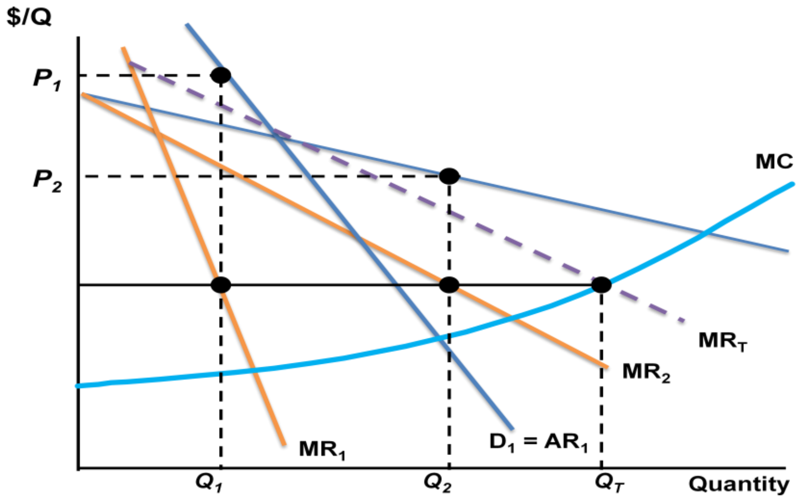

Figure 37: Third-degree price discrimination. Based on [44]

A.4 Net Present Value

NPV have been used in the case study to evaluate if an investment in a project like Lundåsen would be profitable. The NPV express what a future cash flow is worth today, and indicates therefore if the overall investment is profitable or not.

The NVP is calculated in the following way:

$$NPV = -C + \frac{\pi_1}{(1+R)} + \frac{\pi_2}{(1+R)^2} + \ldots + \frac{\pi_N}{(1+R)^N}$$

Here is

C = capital investment costs,

N = Number of periods (usually this is the number of years for the investment horizon),

π_N = amount of profit generated year N and

R = discount rate; the rate used to determine the value of one monetary unit received in the future.

The tricky part in this calculation is choosing the discount rate R. This discount rate should be based on what an alternative investment of this money would have yielded. For instance, if the money was placed in bank, what would the interest have been compared to investment in FTTH (in this thesis). So easily put, R should be chosen by thinking what return could the network owner earn on a “similar” investment (meaning an investment with equal risk). In the case study the discount rate is set to 10 % in the calculations.

The investment decision is further based on what result the NPV gives. If the answer is positive (i.e. NPV > 0) the network should indeed invest in FTTH. NPV < 0 indicates that the investment should not be carried out (at least not with those particular inputs). The final opportunity is if the NPV = 0. The main deduction of this is that the network owner should be indifferent between investing and not investing.

B: Additional comparison of AON, G-PON and WDM-PON

This appendix gives a further comparison of the different FTTH architectures made by FTTH actors in the USA. WDM-PON is for instance not commercially available yet in most countries, including Norway. However, some estimation from the American industry can give an idea about how the cost difference is currently and what one can expect. The following extracts are all from [64].

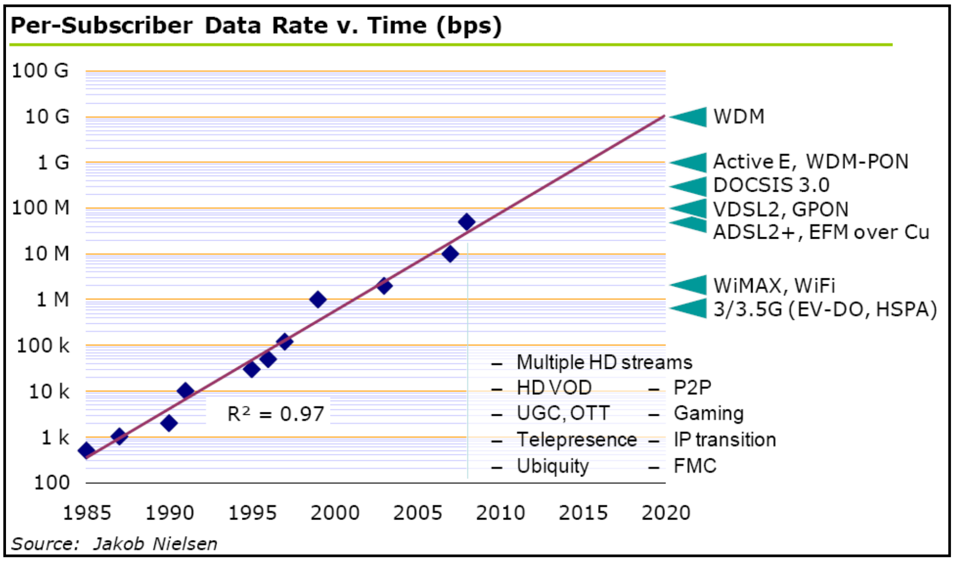

Figure 38: Different access technologies and data rate

Figure 38 shows how the bandwidth demands follow a certain trend. While standard G-PON while be satisfactory for the first 4-5 years, the AON (denoted as "Active E) would manage to satisfy the bandwidth demands at least for a decade forward (1Gbps). However, the best alternative in the future will become the WDM-PON, but big breakthrough in the commercial market would probably not come before certain standards are worked out and components are cheaper.

The cost discussion between the architectures is also a topic of interest. This is illustrated in *Figure 39*. WDM-PONs cost distribution is roughly estimated as mentioned in [64]. The WDM-PON appears as the most expensive solution for the time being with no surprises. Compared to the CAPEX for the other two architectures, the WDM-PON is 44 % and 19 % more costly than G-PON and AON, respectively. The OPEX is 32% and 42% costlier for WDM-PON compared to G-PON and AON, in that order.

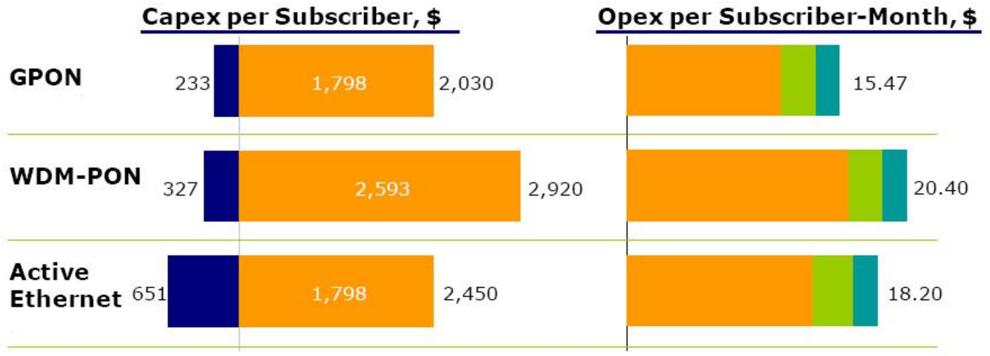

Figure 39: Cost comparison of G-PON, WDM-PON and AON

C: Detailed Business Model for Lundåsen Case Study

This appendix briefly discussed each of the seven first building blocks in the Osterwalder's Business Model Ontology[61] for the Lundåsen Case Study.

Value Proposition

The main value proposition for the customers would be multi-play services, meaning that there are other types of services than just those we find in triple-play. So in addition to telephone, Internet and TV, there should be provided services like alarm and mobile services. Services like e-health and conference services should also be feasible through the network in the future.

One other value proposition is the increase in value of the house that new occupants (i.e. the customers) would get as a consequence of FTTH. The passive fibre infrastructure itself is therefore value proposition. Other value propositions are high bandwidth to cover future services and better quality of life for the residents who move into Lundåsen area.

Target Customers

The main target customers would be the resident buyers. This would mainly be small or larger families who move from other part in the Trondheim region. Singles and students would in first round not be relevant for this area. For student e.g. this area would be too far from NTNU campuses. Singles would most likely not move into houses, since it would be too expensive.

Other customers could also be companies or institutions that establish in the area as it grows. The fibre could also be leased to other actors who wish to utilize the infrastructure.

Distribution Channels

Different distribution channels would important for the success of greenfield development at Lundåsen. This would have impact on the penetration rate and further on the revenue. A good distribution channel would in this situation be the regional newspaper, e.g. Adressa. Adressa is Mid-Norways largest newspaper, thus giving a good covering of potential customers. An article or advertisement about Lundåsen area with future access technology deployed could attract many customers.

There should also be a website dedicated for the project where people who are interested in this development could visit to acquire more knowledge about technology and development that is going to take place in Lundåsen. Websites that belongs to the property developer (i.e. network owner) and other actors who are involved in the FTTH deployment should of course draw attention to this on their web sites. Seminars and conferences like Bredbåndsdagen[39] are also a good opportunity to create relationship with other than customers, for instance vendors.

One should remember that distribution channels would also be important after the new development, if e.g. not all the houses are sold before the new development. Normally, 80% of the houses should be sold in advance, i.e. before the new development starts[65]. So it would be important to also attract customers after the development is finished is there are still houses that are not sold. Important distribution channels can then be already moved in customers, and house prospects that emphasize the FTTH as a part of the house.

Relationship

This building block describes the kind of links the network owner establishes between itself and the customers.

One important relationship would be to provide good enough service to customers and follow-up through the phase after the customers move in. Enough manpower would therefore be crucial to satisfy residents.

Other means of relationships are for instance newsletters or brochure that gives information and updates.

Value Configuration

Value configuration contains the main activities within the Lundåsen FTTH project, and how they relate to each other to create value and thus get customers who are willing to pay for that. As explained in chapter 3 (introduction to business models), the different parts and business roles of the FTTH network will function in different value creating models, while one may regard the whole FTTH deployment as a value chain. The value chain for broadband indicates the basic and important activities that must be performed to have a functional FTTH network for Lundåsen customers.

Other important aspects under this business block have thoroughly been indicated in the previous chapters. The activities can also be divided in two sections: One for activities that are needed prior to deploying FTTH in Lundåsen, the other is after the completion.

Activities before completion: Well planned agreements with developer, cooperation, evaluation of financing models and have an early marketing would be important activities under here.

Activities after completion: This includes pulling off new agreements with other service providers, marketing and selling new services and service providers, plus producing local content and services.

Capabilities

Several capabilities are needed in the greenfield FTTH deployment. These issues have directly or indirectly been touched previously, but I will outline it further here.

First of all, it would be important to *attract new customers*. Customers in this meaning are people who are looking for a new residence and at the same time see the technological advance with a fully integrated FTTH network.

It would also be important to *attract service providers and keep them* in order to offer a variety of choices to the customers. In connection to this, the services that are provided in the network must go through a quality assurance to satisfy and give the most enjoyable service level. Service providers, who are approved for the Lundåsen area, must also have a convenient interface towards the network, so it can be cost and time effective when new actors want to offer services. This is an important capability to get attract as much as possible service providers.

Partnerships

This is a block which is of high significance, especially to pull off an economic profitable FTTH implementation for a greenfield situation like Lundåsen. Effective partnership could be one of the key factors to succeed in a FTTH roll-out like Lundåsen.

Several important partnerships can be identified. Real estate agents may be pointed as a partner. Public instances, like Trondheim Municipality could be a strategic and economic important partner to cooperate with. Especially Trondheim, since the municipality has explicitly announced that they wish to be a regional leader in ICT and ICT infrastructure, and also the technology capitol of Norway [66]. This indicates that early FTTH projects can be carried out with support from Trondheim. The local community could also be a strategic partner, both in marketing the new development, and for maybe a brownfield roll-out in areas around there at a later point.

Different vendors would also be needed to supply the various needed components in the network, so partnerships with these would be necessary.

It could also be relevant to establish partnership with actors who offer mobile broadband to give an additional service offer to the customers, like elaborated in chapter 10.

D: PacketFront and Network Components for Case Study

PacketFront was contacted during this thesis to get input for components and prices needed for implementing a FTTH solution with automation and provisioning system[26]. The solution from PacketFront is claimed to reduce the OPEX compared to other solutions [32]. This information have been used as inspiration to calculate the needed costs in the Lundåsen case study. Below is information about components that PacketFront suggested. Reminder of this chapter is extracted from [63] with minor modifications.

D.1 PacketFront Solution Description

BECS

BECS (Broadband Ethernet Control System) is a network management software suite built to control iBOS™ (Intelligent Broadband Solution) that is used in PacketFront broadband network hardware. BECS consists of a range of server functions designed to handle the specific challenges of building and managing Ethernet Broadband Networks for residential or business services. BECS can be used by the network operator to handle all tasks in the broadband network. All from configuring and installing software on the network elements, to maintaining customers and deploying configurations when a customer requests a new service. BECS includes automated provisioning, service management, mass deployment, network control and multi-operator support.

To support service provider independent networks, BECS provides an extensive application interface for integration to subscriber management and customer relation management systems. In addition the architecture of the system with a central database and distributed cells that manage a defined part of the network allows the BECS system to scale from small installations to the largest broadband networks of the world.

BECS is not used to manage subscriber accounts. PacketFront provides the Subscriber Management Tool (SMT) and Help Management Tool (HMT) for that purpose as described in this document.

[26] PacketFront is only an example for components provider in the FTTH market, and is not meant to be emphasised in any other way in this thesis.

SMT

The SMT software is the PacketFront reference implementation of a service provider subscriber-service management system.

BECS and SMT communicate using a message system to share important subscriber information. Such information includes what services the subscriber is eligible to receive. BECS in return delivers logging information about user activity and other information that the service provider needs to keep track of subscribers and for billing. The open architecture of the message system makes it possible to interact between an existing service provider subscriber management system and BECS. When no such system exists, or when the broadband network subscribers can be managed from a separate system, the PacketFront SMT software provide a complete subscriber management system with BECS integration.

HMT

The Helpdesk Management Tool (HMT) is a software product from PacketFront that makes it possible to offer dedicated customer support by using a helpdesk service. To facilitate helpdesk applications with a web-based GUI interface, HMT extends the functionality of the Subscriber Management Tool (SMT) and BECS™ control and broadband provisioning system.

SSP

The Service Selection Portal (SSP) is a software product which allows the end users to activate and deactivate the services by following simple wizards. Each step presents explanatory texts and asks the user for the appropriate response. Also included in the product there is access to a central Portal Generator that provides a complete administrative tool for service providers. Service providers are given their own user accounts for updating their texts, pictures etc.

D.2 Needed Hardware

The first three partitions of *Table 10* contain components that would be needed for the automation and provisioning part. The last partition in Table 10 covers the components that may be needed in the remote nodes (only the main components are mentioned here). In the ORN (remote nodes) one could use ASR 24-port routers from PacketFront. To cover 650 households like in this case study, one would need 30 routers. Each router also needs its software package. In addition, there is need for two SFP (small form-factor pluggable) for each router, which is a total of 60. SFP is a industry standard for optical transceiver that is hot-swappable. This means that SFP can be upgraded or replaced independant from rest of the router.

In general, the numbers used in the calculations in the case study is partly connected to this component list. Because of confidentialy requirements and difficulties around collecting prices, some numbers are adjusted, after consultation with other sources.

Table 10: FTTH components from PacketFront

PRODUCT NUMBER	PRODUCT DESCRIPTION	NUMBER
T10Z106A-08GB1G	Sun Fire T1000 Server	1
BECS3-START	BECS 3 Starter Kit (one Core, one Cell and one SMT), PS installation excl Expenses	1
BECS3-LIC-PORT-A	BECS 3 type A license for 1 user L3 port	650
BECS-HMT2-LIC-INSTALL	BECS HMT 2 Helpdesk Subscriber Tool and PS installation excl. Expenses	1
BECS-HMT2-LIC-PORT	HMT 2 license per PFDP-enabled CPE device	650
DP-DREAMPORTAL-LIC-INSTALL	Portal with auto provisioning etc for BECS	1
DP-LIC-PORT	Portal per port cost	650
DRG586s-1	8 10/100BaseTX ports, 1 100BaseFX SM Single Fibre SC uplink, 2 VoIP ports w.o PSU	650
ASR5624AC-CO	Advanced Services Router 5624AC-CO, 24 100BaseFX 1-Fibre Bi-direction SC SM	28
SFP-1000BASE-LX	1000BASE-LX SFP	56
SW-ASR-ADV	IBOS advanced software package for ASR5K per L3 port	28

E: Lundåsen Case Study

In relation with the case study, there has been collected economic data and then performed different setups (unit costs, estimation of CAPEX and OPEX etc) to obtain the results presented in *chapter 11*. All of the setups and calculation for this case study is available as Excel-sheet in the electronic attachment.