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Title:

How to reach nationwide coverage of 100 Mbit/s broadband by 2020

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Abstract: This master theses analyses if it would be likely that Denmark reaches the target of 100 Mbit/s broadband access to residential areas by 2020, and provides suggestions to what means that needs to be taken in order to reach that goal.

The analysis has been conducted in six steps: 1) describing the government strategy, 2) status of the rollout of high-speed broadband in Denmark, 3) what is the cost of reaching the political goal, 4) how can the rollout be financed, 5) what are the political instruments available to cover the access gap, and 6) interviews with industry experts in order to validate our findings,

The conclusion is that we find it unlikely that Denmark will reach a nationwide coverage of 100/30 Mbit/s broadband access to residential areas by 2020, but if the demand is present, and the willingness to invest from the public side, then there is no true access gap present that cannot be covered by existing political instruments.

By signing this document each group member confirms that all have participated equally in the project work and that they collectively are responsible for the content of the project report. Furthermore, each group member is liable for that there is no plagiarism in the report.

Master thesis

How to reach nationwide coverage of 100 Mbit/s broadband by 2020

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Executive summary

This master theses analyses if it would be likely that Denmark reaches the target of 100/30 Mbit/s broadband access to residential areas by 2020, and provides suggestions to what means that needs to be taken in order to reach this goal.

The analysis has been conducted in six steps: 1) describing the government strategy, 2) describing the current status of the rollout of high-speed broadband in Denmark, 3) estimating the cost of reaching the political goal based on the current status, 4) discussing how the rollout can be financed, which addresses can be covered commercially, and which addresses needs intervention, 5) describing the political instruments available to cover the access gap, and 6) finally we have conducted three interviews with industry experts in order to validate our findings, and to get their view on the current status and the political instruments.

Based on the uncovered addresses from Tjektditnet.dk, we have estimated the cost of reaching nationwide 100/30 Mbit/s to approximately 9.7-13.2 billion DKK. This is an order of magnitude we do not expect the government or the industry to finance. Our analysis show that at least 45% of the 317.000 addresses that are uncovered can be reached commercially, leaving 55% or 175.000 households in scope for intervention.

The policy tools that are available for the Government or the municipalities are structured in three groups: 1) Tools that can accelerate coverage of commercially reachable addresses mainly by increasing awareness and digitalization, prolonging tax credit ("håndværkerfradraget"), and use resources on providing information to dedicated citizens on the possibilities. 2) Tools that can facilitate the coverage of the addresses outside commercially reach by making it easier to get access to ducts and cell towers, promote technology neutrality in public tenders, and to explore new PPP models, that are supported by the Government on how to conform to European law. 3) Addresses that can only be covered by extraordinary means which is approximately the last 1% that can either be subsidies directly or be covered by issuing a Universal Service Obligation on basic broadband.

The conclusion is that we find it unlikely that Denmark will reach a nationwide coverage of 100/30 Mbit/s broadband access to residential areas by 2020, but if the demand is present, and the willingness to invest from the citizens, the industry, the municipalities, and the Government, then there is no true access gap present, that cannot be covered by existing political instruments.

1. Introduction

Today the competition on the market for high-speed broadband access and services in Denmark builds on the history of the telecommunication regulation implemented by the Danish Government. The regulatory framework has primarily had the aim of supporting service competition but over the last years the incentives supporting infrastructure competition have increased. The regulation has set the framework for the market driven rollout as well as the product development, which adds up to the status for both competition, coverage and services within the broadband market in Denmark to day.

The cabling has primarily market driven except from the copper cables deployed in new built areas that has previously been deployed based on TDC holding the Universal Service Obligations (USO) on telephony. The primary players offering wired broadband access in Denmark are: TDC – the incumbent operator, the regional utilities and two cable companies: Stofa A/S that is a part of the utility company covering south of Jutland (SE), and YouSee that is a part of TDC. In addition to these owners of wired infrastructure several service providers are offering broadband services primarily based on TDCs infrastructure.

The wireless players are primary small companies offering Internet services to a local area. The players are sometimes not known in the public and are easily overseen by people outside the region in which they operate. Examples are AirNet, Osted Nettet, trådløsfiber.dk, and Grenaas.net. In addition to this at least two nationwide operators, Skywire and ZibraWireless, are offering wireless solutions in isolated areas with no existing fibre-infrastructure. To our knowledge ZibraWireless is the only operator offering wireless access with a guaranteed speed above 100 Mbit/s. The wireless solutions offered by the other mentioned operators are based on shared WiFi but the technology can deliver guaranteed speeds above 100 Mbit/s, see *Figure 7*. It is thus expected that technology upgrades can increase the bandwidth offered by the wireless operators significant.

TDC as incumbent operator is the only operator in Denmark with the status of having Significant Market Power (SMP). Based on this TDC is the only operator in Denmark that is being regulated and with respect to broadband services TDC is the only network operator obliged to offer access to other service providers on regulated wholesale terms[1]. Based on the history of being the incumbent operator TDC has almost 100% coverage on cabled narrowband services (up to 2 Mbit/s). Based on

[1] Due to EU legislation, a few specific FTTH-networks are imposed the same wholesale obligation due to the buildout being subsidized from the Government or municipalities (ex. BornFiber).

this coverage and the obligation to offer access on regulated terms to other operators each customer with a copper drop cable has the possibility to choose among different service providers. At least if the demanded speed can be fulfilled by a twisted copper pair.

The focus on ultra-high-speed broadband (above 100 Mbit/s downstream) has increased over the last years. If a broadband speed of 100/30 Mbit/s is used to define a Next Generation Access (NGA), the coverage of this network is less uniform and the individual customer is no longer guaranteed the possibility to choose among different service providers – and some costumers even have no service providers to choose from.

TDC (including YouSee) is currently covering approximately 50% of the households in Denmark with broadband above 100 Mbit/s. The rest of the country is covered by either utility fibre, cable (Stofa), or private infrastructure (typically small local networks). Approximately 12% of the Danish households are not covered by any infrastructure offering services above 100 Mbit/s, see (Energistyrelsen, 2015). To our knowledge[2] no households are covered by 100 Mbit/s offered as a wireless solution.

Looking at ultra-high-speed broadband above 100/30 Mbit/s, 50% of the household's experience competition on the service level, and the remaining 50% are experiencing either no NGA-service and no rights to get service, or NGA-service monopoly (if covered by a utility company or Stofa A/S). Looking at FTTH or cable as the primary technology offering ultra-high-speed broadband above 100/30 Mbit/s, approximately 30% of the households are experiencing infrastructure competition, see (Energistyrelsen, 2015, p. 22).

Among the 50% of the households who experience either no NGA-service or NGA-service monopoly we have focused our thesis on the 12% (February 2017) who are currently in the situation of experiencing no existing NGA-coverage.

[2] This knowledge is confirmed by Hans Teglhus Møller (10052017_Energistyrelsen, 29:10-29:30)

2. Definitions

NGA network: In this thesis, we use the term NGA (Next Generation Access) as a common term for access capable to be used for a 100/30 Mbit/s broadband service. This definition is our interpretation of the definition made by the European Commission, see (Commission, 2013, no. 58). In the guidelines from the Commission a NGA-network is defined to: "*(i) deliver services reliably at a very high speed per subscriber through optical (or equivalent technology) backhaul sufficiently close to user premises to guarantee the actual delivery of the very high speed; (ii) support a variety of advanced digital services including converged all-IP services; and (iii) have substantially higher upload speeds*". The Commission includes FTTx technology, cable network upgraded to at least Docsis 3.0 and some advanced wireless solutions. The FTTx technology includes FTTC (fibre to the cabinet) which leaves the "last mile" to be supported by copper. Apart from 'some advanced wireless solutions' this definition restricts to wired infrastructure and mobile technology is thus excluded. In *section 7.7* there is a more detailed description of the technological development, and how the wired and wireless technologies are converging.

In the definition from the Commission no specific speed is required – only the need to deliver very high speed and substantially upload speed. To make a link to the current ambition from the Danish Government with respect to 100/30 Mbit/s coverage it seems appropriate to use this speed limit as a definition of NGA-network. Looking at the specific technologies this definition includes FTTH (Fibre To The Home), FTTB (Fibre To The Basement), and FTTC (Fibre To The Cabinet) – at least if the cabinet is located a maximum of 300-600 meter from the customer premises[3] – making it possible to deliver a 100/30 Mbit/s service by use of vectoring.

This 100/30 Mbit/s interpretation of NGA is in accordance with the definition used by Jensen, Gutierrez, Henius & Pedersen (2015) but it is a tightening compared to other previous interpretations in papers and reports, ex. (Yoo, 2014) and (Topic, 2013). In these last-mentioned papers, the interpretation of NGA is set to 30 Mbit/s. Our reason for tightening to 100/30 Mbit/s is to conform with the recent tenders in Denmark in which the target speed is set at 100/30 Mbit/s in accordance with the target speed used by the Government. Besides, this definition is appropriate as a tool to investigate the subject of increasing 100/30 Mbit/s coverage.

Access gap: In our thesis, we use the term access gap to account for the coverage left to be covered after competition and general market forces have covered their part. If it is not possible to achieve a

[3] 300 meter if only one copper pair is used, 600 meter if it is possible to use pair bonding with 2 copper pairs.

positive Business Case in deploying coverage in a specific area for an operator even with a deployment subsidy we include this area in a true access gap. The term: “true access gap” is originally used in relation to Universal Service, see (Blackman & Srivastava, 2011), but we have adopted the terminology to be used for general coverage as well.

TjekDitNet.dk: The Danish Energy Agency has collected coverage information from all operators which is presented on the web-page TjekDitNet.dk. On TjekDitNet.dk it is possible per address to check which operators are covering the address and at what speed. The Agency has gathered information regarding all possible technologies and all service providers capable of delivering service on the specific address are listed with a link to the web-page of the service provider. In our thesis, we use TjekDitNet.dk as a reference regarding coverage.

2.1.List of abbreviations

In the literature and in our thesis, a significant amount of abbreviations are used. In *Table 1* below the abbreviations most used in the thesis are listed.

Table 1, list of abbreviations

Abbreviation	Explanation
NGA	Next Generation Access
SMP	Strong Market Power
USO	Universal Service Obligation
FTTx	Fibre To The Home(H), Basement(B) or Cabinet(C)
xDSL	Asymmetric Digital Subscriber Line (A), Very-high-bit-rate DSL (V)
DSLAM	Digital Subscriber Line Access Multiplexer
GPON	Gigabit Passive Optical Network
P2P	Point to point
WiMAX	Worldwide Interoperability for Microwave Access
QoS	Quality of Service
PPP	Public Private Partnership
LRAIC	Long Run Average Incremental Costs
NPV	Net Present Value
MDU	Multi Dwelling Unit, apartment building.
SDU	Single Dwelling Unit, villa
POP	Point Of Presence
ODF	Optical Distribution Frame,
PDP	Primary Distribution Point
SDP	Secondary Distribution Point
CPE	Customer Premises Equipment

3. Problem statement

During the last decade, the focus on ultra-high-speed broadband above 100 Mbit/s has increased and among different authorities (European Commission and the Danish Government) the target is to obtain a substantial coverage with 100 Mbit/s broadband to residential areas by 2020. In Denmark, the target is 100% which, with the current estimated 88% coverage, leaves 12% to be covered in the coming four years.

Based on this our main research question is:

Is it likely that Denmark reaches the target nationwide coverage of 100 Mbit/s broadband access to residential areas by 2020, and what means must be taken to reach this goal?

To answer this question, we will consider the development in the Danish regulation in the period 1997-2017, the different tools used by the municipalities, and the Government to increase coverage as well as incentives driven by the citizens in order to increase coverage in their neighbourhood.

In addition to this we expect to cover the following sub-questions:

- What is the cost of reaching the political coverage goal for households?
- What are the possibilities of financing the rollout? What can be covered by competition, what needs smart subsidies like the broadband fund?
- What are the policy dimensions that can be used to close the access gap? Are there other methods that can be used to close the access gap?
- Is there a true access gap that can't be covered by the current political instruments?

4. Methodology

The idea of looking at different means to promote the investment in Next Generation Access is founded on our doubt, tending scepticism that the target coverage set by the Danish Government will be fulfilled unless extraordinary efforts and investments are made.

We have chosen not to question whether the target is reasonable. We have therefor simply accepted the target as given and we have therefor looked on the not yet covered households to investigate whether it is likely that the market forces and existing initiatives will ensure the remaining rollout within the set time limit.

The research choice we have taken is that of mixed methods. We have collected objective data displaying the address of all uncovered households, and made an estimation of the costs of reaching full coverage i.e. extending the existing coverage to include the ones from the data-set. The remaining part of the analysis is based on desk studies founded on articles and existing literature covering the field.

The main assumption in our thesis is, that it is the Danish Government that has set the target of reaching nationwide coverage and not the market. As a consequence, it can only be left to the market to ensure the rollout if it is plausible that the market will sort it out within the set time limit, i.e. if the necessary demand exists, if sufficient financing is present, and if it is possible to get a sufficient payback on the investment. We have investigated if this is a plausible case and the market therefor can be left alone. If it is not plausible that the market will honour the target coverage, it is our presumption that the Danish Government must look for alternative ways to drive the rollout – either directly or indirectly.

As a supplement to our analysis we have made a few interviews with experts within the field of telecommunication and broadband coverage. The interviewees are: John Strand, Netplan (Anne Mette Kruse Møller and Mette Dalsgaard) and representatives from the Danish Energy Agency (Peter Johnson, Hans Teglhus Møller and Rikke Rosenmejer). The interviews have been explorative and more conversation-like and not stringent interviews. Consequently, the interviews serve as inspiration and input to the discussion and reflections and they are not valid as scientific evidence.

The rollout of NGA-network is an ongoing process and during the period of completion of the thesis, further households have been coved. Our analysis is based on the status known to the Danish Energy Agency at the beginning of 2017. In March 2017 the industry has reported updated information on the coverage and the estimated coverage per March 2017 is approximately 89%. With the ongoing rollout it is expected that the coverage per June 2017 is slightly larger and exceeds the one used as reference in this thesis (88%).

To summarize the thesis is based on the following sources of information:

Table 2, primary sources of information

Source:	**Explorative interviews**
Aim:	Get input to our analysis and validate our conclusions
Used for:	Background information and validation of findings
Bias:	The political/ideological point of view is reflected in the statements from the different interviewees. Particularly John Strand who is very much in favor of leaving it to the market. The fact that we are representatives from TDC probably also affected the discussion.

Table 3, secondary sources of information

Source:	**Source data from TjekDitNet.dk**
Aim:	To get specific information on the households not covered by 100/30 Mbit/s
Used for:	Estimation of costs incurred to deploy nationwide coverage with 100/30 Mbit/s
Bias:	The messure is boolean either covered or uncovered. Households covered by ex. 90Mbit/s are expected to be less willing to pay for additional coverage compared to ex. households covered by 5Mbit/s. This difference is not visible in the data.
Source:	**LARIC data sheet**
Aim:	To get information on costs of assets used to deploy FTTH
Used for:	Estimation of costs incurred to cover the yet not-covered households with FTTH.
Bias:	The costs are based on political objectives and used for a genric greenfield build out, aiming at calculating average costs and not specific costs.
Source:	**Governmental reports**
Aim:	To get background information on status, political initiatives etc
Used for:	Description of the current status of regulation, existing coverage, and key statistics used in the thesis
Bias:	Expected to be objective but will probably have a minor bias towards the existing official political point of view.
Source:	**Academic papers and articles**
Aim:	Background information on the theoretic aspects
Used for:	Setting the theoretical framework for the thesis
Bias:	
Source:	**Knowledge within the project group**
Aim:	Validate information from interviewes and government reports, to provide cost estimates based on the available sources of information.
Used for:	The sections 'status', 'cost calculations', 'finansing the gap', 'policy dimensions', 'conclusion', and 'discussion'.
Bias:	Beeing employees of TDC the view on government intervention and competetive build out may be biased in favor of TDC

4.1.Method of analysis

In our thesis, we have used a method inspired by H. Jussi (2011) who has made different estimates of the costs of meeting the target set by the European Commission with respect to basic broadband coverage, NGA-coverage and uptake of 100 Mbit/s subscription in Europe. H. Jussi (2011) first estimates the costs of reaching the set target – this is done by describing the target, looking at the current status and estimating the coverage gap. Having estimated the total cost, a Business Case perspective is used to estimate the realistic level of investment, that can be expected to be financed by the industry. In order to close this financing gap, H. Jussi (2011) recommend some kind of public intervention which can be seen as a public investment with a substantial payback, depending on the value of the additional coverage seen from a national point of view.

In our thesis, we have suppressed the discussion of the value of reaching the target coverage. As seen in *Figure 1,* we have otherwise followed almost the same structure.

Figure 1, illustration of method of analysis

Government strategy:
What are the digitalization plans in EU and in Denmark, and what has the impact of these plan been on the development in regulation of broadband coverage in the period 1997-2016?

Status of roll-out:
What is the status of the current rollout of broadband in Denmark?

Cost of coverage:
What is the cost of reaching the political coverage goal?

Financing the gap:
What are the possibilities of financing the rollout. What can be covered by competition, what needs smart subsidiaries like the broadband fond etc. and is there a true access gap that can't be covered by the current political instruments.

Policy dimensions:
What are policy dimensions that can be used to close the access gap?

Validating the findings:
Validate the key findings with industry experts and knowledge people.

As a starting point, we have the described a theoretical framework that can be used to investigate market intervention by the Government both by regulatory and non-regulatory instruments. This discussion is the content of section *5*. In this section, we also go into more detail of the theoretical framework in which the Government intervention can be seen. The different instruments of intervention described in *section 5* will be referenced in *section 10*, in which we have listed some actions that can be taken to facilitate a reduction – or even closure – of the coverage gap.

As illustrated in *Figure 1* we begin the analysis with a description of the status of the current rollout, the most resent initiatives in Denmark supplemented by the political position regarding the matter - both in Denmark and in EU. In *section 6* we start by describing the strategy of the Danish Government as well as the targets and strategy from the European Commission. This section is followed by a status of the current role-out, including a listing of some of the players in the field. The result of the latest market analysis, and the current initiatives both facilitated by the Government, by the municipalities and by the dedicated citizens. In the following section, *section 8*, we have devoted a part of the thesis to describe our method of estimating the cost of reaching nationwide NGA-coverage for households, based on covering the remaining households by FTTH. The methods used are based partly on methods used by other contributors having estimated cost deploying nationwide coverage, ex. (Analysys Mason, 2008) and (TERA consultants, 2014), modified to fit the remaining households not covered in Denmark. The two sources mentioned have not taken into account addresses already covered since the aim of the analysis of both (Analysys Mason, 2008) and (TERA consultants, 2014) are to estimate costs of moving from zero coverage to a set target coverage. *Section 8* concludes with an estimation of both the total cost of reaching nationwide NGA-coverage as well as a cost-distribution curve showing the total cost as a function of coverage. The cost-distribution curve is the primary input to *section 9*, in which the financing of the remaining coverage is discussed. We have divided the remaining coverage in coverage that we expect can be covered by general competition and market forces primarily driven by a demand pull, and coverage that needs targeted initiatives to be dealt with.

The primary methods of reaching coverage are grouped based on primarily the ways for an operator to get a valid Business Case. The headlines used in our thesis are: 1) commercially reachable coverage, 2) coverage that needs intervention from either Government, municipalities or local associations or business, and 3) coverage that is only possible to reach by extraordinary funding, lowering the target bandwidth, or introducing wireless or mobile technology.

The focus of *section 10* is to describe the different initiatives driven by the Government that can be used to encourage the rollout. The different types of initiatives are based on methods mentioned in the literature (referenced in *section 5*), exemplified with specific initiatives seen in Denmark. We have organized the initiatives according to whether they support a demand pull or a supply push effect.

Finally, we have validated the findings with industry experts. In *section 11* we have included a short summary of each interview. Specific points of relevance we have referenced in the thesis in the section most appropriate.

Based on our findings and analysis we conclude on the research question in *section 12* and finally we have dedicated *section 13* to discussion of the method, the analysis, our findings and key learnings. In this section, we also have suggestions for further research and possible interventions from the market and the Government.

4.2. Validation of coverage data

The data obtained from TjekDitNet.dk is based on the reporting made by the operators. To control the validity of the data we have made the following two exercises:

i) Based on a small sample of random chosen addresses already covered with 100/30 Mbit/s we have matched the information on TjekDitNet.dk with that of the operator who is listed as supplier on TjekDitNet.dk.
ii) The households not covered by 100/30 Mbit/s are linked with internal TDC-information on TDCs capability to deliver 100/30 Mbit/s to the address. It is expected that no addresses included in the data-set from TjekDitNet.dk are covered by 100/30 Mbit/s according to internal TDC-information.

The result of the validation is that among 20 randomly chosen addresses, not represented in the dataset all have access to a broadband service with speed above 100/30 Mbit/s, at least according to TjekDitNet.dk. The discrepancy is thus not between the data-set we have received and the information on TjekDitNet.dk, but primarily between the information on TjekDitNet.dk and the webpage of the operator listed on TjekDitNet.dk as being able to deliver the service. Even though the sample is too small to make any statistical validation we can conclude, that some discrepancy exists. The chosen addresses and the information on TjekDitNet.dk as well as that of the operators are listed in *Appendix A, validation of coverage data*.

The linking of the data-set with internal TDC-information shows, that among the 317.000 uncovered addresses, 7.450 are covered by 100/30 Mbit/s by TDC-infrastructure. This small discrepancy (2,5%) can be explained by rollout made by TDC between to updates of the information on TjekDitNet.dk. A small discrepancy is also expected due to different interpretation of the address corresponding to a specific household. Additional information on infrastructure covering the 7.450 addresses can be found in *Appendix A, validation of coverage data*.

The primary use of the data is to estimate order of magnitude and the cost distribution, and small changes in the data are not critical for the conclusions. Based on this we are confident, that the validity of the data is sufficiently as foundation for our analysis, even though some discrepancy exists between the information on TjekDitNet.dk and that of the different operators.

5. Theoretical framework

In the 2020 vision from the European Commission, one of the flagship initiatives is the digital agenda that aims at speeding up the role out of high-speed Internet (Commission, 2010). Now each member state is in the progress of realizing the strategic target by building policy frameworks that can stimulate the investments in NGA-networks and services (Bauer, 2010). When building a policy framework, one of the key discussions is what role the state should play in the market development.

The most predominant point of view today is the neoclassical, where the state should only intervene in case of market failures. This development model is being questioned by Ha-Joon Chang (2002), who is questioning the neoclassical concept of the free market. His argument is that the "free" market is based on institutions that regulates who the legitimate players are, which goods and services are present in the market, and under what laws and rules do the players interact. Hence there is no free market, and there is a need for a new framework to analyse the state, institutions and political intervention. We acknowledge this point of view, but in out theses we have used the predominant point of view.

5.1. Free market forces versus regulation

The goal of the neoclassical development model is to provide an efficient allocation of scarce resources by focusing on prices, market output, and income distribution based on supply and demand, while minimizing Government failures. Government failures arises when the Government intervene in the market, and creates inefficiencies and misallocation of resources. An example is if the Government awards subsidies to inefficient companies, or reduces the cost for the existing players and thereby creates barriers for new entrants. The key assumption in the neoclassical development model is that the market consists of rational players that seek to maximize their own utility or profit. The limited Government involvement in applying policies is to ensure that there are clearly defined property rights and a legal system with monetary incentives. The Government involvement must secure that disputes can be settled by court, Joseph E. Stiglitz (2010). However, these incentives might not always be sufficient, hence ex post compensation is not enough, and means must be taken to settle disputes ex ante if possible. This will require an institutional arrangement that minimizes the impact of Government failure, while preserving the benefits that comes from correcting market failures by regulation.

Critics state that the conditions in the neoclassical market definition will never be fully achieved, as information is imperfect, markets are incomplete, natural monopoly is present, and transactions costs exists, Joseph E. Stiglitz (2010). This results in a situation of market failure, where the allocation of resources is not optimal, due to the presence of natural monopoly, imperfect information, externalities or public goods.

This suggest that the Government has a signification role to play in the economic development, but where the policy makers limit their functions to issues where they have an advantage over the private sector (provisioning of public goods, assigning and enforcing property rights, and even access to information), and where they can use well designed regulatory frameworks to limit the effect of market failures. According to Joseph E. Stiglitz (2010), other types of "market based" interventions, like taxes and subsides, has not proven as effective compared to regulation in ensuring efficiency in the market. The regulatory tools are grouped into three categories, (Joseph E., 2010): 1) Information requirements that aims at ensuring full disclosure of information to ensure the market can function. 2) Proscriptions which focus on regulating factors that might affect behaviours, or by putting restrictions on ownerships to restrict any competitive actions or monopolies. 3) Mandates like interconnectivity in networks that are related to anticompetitive behaviour that benefit the public without spending money.

These categories of regulatory tools have been the instruments for the Government agencies that have been facilitating the transition from Government monopoly to an open market place with a high degree of competition. However, in the case of supporting the rollout of a NGA-network, the purpose of the policy framework is to extend the pure regulatory instruments with industrial policy instruments – like tax incentives, subsidies, Public Private Partnerships, and direct governmental investments – to develop the right combination that will drive the innovation and investments, (Bauer, 2010).

5.2. Policy framework

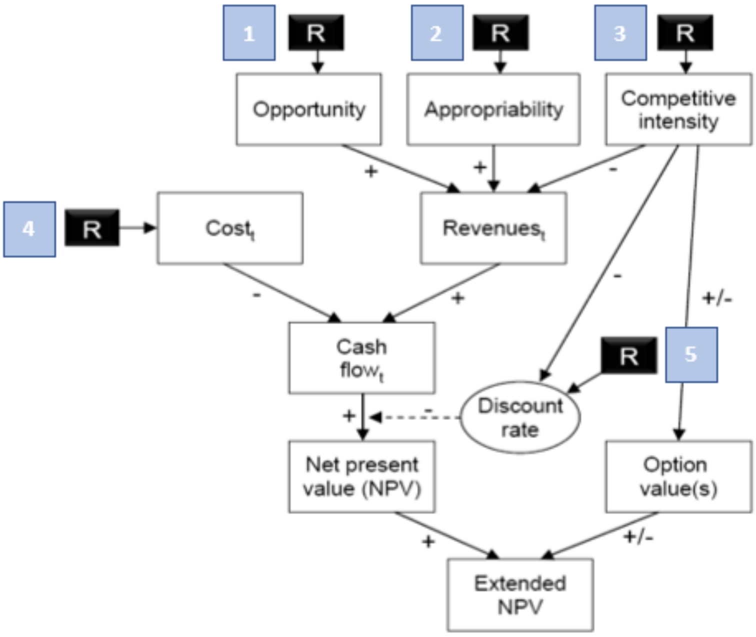
The policy framework must consider the implications of the regulatory and public policy tools on the market players, and their decisions on investment and innovation. According to Johannes M. Bauer (2010) the investment and innovation incentives in the NGA-network differs in three ways from the traditional telecom marked: 1) the market place has develop from a monopoly environment to an ecosystem of regulated and unregulated players, 2) new forms of corporations arises, and competition between players with strong complementary relations increases, resulting in highly complex and dynamic market processes, and 3) a significant portion of the new infrastructure has to be build, either by upgrading existing infrastructure or by rolling out new technology.

The characteristics of the NGA-network is that it consists of a vast number of different players: Regulated and unregulated network operators, and application- and content providers. These players are assumed to decide the level of investments based an analysis of the Net Present Value (NPV) of an investment as part of a Business Case, and in case of a positive Business Case, they will pursue the investment. This means that regulation cannot force any providers to do investments, but can only set the overall framework that affects the Business Case, and hence the willingness to invest. Therefor there is a need for extending the traditional policy instruments with industrial policy instruments that affect other dimensions in the NPV-calculations (Bauer, 2010, p. 67).

Johannes M. Bauer (2010) presents a framework for the design of a policy framework. This framework builds on the notion that the communication industry is a technology dynamic sector where innovation and investment decision are closely related. The different implications of the regulation, on the static and dynamic sector performance, and between regulated and unregulated players in the ecosystem must be evaluated carefully. The framework, illustrated in *Figure 2*, examines what influence different factors like the 1) **opportunities** that arises from new technical and economical possibilities, the 2) **appropriability** of generating revenue from a given investment, and the 3) **competitive drive** from other players to invest in the market, have on expected NPV of a given investment in the market. A similar framework has been proposed by William H. Melody (2005).

In *Figure 2* the different intervention points with respect to public policy and regulation are illustrated by an "R" and instruments associated with the different intervention points are listed in *Table 4,* (Bauer, 2010). In *Figure 2* the NPV of the investment being considered must be compared with the value of other opportunities – i.e. other investments that could have been made. This "Option value" is illustrated by the bottom right box. Only if the NPV is sufficiently large compared to the NPV of alternative investments the extended NPV is positive and the investment in question will be considered.

Figure 2, intervention points (R) of policy and regulation in the NPV-calculus



Source: (Bauer, 2009, p. 11), supplemented with numbers 1-5

The effect of the regulatory choices depends on the status of the market, and the actual design of the regulation. If the intention of the regulators (R) is to increase the service competition, this can be done by increasing **competitive intensity** (e.g. unbundling obligation). This will make the entrance cost of the service-based players lower and increase their profit potential (Bauer, 2010). On the other hand it reduce the opportunities [1] of the infrastructure owners in the market, and risk a decrease in infrastructure rollout. As illustrated in *Table 4,* depending on the intervention point of the regulators, there are various regulatory and public policy tools available that will affect the horizontal or vertical structures of the market and thereby affect the investment decisions for both incumbents and new entrants. The traditional wholesale regulation like unbundling and interconnection will influence the level of competition in the market, and indirectly affect investment decisions of both incumbents and new entrants. The **competitive intensity** will influence the **appropriability** condition, the pressure to invest, the level of uncertainty and hence the discount rate, and the value of different management strategies (option value). This illustrates that the company compares investment initiatives to identify which investment gives the company most value for their money. An example is that the NPV of deploying parallel infrastructure in an urban area exceeds the NPV of deploying fiber in a small rural area, due to difference in cost and potential revenue.

Table 4, public policy instruments affecting investment incentives

Table 1
Public policy instruments affecting investment incentives.

	Intervention point	Regulation	Public policy
3	Competitive intensity	Licensing conditions Unbundling, open access Network neutrality	Antitrust enforcement
1	Opportunity	Line-of-business restrictions	General business climate
2	Appropriability	Profit regulation Retail price regulation Non-discrimination requirements	Patent and copyright provisions Antitrust provisions
4	Cost	Quality-of-service requirements Unbundling, open access Network neutrality	Tax policy (investment tax credits, depreciation, carry-over of losses) Subsidies
5	Discount rate	Stability of regulation	General business climate
	Option value(s)	Unbundling, open access Network neutrality	General business climate Patent and copyright provisions Antitrust provisions Taxes and subsidies

Source: (Bauer, 2010, p. 68) , supplemented with numbers 1-5

The task of regulation is to find the right level of competitive intensity, that provides the optimal level of incentives to invest in the market, since too little or too much competition may causes weak innovation performance (Bauer, 2010). However, this optimum is not known, and the regulators must define a combination of safeguards and interventions that keeps the competitive performance above a lower threshold where the dynamic performance falls, and below an upper threshold where the prices are falling below a point where there is no incentive to innovate and invest.

In summary, Joseph E. Stiglitz (2010) and Johannes M. Bauer (2009, 2010) argue the need for regulatory instruments to allow Government intervention to address market failures. However, they have a different point of departure in the definition of the market, and the objectives of the regulator. Joseph E. Stiglitz (2010) defines a set of regulatory instruments that can be deployed to ensure an open, efficient market without addressing the transition from historical static market structures to the present, where many markets have become an ecosystem of many players from different industries. Johannes M. Bauer (2009, 2010) argues that change into dynamic ecosystems requires the regulator to focus on the impact of the regulation and public policies on investment and innovation decisions that will shape the future of the sector. He proposes a classification of the available instruments into 1) horizontal regulatory instruments that affect the structure and competitive intensity between players at the same level, 2) vertical regulatory instruments that structures the rights and obligations that governs the interactions between the players across layers, and finally 3) the non-regulatory public policy that are designed to affect the investment incentives of all the market players.

5.3. Policy tools

The **horizontal instruments** are used to govern the transactions between facilities and service-based network providers operating within the same layer, by leveling the competition and reducing the transactions costs. As mentioned above, the regulatory instruments have been developed to support the transition from monopoly to an open and competitive market, and consist of access to rights of way, colocation, interconnection, unbundling, resale, provisions governing number portability, and to some level also licensing policies. All instruments are not applicable in the NGA-market, but similar instruments are available. These are access to ducts, dark fiber, colocations at various sites, full and sub loop unbundling, and bit stream access (Bauer, 2010).

Vertical instruments are used to influence the relationships between the players in the ecosystem, across layers, and hence affects the incentive to invest and innovate in the market (Bauer, 2010). They allow for a wide range of non-discrimination obligations that affect the overall investment and innovation dynamics by constraining the charges, conditions and transaction cost between network operators and content providers. In the NGA-market these instruments are used to stimulate demand, hence the discussion concerning net neutrality is an example of the issues that relate to designing vertical rules, as it concerns two interrelated problems 1) the potentially abuse of market power by a vertically integrated company, and 2) the concern about the regulatory framework that best facilitates dynamic efficiency.

Non-regulatory public policy is designed to affect the investment incentives of the market players. The policies are divided in demand-side tools and supply-side tools. If the demand-side and supply-side tools are designed properly they should have an expansionary effect on the investment and innovation in NGA-networks.

Demand-side tools are tax credits, subsidies and voucher programs that benefit household or Government agencies that boost ICT-demand. The most important **supply-side** tools are tax credits for investment in networks and innovation expenditures, carry over of losses, accelerated or decelerated depreciations, subsidies, and measures that lower interest rates (Bauer, 2009). Investments or innovation tax credits can be awarded either generally or by a specific qualifying project in e.g. a specific geographic zone or a specific purpose like NGA-network deployment. Another non-regulatory Government instrument is to reduce the cost of financing the projects though polices that effect the interest rate. The third possibility for the Government is to take a more proactive and direct role, either by coordinating infrastructure investments or by investing directly. The experience over the past few years in the US suggests that community models that aims at full community coverage are not sustainable without any form for subsidy (Bauer, 2009), at least not with the fiber based technology, but this might change with a wireless technology like WiMAX or WiFi (Bauer, 2010).

Designing a regulatory framework that covers NGA is complicated due to the interdependencies between the horizontal and vertical players in the value network. The regulatory framework need to evaluate the effect not only to the regulated company and market segment, but also their impact on non-regulated companies and market segments. Traditionally the regulators have been performing analysis of the existing market structure, and based on the findings they have found the best fit of regulatory tools. The NGA-market however, is a dynamic market under development and it is evolving over time, so any regulatory intervention will affect the investment and innovation choices of the players in the different layers hence affecting the future development of the market (Bauer, 2010).

The classification in *Table 5* is adopted from (Bauer, 2010) and illustrates the various regulatory and policy options available for the policy makers to apply, depending on how the regulators want to intervene in the NGA-market. Regulators can intervene to drive infrastructure development, to increase service competition, or to increase coverage or uptake. Depending on the targeted effect the regulator must decide on a regulatory framework, or to use a non-regulatory policy (development approach).

Table 5, available regulatory and non-regulatory policy instruments

Instruments affecting Demand:	
Vertical Instruments	e-government, e-health, e-education, Consumer awareness and information
Non-regulatory instruments	Subsidies, Tax credits, Voucher programs, Low interest financing, Public Private Partnerships
Instruments affecting Supply:	
Horizontal Instruments:	Unbundling, Access to rights of way, Colocation, Interconnect, Wholesale, Licensing policies, Universal Service Obligation, Technology neutrality
Vertical Instruments	Separation between network and content, Limiting exclusivity between players, Network neutrality, Common Carrier
Non-regulatory instruments	Tax credits on investments, Subsidies, Public Private Partnerships, Deprecation on investments, Low interest financing

Source: (Bauer, 2010)

The framework illustrated in *Figure 2* and the regulatory options listed in *Table 5* will be used in *section 10* to analyze what combination of regulatory instruments, that can be used to drive innovation and investment in the NGA-market.

5.4. Universal Service and Universal Service Obligation

Universal Service is defined in (Blackman & Srivastava, 2011, Chapter 6) as a service available to all individuals or households to be used privately. The service must be both available, accessible and affordable. A service must fulfil certain requirements to be covered by a Universal Service policy, and thereby be optional to be included in a Universal Service Obligation. In (Blackman & Srivastava, 2011, Chapter 6) the requirements are that the service must be essential for social inclusion, and normal commercial forces are not sufficient to guarantee the presence of Universal Service. In the Universal Service Directive, (Parliament, 2009), it is also stated that a disproportional financial burden must not be imposed on the sector undertakings due to a risk of endangering the market development and innovation. It is however stated, that Internet access is expected to be fulfilled by the traditional telephone connection, but "*Member States should be able to require the connection to be brought up to the level enjoyed by the majority of subscribers so that it supports data rates sufficient for access to the Internet*", (Parliament, 2009). Based on this basic broadband is potential to be included in a Universal Service Obligation by the member states. NGA and NGA-services are however not meeting the requirements of being 'essential for social inclusion' and therefore it is not possible to issue a Universal Service Obligation on NGA in the European member states.

According to H. Jussi (2011) some European countries have classified basic broadband as an Universal Service with the consequence that operators are obliged to supply each citizens with Internet if they apply for it. This basic broadband is however with very limited capacity ranging from 1-3 Mbit/s. H. Jussi (2011) has looked at the costs of meeting the requirements of the Digital Agenda for Europe (Commission, 2010), by first looking at reaching broadband access for all in 2013, increasing the speed to 30 Mbit/s in 2020, and finally having more than 50% of the European households subscribe to 100 Mbit/s Internet connections. The result is, that on this journey of increasing coverage the most expensive part is the first: 'reaching broadband access for all households', even with a limit of 1 Mbit/s as the target speed.

It is not possible to issue a Universal Service Obligation on NGA-services due to EU legislation. It is however possible to include basic broadband in a Universal Service Obligation. Based on the calculations made by H. Jussi (2011) it is expected that even a USO on basic broadband, in some areas will drive rollout of NGA-services or at least high-speed broadband.

6. Government Strategy

The European Commission realized in the 1990's that in order to be able to compete with the American and Asian technology companies, they needed to reform the telecom and ICT markets, implementing a policy that promotes innovation, creates and stimulates a common EU wide market, and enables European companies to increase their competitiveness (Commission of the European Communities, 1989). This policy can accordingly to William H. Melody (2013) be divided into three phases: an establishment phase, a growth phase, and a maturing phase. The different phases illustrate the change in focus based on the changing role of the industry and the importance to the economy, as well as the successfulness in implementing the regulatory framework needed to support the transformation.

6.1. The regulatory history in Denmark

In Denmark, the Danish Government issued the first national law in 1996, (IT- og forskningsministeriet, 1996), that was the starting point for liberalization of the telecom industry, enabling full competition that should provide the Danish citizens with the best and cheapest telecommunication offerings. The focus of the Danish Regulator was then on achieving service competition and it was supplemented with a Universal Service Obligation (USO), that initially has been on fixed line telephony, including ISDN and low capacity leased lines. The obligations to ensure Universal Service has been put on TDC as the incumbent operator holding Strong Market Power (SMP). The number of services covered by the Universal Service Obligation has since decreased dramatically and at the latest update in December 2016 only telephony, maintaining a nationwide register of phone numbers, and some additional services for disabled are included in the Universal Service Obligation. The operator that carries the USO is however still TDC.

In the second phase the focus has been on trying to catch up with the fundamentally changing telecom and ICT sector that has been driven by the rapid technology development, and the convergence of telecom and ICT. According to William H. Melody (2013) the focus in the European Commission changed from national liberalization towards creating a common market across EU-markets for communications- and Internet services. In Denmark, this convergence was politically addressed in a principal agreement containing new targets for the telecom policy to address the network society. This agreement is an update of the political vision "best and cheapest", with equal importance. The original vision aimed at promoting a market development that would ensure innovation and growth, and would provide access to modern communication technology for all citizens, (IT- og forskningsministeriet, 1996). The main purpose of the updated agreement, (Venstre & Folkeparti, 1999), is to move from the sector based regulation from 1996 to use the competitive law as the main general principle, but with a focus on sector regulation in the telecom area to ensure Universal Access and Universal Service principles, to provide high-speed access to the information society.

In 2014 the Danish Government (Statsministeriet, 2014) issued a status update on the progress of the digitalization effort, setting the goals for the following years. Among the results of the previous years is, that in 2013 almost all citizens have access to a basic 2 Mbit/s download, 70% have access to a download of 100 Mbit/s download and 58% an upload of 30 Mbit/s – leaving Denmark as number 8 in the EU. In 2014, Denmark was number 3 in OCED in uptake of broadband services, but with a limited uptake on the high-speed service, even though 70% has access to it, (Statsministeriet, 2014). To support the development of the digital infrastructure and to promote long term infrastructure investments, the Government sets a goal of 100% coverage by 100/30 Mbit/s in 2020 for business' and households, see (Danish Goverment, 2013).

This increase in broadband coverage should be market driven, technology neutral, based on net neutrality, and with the Government, regions and municipalities to support the rollout of digital infrastructure in areas where the market forces are not driving the rollout, (Danish Goverment, 2013). The key pillars to ensure growth in digitalization is education, increased uptake of digital services in the enterprises, and continuously public effort in digitizing the communication between the public and the enterprises, (Statsministeriet, 2014).

The goal set by the Danish Government to reach 100% coverage by 100/30 Mbit/s in 2020 has its origin in the flagship initiative "A Digital Agenda for Europe", (Commission, 2010). In this initiative, The Commission aims at getting: "*access for all to much higher Internet speeds (30 Mbps or above) by 2020, and 50% or more of European households subscribing to Internet connections above 100 Mbps*". To reach the goal of 50% subscription on Internet connections above 100 Mbit/s the coverage of 100 Mbit/s must be at least 50%.

6.2. The digital Europe

In 2010 the European Commission's Europe 2020 , see (Commission, 2010), put forward seven flagship initiatives, that should act as catalyst to archive the overall goal of smart-, sustainable-, and inclusive growth, to bring the member states out of the financial crisis and to eliminate some structural weaknesses that have been a boundary for achieving similar growth rates as the rest of the world. Smart growth means making the full use of information and communication technologies (Commission, 2010) to cater for innovation, new products and services, that helps addressing the societal challenges in Europe.

The Commission has three major focus areas: innovation, education and digital society (Commission, 2010), that need to be addressed for Europe to succeed in creating sustainable digital growth. A common denominator for these three areas is the need for ICT and high-speed Internet covering both urban and rural areas, as well as the creation of one common market place across Europe for online dissemination of knowledge and online distribution of goods and services.

The purpose of the digital society initiative is to increase the European market share of the global information and communication technologies. Europe is falling behind on high-speed Internet which affects the ability to innovate, the online dissemination of knowledge and online distribution of goods and services, as stated by the Commission (2010).

These efforts are collected in one flagship initiative: “A Digital Agenda for Europe”, that should facilitate a digital single market, based on fast and ultrafast Internet and interoperable applications, with broadband access for everybody in 2013, increased speed to at least 30 Mbit/s by 2020, supplemented with a target of more than 50% subscribing to Internet access above 100 Mbit/s, also by 2020, (Commission, 2010).

At the EU level the Commission will work to establish a legal framework that stimulates investments into high-speed Internet infrastructure, using EU structural funds to support this agenda, as well as reform the research and innovation funds in the ICT area too. The Commission wants to create one single digital market in the EU promoting Internet access to and take-up by all citizens (Commission, 2010).

The individual member states should operationalize the agenda from the European Commission by creating a strategy for deploying high-speed Internet, with a focus on providing public funding to areas not supported by private initiatives. The member states should build a legal framework that coordinate the public work so that it reduces the cost of network rollout. To promote the take-up, the member states should actively promote deployment and usage of online public services (Commission, 2010).

The goal from the European Commission with respect to the number of subscriptions of a 100 Mbit/s broadband service takes more than pure coverage and means to increase the uptake of 100 Mbit/s broadband subscriptions will not be examined in this thesis. To support a demand driven rollout the exact speed is less important. If demand is increasing for bandwidth above the speed supported by copper and xDSL this is sufficient to drive NGA-rollout – this is the case regardless of the demanded speed is 50 or 100 Mbit/s. In the thesis, we will therefor address demand with no specific bandwidth, and just assume that an increase in demanded bandwidth will eventually lead to an increase in the demand for additional coverage of NGA.

6.3. Viewpoints from the interviews on the matter

To summarize the European Commission has set a target for broadband coverage in EU by 2020 on 30 Mbit/s, whereas the Danish Government has set the target for 2020 to nationwide coverage by 100/30 Mbit/s. One of the expectations from the European Commission, as stated in (Commission, 2010), is that the member states will target different kinds of public funding on areas that cannot be served on commercial terms.

In Denmark, the Government has made a loan fund of 150 million DKK that can be applied for by municipalities to cover expenses in relation to establishing coverage. In 2014 the Government earmarked 60 million DKK to increased broadband coverage on Bornholm. In addition, a national broadband fund ("Bredbåndspuljen") constituted by 200 million DKK earmarked to deployment of NGA-network in the period 2017-2020. This is for the time being the only "direct" Government funded rollout, and at it will be clear in *section 8* this is an extremely modest contribution to the total cost of reaching nationwide coverage. This lack of willingness or focus on granting money from the Government on the matter is in accordance with the following statement from Rikke Rosenmejer, regarding the goal from the commission of reaching nationwide coverage with 30 Mbit/s: "*Det er jo ikke vores mål som sådan, det er ikke noget vi nødvendigvis går efter (...) det er kommissionens mål*", (10052017_Energistyrelsen, 18:02-18:10).

During the interview with Netplan, Anne Mette Møller raises the question whether the Government actually means the goal: *".. den der meget smukke tanke med at så sige ud i naturen (..) mener man det? Det tror jeg ikke*." (01052017_Netplan, 1:03:50-1:04:02). At least if the Government are serious about the digitalization, there should be some rights from the citizens to get sufficient broadband speed to be a part of the digital Denmark, e.g. being able to download education material, (01052017_Netplan, 01:16:40-01:17:00).

7. Status of infrastructure role out

In May 2017, the broadband market in Denmark is constituted by a broad and varied group of players, ranging from the old incumbent operator TDC, offering ultra-high-speed broadband to approximately 50% of the households, to a smaller company Gigabit.dk, who is primary service provider using TDCs network, but is starting to deploy their own fibre infrastructure in 2017 in a specific small area in Herlev, with less than 100 households[4].

As mentioned in the introduction, the primary infrastructure owners offering wired ultra-high-speed broadband are cable TV companies, utility companies and TDC. Primarily using TDC infrastructure this is supplemented by a few service providers, ex. Hiper and Gigabit.dk. Most service providers are relying og TDCs copper network, ex. Telia and Telenor, and they need a technology upgrade to be able to deliver ultra-high-speed services on TDCs fibre or cable network. In (Larsen, 2016) this is supplemented with the problem faced by the traditional competitors that they want a nationwide product portfolio. In order to maintain a nationwide NGA-service, the service providers need access and agreements with all the NGA-operators which is both complex and time consuming. For the time being the conclusion form these service providers is to remain with a portfolio based on the nationwide access to TDC copper.

Supplementing the primary players, a still increasing group of diverse small or medium sized players deploying primarily wired NGA-infrastructure are slowly entering the field. Eg. BornFiber, Fiberby, Parknet.dk, Gigabit.dk, and GlobalConnect. Fiberby, Parknet.dk. Gigabit and GlobalConnect are primarily focusing on the area of Copenhagen, whereas BornFiber is offering ultra-high-speed broadband to addresses covered by Østkrafts FTTH-network and supplementing it with deployment of 7.000 additional addresses on Bornholm, primarily by use of fixed wireless technologies.

In addition to the wired NGA-infrastructure, focus on reaching coverage in the more densely populated areas of Denmark is nurturing a group of wireless infrastructure players. As mentioned in the introduction, the focus is on WiFi solutions, capable of delivering up to 100 Mbit/s. The only known exception to our knowledge is ZibraWireless, who are offering up to 1Gps speed at a 50km range using WiFi.

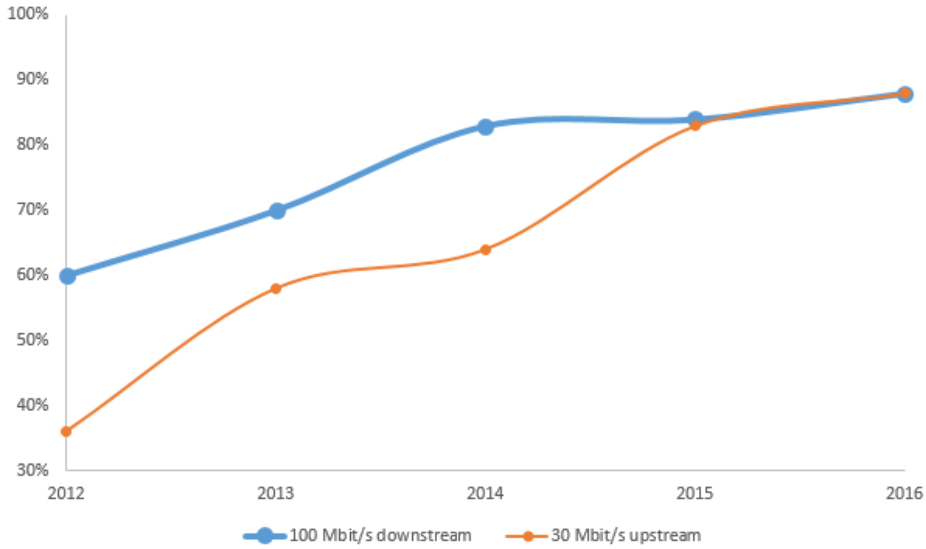
[4] https://gigabit.dk/projekter.html

In the remaining of this section we describe the current coverage as well as the current political framework used by the Government and the municipalities. We also describe some cases to serve as examples illustrating the different possibilities and initiatives.

7.1.Status on coverage

In the two documents describing the status and development in broadband coverage in Denmark (Energistyrelsen, 2015) and (Energistyrelsen, 2017) the development of NGA-coverage is listed. In (Energistyrelsen, 2015) the coverage of upstream- and downstream speed is estimated separately (2012-15), which is the reason for the two graphs in *Figure 3*.

Figure 3, coverage for households and business

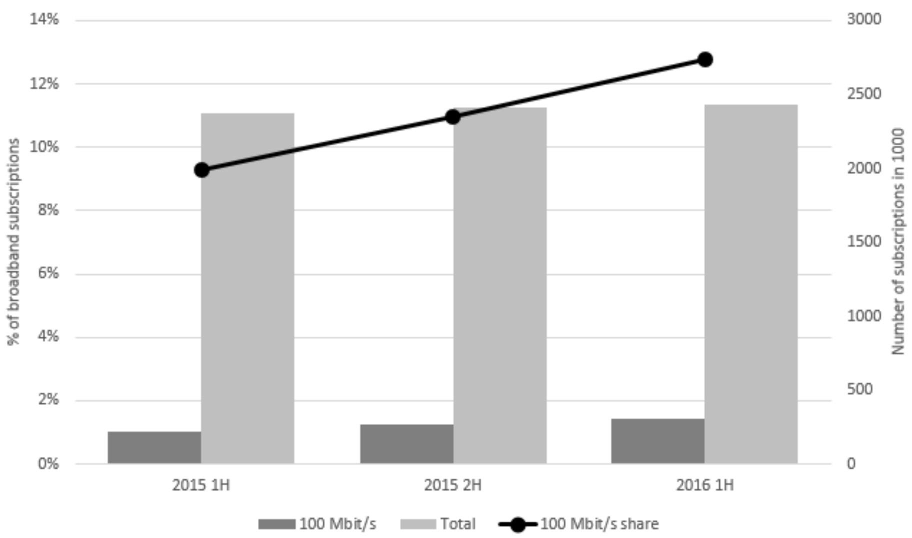


Source: (Energistyrelsen, 2015) and (Energistyrelsen, 2017)

With the introduction of TjekDitNet.dk in 2015 the method of calculation has changed and a small increase of 1% from 2015 to 2016 can be explained by this change in calculation method. The coverage for households has not been reported specific before 2015, which is the reason for the graphs in *Figure 3* being the combined coverage for both households and business. Prior to 2014 the increase in coverage has been both on upstream and downstream coverage whereas the development from 2014 to 2015 primarily has been on increasing upstream coverage. Since 2015 the coverage has only increased 3%, and from our interview with The Energy Agency (10052017_Energistyrelsen) we know that during one period of reporting coverage the NGA-coverage has increased approximately 1%, resulting in a NGA-coverage for households per April 2017 of approximately 89%. With an assumption of continued small linear increase in coverage (2% per year) the estimated NGA-coverage by 2020 for households will be approximately 95%.

In (Energistyrelsen, 2016) the different statistics regarding the number of subscriptions, traffic, download are stated. From this report, we have extracted the number of broadband subscriptions having at least 100 Mbit/s download as well as the total number of broadband subscriptions. The result is illustrated in *Figure 4.* Comparing the NGA-coverage to the number of broadband subscriptions it is seen that the demand for ultra-high-speed broadband is lacking behind the opportunities. In *Figure 4* it can be seen, that in the first half of 2016 the share of broadband subscriptions having at least 100 Mbit/s downstream was 13%, which can be compared with a coverage of approximately 85% at the time.

Figure 4, 100 Mbit/s broadband subscriptions



Source: (Energistyrelsen, 2016)

7.2.The latest market decision

From the latest market decision, (Larsen, 2016), we will summarize a few points regarding market 3a 'wholesale local access provided at a fixed location'. As a part of this market decision TDC is continuously appointed SMP and thereby exposed to regulation, but opposed to previous market decisions the market analysis is revealing geographical areas where TDC is less dominant and it is expected that a partly deregulation will slowly begin.

Market 3a is in the latest market decision still one nationwide market but it is expected from the market analysis that the need for geographical markets will increase. The reason for this is that in some areas, primarily areas with utility NGA-coverage, demand for higher bandwidth and NGA-services is causing TDCs market share to decrease, while the utility companies are experiencing increased market share. The consequence of this development is, that TDC in some areas are experiencing market shares below 40% which is the limit set for SMP. In the areas identified in the market analysis TDC has been exempted some of the regulatory obligations, e.g. the drop cable obligation.

On this point, the market analysis coincides with John Strand, who stated that the marked forces are in function, and if this process of decreasing TDC market shares eventually leads to NGA-monopoly, the Government has well proven tools to handle this, either by using ordinary competitive law or by regulation, (28042017_John Strand).

In the process, if the utility companies keep on having a closed network, less service competition will be present in the areas served by other companies but TDC. According to John Strand (28042017_John Strand), some of the utility companies are in the process of opening the infrastructure for other service providers, expectedly based on a bit stream access product and not raw fiber. This will expectedly result in increased service competition, but due to the complexity of handling multiple interfaces towards different network operators it is probably a slow process.

In the introduction, we have mentioned the change in focus from the Danish regulators. At first, in 1996, the focus was on service competition whereas the focus has changed in direction of more infrastructure competition over the last years. Latest the change in the law related to digging along public roads ("graveloven")[5] valid from medio 2016 all owners of passive infrastructure (e.g. ducts) are obliged to meet all reasonable requests for access, if the request has it origin in a deployment of high-speed services for communication. Supplementing this all projects receiving subsidies from e.g. the national broadband fund must include a deployment of spare capacity in ducts to be used by other operators.

In the latest analysis and recommendations regarding USO in Denmark, see (Energistyrelsen, 2016), it was concluded that USO on basic broadband was not a god idea primarily due to two factors: i) the cost is substantial and needs to be covered by the industry, and ii) if TDC is imposed with a Universal Service Obligation, it must be expected that TDC is SMP also in the coming years and besides it will contribute to maintaining TDC as SMP. In the analysis, the Danish rules, the EU regulation, the status of the broadband market both in relation to coverage, competition and expected development, and the estimated cost of different USO-scenarios are included.

[5] https://www.retsinformation.dk/forms/R0710.aspx?id=171701

According to (Energistyrelsen, 2016) the legislation are already in place to issue USO for broadband at the speed necessary to access the most fundamental Internet services: email, homebanking, and communication with the public (ex. e-box). If a basic broadband USO is issued, it is recommended to set the speed limit at 4-5 Mbit/s in download and 0,5-1 Mbit/s upload. According to (Energistyrelsen, 2016) a total of 153.000 addresses are not covered by broadband with this speed per 2014. Assuming, that coverage can be reached by deploying remote DSLAMs the report estimates a total cost of 2,3-7,5 billion DKK to cover the 150.000 addresses and thus fulfilling the USO.

7.3.EU guidelines on state aid

The main purpose of EUs guidelines on state aid, (Commission, 2013), is to make sure that public funding is targeted areas that are not covered by commercial deployment, and the different rules are set to make sure that public funding is not repressing commercial deployment.

The primary rules from EU guidelines on state aid is the following: i) public funded deployment is to be target areas that are not already covered by a commercial operator, ii) public funding must not distinguish between residential and business users, and iii) the operator receiving public funding must not "*refuse wholesale access to the infrastructure on a discretionary and/or discriminatory basis*", (Commission, 2013, no. 22).

In previous tenders the requirement i) has been difficult to assess due to lack of information. Based on this the information on TjekDitNet.dk is a strong tool to be used in public tenders. This makes it more straight forward to make the needed pre-tender investigation on current coverage in the area in question and if this information is supplemented with a hearing, asking the operators for coverage plans for the coming three years period the requirements i) are expected to be met. The tender in the municipality of Ringkøbing-Skjern failed on this condition which in the end made the planned subsidy of 70 million DKK in conflict with the rules. After an agreement with Energi Midt to supply the municipality with ultra-high-speed broadband (FTTH) is was revealed that some of the addresses in question was already covered by a small wireless company AirNet offering high-speed broadband in the area, and the public funding would degrade the business opportunity for this company. The conclusion was that the agreement between the municipality and Energi Midt was cancelled but RAH fiber (on behalf of Energi Midt) chose to continue the FTTH-deployment on commercially terms. The deployment is now primarily driven by a commitment from the public and RAH fiber requires a 40% subscription before the rollout is completed.

Based on our interview with Netplan, and looking at the failure of some of the tenders in Denmark we expect that the most difficult part of the EU guidelines for State aid to fulfil, is the part with wholesale access. According to Netplan (01052017_Netplan, 24:50-25:40), it is not clear on which terms and conditions the wholesale access should be given. Uncertainty was according to (01052017_Netplan, 47:10-47:50) the reason for the agreement between the municipality of Læsø and Energi Nord to fall apart.

In 2016 the municipality of the small island Læsø held a tender to get 100% NGA-coverage on the island. The winner was the local utility Nord Energi Fiber (NEF), who planned to deploy FTTH on Læsø receiving a compensation of 10,6 million DKK by the municipality. NEF does not offer broadband services themselves and the arrangement was therefor that the service should be offered by Bredbånd Nord, an operator owned by NEF. According to a press release from the municipality the agreement has later been cancelled and NEF have nevertheless offered to deploy NGA to the island. According to NEF the commitment and interest in the community is sufficient to make a commercial deployment. This argument does not completely conform with the opinion of John Strand. In his opinion, the EU legislation ensuring wholesale access on fair and equal terms end up being the end of the agreement between NEF and the municipality of Læsø since NEF are obliged to offer access to other operators on the same terms as the agreement made with Bredbånd Nord, which according to John Strand is very favourable for Bredbånd Nord. The conclusion from John Strand (28042017_John Strand, 44:50-45:20) is that facing a competitor offering services based on wholesale access to the infrastructure on Læsø, led NEF to the conclusion that the value of keeping the network closed and thus not offering wholesale access exceeded the 10 million DKK given in subsidies by the municipality. This led to the conclusion that NEF would rather rollout on commercial terms and did not need funding from the municipality. Whatever the complete background is the agreement between NEF and the municipality of Læsø was cancelled but with a continued NGA-deployment.

It is also mentioned in the EU guidelines for State aid rules, that the tender used to grant public funding or aid must be technology neutral, i.e. no technology meeting the criteria can be disregarded.

7.4. Government initiatives and initiatives driven by The Energy Agency

From our interviews with Netplan A/S (01052017_Netplan) and The Energy Agency (10052017_Energistyrelsen) our understanding of the role of the Agency is primarily to set the playing field, offering a usable framework for all the different players, not focusing on specific technologies, geographical areas, or supporting operators willing to deploy NGA-infrastructure in specific high cost areas. The only exception is the current initiative the national broadband fund ("Bredbåndspuljen"), consisting of 200 million DKK earmarked for NGA-deployment in areas with access to less than 10/2 Mbit/s. The 200 million DKK is distributed based on a well-defined rating of project applications send to the Agency from groups of citizens. The expectation is that the broadband fund will facilitate NGA-deployment to approximately 10.000 addresses and thereby accounts for approximately 3% of the remaining uncovered addresses.

According to Rikke Rosenmejer (10052017_Energistyrelsen, 25:10-26:30) the framework set by the Government and the different Agencies consists of traditional regulatory duties: Ensure permission to digging, reuse of ducts, placing antennas (rights of way), and stable regulation with well-known rights, obligations and legislation. In addition to this, different tools to improve financing opportunities are investigated, i.e. addressing general barriers. Specific from The Energy Agency the broadband fund is facilitated as well as the information on TjekDitNet.dk, which makes it easy to get an overview of the current coverage in a specific area. A few years ago, the Agency published more specific guidelines[6] to be used by the municipality if they wish to support an increased NGA-coverage in the area, or to be used by dedicated citizens who seek information on how they can affect the NGA-deployment in their neighbourhood. This tool way also mentioned by Netplan A/S (01052017_Netplan, 22:25-22:50) to be very useful.

The broadband fund is planned to run for four years (2016-2019), with 80 million DKK the first year and 40 million DKK the following three years. Since the funding given by the Energy Agency through the broadband fund also must be in accordance with EUs guidelines for state aid, the infrastructure deployment must be open and access must be given on equal and non-discriminating terms. The result of the first years funding is that TDC is partner in 17 out of 31 projects and Stofa, Energi Fyn and NEF is partner in 6 projects. The remaining 8 projects are expected to be completed in partnership with 5 smaller operators primarily experienced with TV-distribution to antenna associations or with limited experience. To summarize Mette Dalsgaard from Netplan states: "*Det er sådan, at dem, der har budt ind på Bredbåndspujlen, det er TDC og så dem, der tager chancen*", (01052017_Netplan, 43:24-43:29). Mette Dalsgaard is slightly overstating, but the point is that particularly the requirement on openness and the lack of clear interpretation has probably lead the medium sized operators and utility companies not to participate.

[6] https://ens.dk/ansvarsomraader/bredbaand/guide-til-bedre-mobil-og-bredbaandsdaekning

Supplementing the tools offered by The Energy Agency and the broadband fund, the Danish Government has adopted a new law allowing the mortgage institutions to lend money to companies deploying digital infrastructure. The introduction of mortgage loans on digital infrastructure is a way to obtain a lower cost of money and thereby improve the Business Case for the operator and making it possible to increase the deployment of e.g. NGA-infrastructure, as discussed in the theory framework in *section 5.2* and illustrated in *Figure 2*.

To make it more affordable for the individual households the Danish Government has also adjusted the tax reduction on specific services for 2016 and 2017 to include expenses in getting a broadband connection ("håndværkerfradrag").

7.5. Initiatives driven by the municipality

Anne Mette Kruse Møller from Netplan stated that: "*kommunerne de har fået sådan en opgave fra staten, hvor de så siger at hvis der skal ske noget, så er det jo i kommunerne, det skal ske*" (01052017_Netplan, 21:40-21:50). This municipality driven deployment takes many forms and a thorough description of the different possibilities can be found in the guidelines from the Energy Agency. The advices and guidelines from the Energy Agency to the municipality is quite complex primarily due to the possibility of introducing public funding, and it is covered by both "Erhvervsfremmeloven" on the one side and EUs guidelines on state aid (Commission, 2013) on the other. The guidelines to the municipality is to first clarify internal procedures (clear objectives, and well-defined procedures e.g. regarding applications for permission to dig or place antennas), then make thorough preparations (establish coverage maps, define the objectives, estimate demand and determine on financing), and finally the actual action must be determined (perform a tender, use public funding, build passive infrastructure or motivate local dedicated citizens to drive the rollout).

With respect to using money from the municipality budget, the municipality has different options within the limit set by different rules and legislation. The most important rules and legislation is "erhvervsfremmeloven", "kommunalfuldmagten", and EUs guidelines on state aid. EUs guidelines on state aid is already described in *section 7.3* and the two others will be commented on in this subsection. In "kommunalfuldmagten" it is stated that the municipality is not allowed to compete with private investors, or offer telecommunication services in competition with commercial operators. The consequence of this is that the municipality is not allowed to build and run a broadband service to be used by the business' and citizens in the municipality. They can however build a telco infrastructure to be used by the institutions in the municipality and if this infrastructure has spare capacity this can be rented to commercial operators. The municipality can also build passive infrastructure and make it available to the operators on market conditions.

An example of the first possibility was exploited by four small municipalities in southern Jutland in 2002. The initiative called "det digitale midtsønderjylland"[7] consisted of the municipalities financing a common IT-infrastructure with a backbone of 77 kilometre of fibre cable. The idea was to rent spare capacity in the backbone to commercial operators and it was the foundation for an agreement between the four municipalities and Syd Energi, in which Syd Energi made a commitment of deploying fibre to the citizens within the following 5 years (2002-2007).

An example of the second possibility is the current investigations facilitated by Syddjurs and Norddjurs municipalities. The municipalities have invited operators to use a duct infrastructure planned by the municipality[8]. The duct infrastructure is not deployed yet, but if one or more operators are willing to use the infrastructure on commercial terms to rollout NGA-network, the municipalities will deploy the ducts.

The municipally funded deployment of passive infrastructure has its legal basis on "erhvervsfremmeloven"[9]. With reference to this legislation, it is possible for the municipality to partly finance broadband deployment if the deployment is based on 1) the existing coverage does not cover the requirements from the local businesses, and 2) no commercial rollout is planned within the coming three years. The financing of broadband rollout can be in the form of a public tender, e.g. asking for coverage of the institutions of the municipality and supplementing this with requirements of coverage of specific areas, areas that are also of relevance to the local business community. Another possibility permitted by "erhvervsfremmeloven" is the deployment of passive infrastructure.

One issue with particularly the public tenders is that they must also be in accordance with EUs guidelines on state aid which we have already commented on, see *section 7.3*,

"Erhvervsfremmeloven" and EUs guidelines for State aid, are both defining a set of frames to be complied to by the municipalities if they wish to push rollout by use of subsidies. Another way for the municipality to push the deployment without getting in the minefield of EU and state legislation is to facilitate the dedicated citizens. Examples mentioned by Netplan (01052017_Netplan, 32:13-

[7] https://www.livogland.dk/vidensbase/projekter/digitale-midtsoenderjylland
[8] http://www.djurslandonline.dk/udbygning
[9] https://erhvervsstyrelsen.dk/sites/default/files/media/vejledning.pdf

33:00) is the recruitment of a person in charge of coordinating the different broadband initiatives in the municipality. An example is the municipality of Guldborgsund, who is facilitating a web-page gathering and displaying different information regarding the broadband coverage in the municipality.

Figure 5, part of web-page from the municipality of Guldborgsund

Source: http://www.guldborgsund.dk/bredbaand

One of the tools offered by the municipality is a map showing the coverage on copper and fibre based on information from TjekDitNet.dk supplemented with different initiatives from the dedicated citizens in the municipality.

7.6.The dedicated citizen

In the guidelines from the Energy Agency to the dedicated citizen the primary advice is to get in contact with at least one operator, getting an agreement on the needed commitment from the community and based on this get associations, organisations, local companies, and if possible additional dedicated citizens all working together on gathering the needed local support for the project. This advice coincides with an observation from Netplan (01052017_Netplan, 35:30-46:00) that the utility companies are very keen on projects driven by local enthusiasm. Particularly the utility company supplying the specific area is expected to deploy fibre if the commitment from the citizens is substantial and the Business Case is reasonable. Even in case of a medium Business Case it is possible to get the local utility company to deploy NGA in the area. The utility companies are firmly funded in the local area and due to the local citizens and the local community being cooperative members of the company it is likely that they will contribute by increasing coverage driven by the local commitment.

7.7.Technology status

As part of the preparations for the 2020 digitalization strategy, different players in the market have been discussing the need for broadband speed in the future, what would be a reasonable target to aim for in the future development of infrastructure to support the digital society. The target from the European Commission has been set for everybody to have access to 30 Mbit/s, and for 50% of the population to subscribe for broadband above 100 Mbit/s in 2020 (Commission, 2010) – but there are no real elaboration on how this target has been set. In Denmark, the Government and TDC has been asking the consultancy to estimate what the future broadband demand would be in 2020 (Thimmer & Hansen, 2014) and (Falch, Henten, Skouby, & Tadayoni, 2013).

The conclusion is that future services like video conferencing, streaming TV, gaming, various cloud services, and virtual-/augmented reality will require more connections, less delay and higher bandwidth in the future, hence the Government goal of 100/30 Mbit/s. Even if the future need is expected to be lower than 100 Mbit/s, then the bandwidth demand "*continue to grow at more than 20 % per year driven by more and more video streaming and proliferation of cloud computing, big data, social media, and mobile data delivery*" (Ma & Jia, 2017, p. 43), and the trend is that the users expect the same quality of experience from applications anytime, anywhere, and through any type of connectivity (Ma & Jia, 2017).

A wide range of technologies are emerging in the wired and wireless network areas to meet these growing demands for bandwidth, Quality of Service (QoS) and device independent requirements. The traditional technologies are constantly evolving with new electronic updates to increase speed, and converged fixed-wireless systems are emerging, that holds great promise to be the future solution for providing broadband access, by combining two separate systems into one realizable service for mobile and fixed users. "*It is believed that fiber-wireless system will play more important role in future evolved broadband access networks*" (Ma & Jia, 2017, p. 32).

Broadband wired access network provides a stable bandwidth to the customer over access technologies like: copper, cable (coax), fiber or a hybrid of fiber and copper. All types of wired access networks co-exist and in Denmark all types are present within the network of TDC.

Fiber is the most popular access network (Ma & Jia, 2017), since it allows end-users to connect to the network with speeds as high as 1 Gb/s over a wide range. This statement is in accordance with the following statement from the latest market decision, (Larsen, 2016): "*Fibernet er i sin natur NGA-net*".

xDSL is using the existing copper infrastructure, and with technologies like VDSL, VDSL2/2+ it can provide more than 50 Mbit/s over several hundred meters. Especially with VDSL2+ and vectoring it is possible to get a download speed of 100 Mbit/s up to 500 meters, but unfortunately with no increase in performance for upstream. This means that with this technology it is possible to get a 100/20 Mbit/s connection up to 500 meters from the DSLAM. If the demanded speed is however 100/30 Mbit/s the coverage range is still only 300 meters, as with ordinary VDSL2 and vectoring.

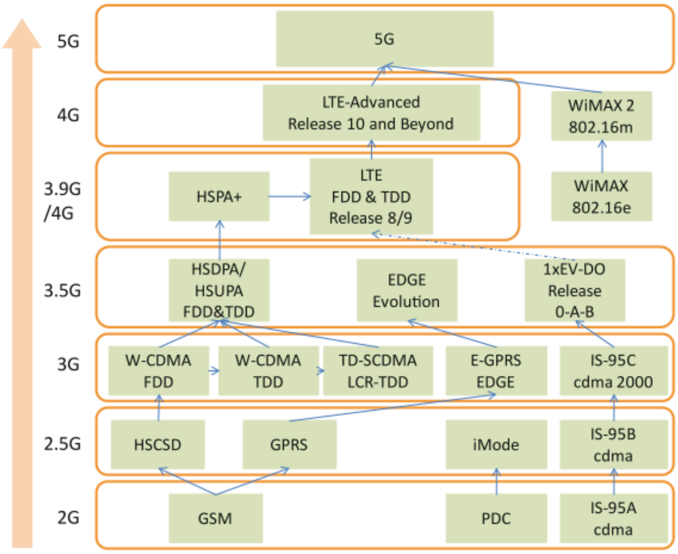
To increase the coverage of ultra-high-speed broadband facilitated by a copper drop cable, it is possible to decrease the distance from customer to DSLAM by deploying remote DSLAMs closer to the customers – fiber to the cabinet (FTTC).

Broadband using long-range wireless technologies can service users over a widely distributed geographical area, where as short-rang wireless only covers a small area. Wireless solutions need to be supplemented by wired backhaul to be able to provide an end-to-end solution for the end-customer.

There are many different wireless access systems that co-exit, but differentiated by spectrum, bandwidth, range and applications (Ma & Jia, 2017). The two technologies that are most popular to provide broadband services are: IEEE802.11 wireless LAN (WiFi), and the current (4G) and future (5G etc.) generations of cellular technology.

Mobile networks provide voice and data services in a large geographical area, and supports mobility through roaming. Mobile networks are highly complex as they are designed to support carrier grade services to millions of subscribers. The number of mobile broadband subscribers is exceeding the fixed broadband subscribers, the same goes for the way we are using devices and services. The new innovative services are developed on mobile first, and many services are customized to low bandwidth to be used on a smartphone (28042017_John Strand). Two trends will drive the mobile network development in the coming years: 1) everything will be connected; hence the network will need to support Machine to Machine (M2M) services and Internet of Things (IoT), and 2) the real-time streaming, virtual- and augmented reality in high resolution will require more bandwidth and Quality of Service (QoS) realized in the 5G standard that are expected to deliver 1 Gbit/s speeds. *Figure 7* illustrates the development of the mobile network towards the 5G standard.

Figure 6, development in mobile network technology



Source: (Ma & Jia, 2017, p. 64)

WiFi is the most commonly deployed wireless infrastructure both for in home wireless networks and for operators to provide Internet access from a fixed location using direct line-of-sight between the end-user location and the mast. There is a growing ecosystem of Wireless Internet Service Providers (WISPs) that provides wireless broadband with speeds up to 100 Mbit/s. These provides are using unlicensed spectrum to provide the Internet service on 5GHz. The range is up to 50 km. with a clear line of sight. The term fiber-wireless is capitalizing on the investments already done in high capacity fiber infrastructure with the flexibility of the wireless solutions to provide broadband to rural areas. *Figure 7* illustrates the development in the WiFi technology over the past years.

Figure 7, development of WiFi technology

- 1991: Wi-Fi was invented by NCR Corporation/AT&T with speed of 1/2Mbps.
- 1999: the Wi-Fi Alliance was formed and the first standard was released.
- 2000: first commercial use of the term Wi-Fi.

Ratified year	1997	1999	1999	2003	2009	2013	Future
IEEE Standard	802.11	802.11a	802.11b	802.11g	802.11n	802.11ac	802.11ad
Frequency Band	2.4GHz	5GHz	2.4GHz	2.4GHz	2.4GHz, 5GHz (Concurrent or selectable)	5GHz	60GHz
Max Data Rate	2Mbps	54Mbps	11Mbps	54Mbps	600Mbps	1.3Gbps	7Gbps
Technology	SISO	SISO	SISO	SISO	MIMO	MU-MIMO	MU-MIMO

Source: (Ma & Jia, 2017, p. 61)

In conclusion, it seems that the technologies are converging and that the focus of the operators will be to provide a seamless user experience across devices and access technologies, hence the technology development is driving the wireless and cellular technologies towards the same speeds and quality parameters as the fiber and xDSL infrastructures. The best most promising technology to deliver the needed capabilities will be a converged fiber-wireless access network covering urban and rural areas (Ma & Jia, 2017).

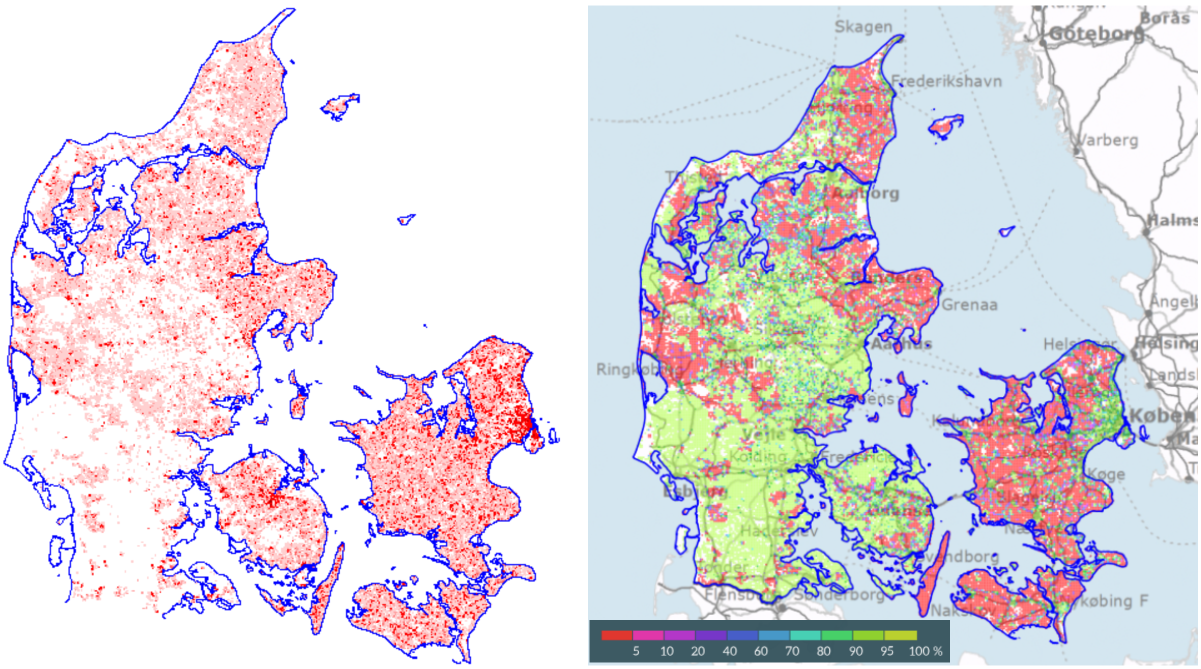
8. How much will it cost to close the coverage gap

In this section, we will estimate the magnitude of costs associated with the deployment of NGA to achieve a nationwide coverage of 100/30 Mbit/s to households. The estimation is based on the specific addresses not covered and a modelling of the necessary rollout to enlarge the existing network to cover the uncovered addresses.

The specific addresses not covered can be identified based on the broadband mapping facilitated by the Danish Energy Agency and visible on TjekDitNet.dk. Based on the data reported by all operators in Denmark the households not covered by 100/30 Mbit/s can be extracted from the database. Nicolaj Koch from the Agency has made this extraction for us and we have received a file containing the 317.000 households/dwellings not covered per February 2017 with 100/30 Mbit/s by any operator. In this respect, a household/dwelling is defined to be an address where the use of the facility is of permanent habitation and the number of households/dwellings per address is defined by the number of kitchens[10].

The geographical distribution of the households/dwellings not covered can be seen in *Figure 8 (left).* The darker the tone of read the more households are not covered. In *Figure 8 (right)* the corresponding coverage is illustrated, green areas have high coverage, red areas low coverage.

Figure 8, the 317.000 households not yet covered with 100/30 Mbit/s (left) and the coverage in percentage (right).



[10] See TjekDitNet.dk for further details.

In order to estimate the costs of covering the remaining parts of the households with 100/30 Mbit/s we have made calculations based on a FTTH-deployment and using some of the same methods as used by Analysys Mason (2008) in their calculations of the costs of deploying NGA in UK. Analysys Mason (2008) have estimated the costs of both FTTC/VDSL, FTTH/GPON and FTTH/P2P - but since we are estimating the costs of deploying a NGA-network capable of delivering 100/30 Mbit/s to all households, we find FTTH as the most appropriate technology. The analysis made by Analysys Mason (2008) concludes that between FTTH/GPON and FTTH/P2P the GPON technology is slightly cheaper compared to P2P. Based on this we have decided to base our estimations on the GPON technology. The current FTTH coverage is based on both P2P and GPON technology. In *section 8.1* we describe the assumptions and cost adjustments necessary to use the GPON calculation even though the existing infrastructure is P2P or even FTTx or cable.

8.1.Calculation methodology

Compared to Analysys Mason (2008) who are estimating the cost of reaching full coverage starting from almost no coverage at all, we have to take the existing coverage into account. The addresses already covered are primarily covered by either FTTH (P2P or GPON), cable, or FTTx (VDSL technology). Technologically it is possible that a minority of the addresses are covered by fixed wireless, but according to Hans Teglhus Møller (10052017_Energistyrelsen, 29:10-29:30) this is not the case.

Since we have no knowledge of the specific technology covering the already covered addresses we have based the calculation on the assumption that the network being enlarged is a FTTH/GPON-network. The basic cost elements and topology in this FTTH/GPON-network is adopted from Analysys Mason (2008), and it is illustrated in *Figure 9*.

To estimate the extra costs incurred because the existing infrastructure is not in all cases a FTTH/GPON-infrastructure, we have divided the cases in three scenarios based on the closest existing infrastructure, i.e. the infrastructure that must be enlarged to reach coverage in the area. The predominant infrastructure in the area is defining the infrastructure to be enlarged and is referred to as the major infrastructure. The scenarios are as follows:

Scenario 1: The major infrastructure is FTTH, either GPON or P2P.
Scenario 2: The major infrastructure is cable (coax).
Scenario 3: The major infrastructure is FTTx.

As mentioned before we exclude the scenario in which wireless broadband is the predominant infrastructure. We base this exclusion on the expectation that only a very limited number of addresses are covered by 100/30 Mbit/s offered by wireless broadband. In Denmark is has not been possible for us to find any wireless broadband operator offering speed above 80 Mbit/s.

In (Energistyrelsen, 2015) the current coverage by infrastructure - not bandwidth - is summarized in *Table 6*.

Table 6, coverage by infrastructure

Tabel 13
Dækningen fordelt på fastnet teknologi

DÆKNINGEN FORDELT PÅ FASTNET TEKNOLOGI

	Boliger og virksomheder	Boliger	Virksomheder	Sommerhuse
xDSL	96 pct.	97 pct.	83 pct.	70 pct.
Kabel-tv	63 pct.	68 pct.	12 pct.	6 pct.
Fiber	51 pct.	51 pct.	50 pct.	26 pct.
Fast trådløs	2 pct.	2 pct.	3 pct.	10 pct.

In addition to the coverage by infrastructure the overlap between different infrastructures is illustrated in *Table 7*.

Table 7, amount of overlapping infrastructure

Tabel 14
Dækning med flere teknologier. Boliger og virksomheder

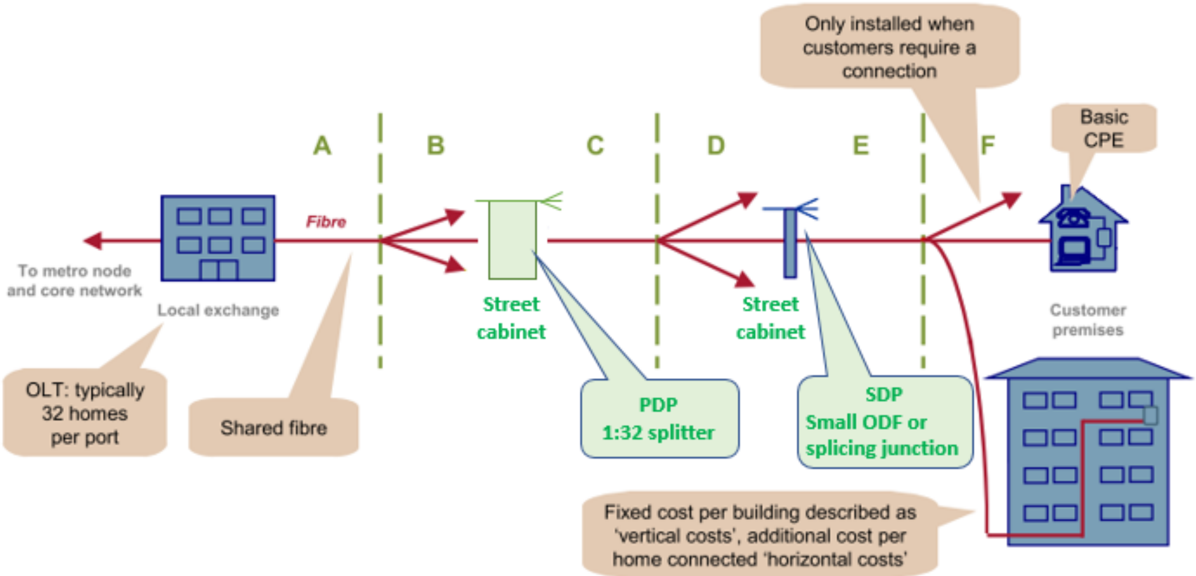
OVERLAP MELLEM FASTNETTEKNOLOGIER	
Mulighed for adgang via 1 teknologi	16 pct.
Mulighed for adgang via 2 teknologier	51 pct.
Mulighed for adgang via 3 teknologier	30 pct.

Since almost all addresses are covered by copper it can be assumed that the 16% of households and companies covered by one technology is covered by copper (xDSL). Using the same logic for the remaining two categories in *Table 7* it can be estimated that approximately 30% are covered with both fibre and coax, whereas 51% is covered by either fibre or coax. This adds up to 81% of the households (and businesses) being covered by either fibre og coax. Limiting the conclusion to households alone the percentage can be expected to be even larger due to the larger coverage of households with coax. Since almost all households having access to either coax or FTTH are covered by 100/30 Mbit/s and comparing the estimated 81% with the total coverage of approximately 88% for households only about 7% of the already covered addresses are covered with 100/30 Mbit/s based on xDSL or FTTx.

Since it is easier to enlarge a FTTH network (scenario 1) we allocate addresses covered by both fibre and coax to scenario 1. This gives an estimate of 51% of households being covered by FTTH (*Table 6*), and the remaining 30%[11] being covered by coax. Normalising to the 88% of households being covered and assuming, that the probability of three scenarios follow the coverage of the three infrastructure types an estimated possibility for each scenario is: Scenario 1: 58%, scenario 2: 34% and scenario 3: 8%.

In scenario 1 (the GPON case) the enlargement of the network is illustrated in *Figure 9*, which is adopted from Analysys Mason (2008). Green ink indicates a difference compared to the original illustration "figure 3.3".

Figure 9, FTTH/GPON network topology



Source: adopted from (Analysys Mason, 2008)

In the estimation made by Analysys Mason (2008) the total cost of deploying P2P is approximately 20% higher than the cost of deploying GPON, primarily due to less reuse of existing ducts since more cabling needs to be done. We expect the extra cost in our scenario to be less and approximately no more than 5%. This is based on our experience with TDC deployment of both P2P and GPON, and due to our estimated rollout to be an extension of the existing network. This allows optimization between further deployment of P2P (in case of few additional households) or a technology shift to GPON specific for the enlargement (in case of many additional households).

[11] 81%-51%=30%

In scenario 2 we have no detailed reference of the cost scenario of enlarging a cable network but since the primary cost is digging and the network topology for cable deployment used in the latest LRAIC model in many ways coincide with the one used for FTTH/GPON, we assume that enlarging the cable network is comparable to enlarging a FTTH-network, at least if the cable network in question is an FTTC-network[12]. Based on this we assume that enlarging a cable network can be done within the same 5% cost limit as assumed with the FTTH/P2P scenario.

The scenario with most uncertainty and potentially the largest cost addition is in scenario 3. In this case, additional trenching of op to 600 meters can be incurred to get from the nearest already covered address to the DSLAM serving this address, and specifically to the fiber being present at the DSLAM location. If it is assumed that an average of 300 meter digging and cabling is needed to serve 8% of all squares the total cost will increase by 400 million DKK, which is relatively small addition to the total cost illustrated in *Figure 15*.

Based on the above observations we conclude that the cost estimate based on FTTH/GPON is probably slightly optimistic but the order of magnitude is expected to hold. Since we have no knowledge of the scenario per address we have no means to make accurate estimations and it is our opinion, that compared to other aspects of uncertainty in the calculation a known small underestimation regarding a limited share of the households is acceptable.

8.2.Different geotypes used in the estimation.

The cost estimates are based on 4 different geotypes made with inspiration from the 13 geotypes defined by Analysis Mason (2008). To each geotype the cost of deploying FTTH consists of costs of deploying a distribution network, and costs of connecting the distribution network to an existing FTTH-network.

In our cost calculations, we have used a grid of 250*250 meters as a basis for grouping the uncovered addresses. These squares are the basis of the different geotypes, and all addresses within one square is assumed to belong to the same geotype. The different geotypes are based on the following parameters:

i) Type of area, i.e. whether the square is in a city, a provincial town, a town, a village, a recreational area or on the countryside.

[12] The abbreviation FTTC in a cable infrastructure is different from the one used for copper. In the cable infrastructure a CMC (coax media converter) is placed in the cabinet and not a DSLAM, as is the case for copper.

ii) Distance from the centre of the square to the nearest address[13] already covered by 100/30 Mbit/s (distance to coverage).

Based on these parameters, the 250*250 meter squares are grouped in the following geotypes:

Urban (a): > 1000 lines (a) – less than 1 km from POP

Urban (b): > 1000 lines (b) – more than 1 km from POP

Rural (a): < 1000 lines (a) – less than 1 km from POP

Rural (b): < 1000 lines (b) – more than 1 km from POP

The categorisation (a) and (b), distance to POP, is evaluated not as exact distance to POP, due to the fact, that this distance is not known, but simply by using ii) the distance from the centre of the square containing the uncovered address and the nearest address already covered. Squares with less than 500 meters to the nearest covered address are assigned to the (a) category, and squares with more than 500 meters to the nearest covered address are assigned to the (b) category.

Based on the specific area, the squares are divided between urban and rural. Urban squares are areas in cities, provincial towns, or towns whereas rural squares are areas in villages, recreational areas or on the countryside.

Using the above definitions, we have calculated the following summary of the households/dwellings not covered by 100/30 Mbit/s can be made:

Table 8, summary of households not covered by 100/30 Mbit/s

Geotype	House-holds	% MDU[14]	Households per square	Distance to coverage ii)
Urban (a)	119.000	19%	13	50 m
Urban (b)	1.000	1%	14	640 m
Rural (a)	79.000	5%	3	270 m
Rural (b)	118.000	0%	2	1.270 m
Total	**317.000**	**8%**	**3**	**890 m**

8.3.Cost elements

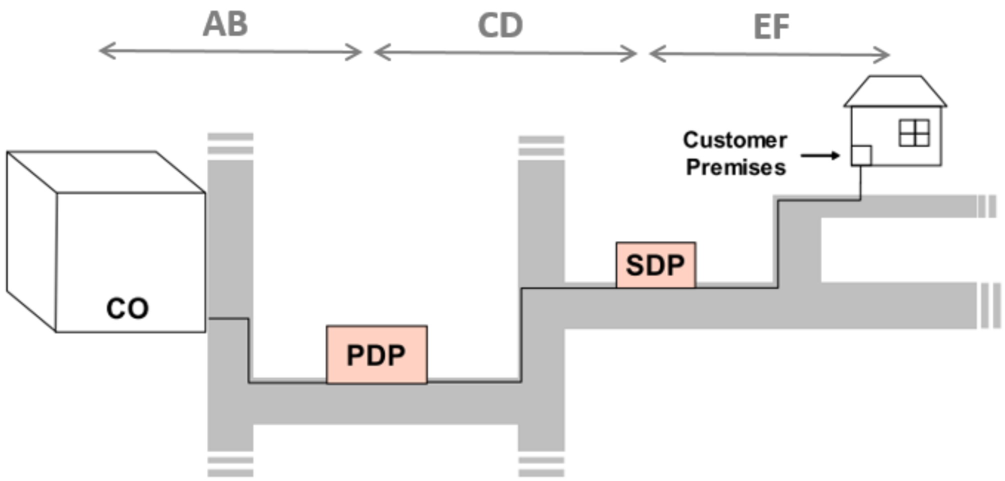
The network topology used in the latest revised LRAIC model (TERA consultants, 2014), is similar to the one used by Analysys Mason (2008) as illustrated in *Figure 10*. To use a set of costs already

[13] This is estimated as the average of the two nearest addresses already covered by 100/30 Mbit/s.

[14] MultiDwellingUnit (MDU), i.e. apartment building. In this thesis, an apartment building is defined as more than four households sharing the same address.

agreed upon in the industry, we have therefor decided to use the specific costs elements from the latest LRAIC model in our estimation of FTTH/GPON deployment.

Figure 10, architecture of access networks modelled in (TERA consultants, 2014)



In the LRAIC model the estimate of the digging length is based on the length of the roads in each geography. We have adopted this method and used the length of roads in each square as a basis for the estimation of the digging length needed to deploy NGA to the uncovered addresses in the squares located in urban areas. We have used the same method in some of the rural areas but for very densely populated rural areas a more theoretical approach is used. This is due to some squares being crossed by many roads even though only one household must be connected.

The key cost elements are:
Passive infrastructure: Digging, trenching and cable in the different parts of the network (AB, CD, ad EF), costs of SDPs including splitter, and PDPs. Includes also splicing and connecting the enlargement of the infrastructure to the existing infrastructure.
Active equipment: Ports in routers/switches, DSLAMs, linecards in xDSL equipment, and SFPs.

From the LRAIC model, the cost-elements shown in *Table 9*, *Table 10* and *Table 11* are used.

Table 9, prices on trenches

Asset	Description	Unit	LRAIC cost
T1	Digging, incl. planning	DKK per meter	151,00
T2	Duct handling	DKK per meter	19,00
T3	Cable deployment in duct	DKK per meter	17,00
T4	Jointing hole	DKK per unit	2.200,00

Table 10, prices on cables, ducts, DP, joints & chambers

Asset	Description	Unit	LRAIC cost
C2	Fibre-cable-out-x (24SM)	DKK per meter	4,00
C3	Fibre-cable-out-6 (96SM)	DKK per meter	12,00
D1	Fibre-duct-standard-1 (40 mm)	DKK per meter	5,00
D2	Fibre-duct-finaldrop-1 (7-way, 10mm)	DKK per meter	17,00
DP1	Fibre-dp-out-1 (48 fibres)	DKK per unit	3.000,00
DP2	Fibre-dp-out-2 (144 fibres)	DKK per unit	7.000,00
DP3	Fibre-dp-out-3 (576 fibres)	DKK per unit	15.000,00
DP4	Fibre-dp-splitter-1 (1:32)	DKK per unit	2.000,00
J1	Fibre-joint-out-2 (144 fibres)	DKK per unit	11.000,00
J2	Fibre-joint-out-3 (288 fibres)	DKK per unit	19.000,00
J3	Fibre-joint-in-3 (24 fibres)	DKK per unit	2.500,00

Table 11, prices on active equipment

Asset	Description	Unit	LRAIC cost
D1	DSLAM (16 cards)	DKK per unit	50.000,00
D2	DSLAM cards (8 ports)	DKK per unit	5.000,00
D3	DSLAM SFP	DKK per unit	400,00
S1	Switch 10G card (2 ports)	DKK per unit	8.500,00
S2	Switch SFP	DKK per unit	2.000,00

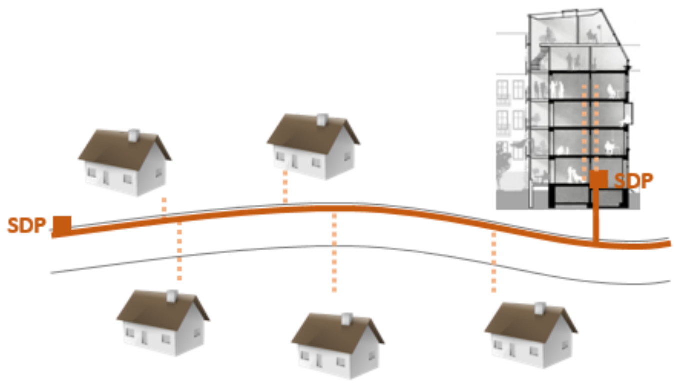
In our modelling, we have placed the splitter at the PDP to minimize the investment in splitters and SFPs/linecards at the POP. Based on this the SDP only consists of a small cabinet (DP1), whereas the PDP is either a large cabinet (DP2) or an extra-large cabinet (DP3) depending on the area and geotype in question. Each PDP is equipped with one splitter – additional splitters are seen as a capacity investment issued when customers are connected to the network, and are thus left out. The same goes for additional SFPs at the POP, as well as additional up-link from the POP and eventually additional DSLAMs. We assume, that ODF, power etc. are already present at the POP – and to some extent DSLAMs, switches, or routers used as aggregation node equipment. We have however included one DSLAM SFP per splitter, 1/7 DSLAM linecard (a usage of 90%), 1/90 DSLAM (70% usage) and corresponding 1/90 switch SFP, and 1/150 switch linecard. In total this adds up to 1.750 DKK per splitter.

8.4.Cost calculation

With the definition used by TjekDitNet.dk it is sufficient for the households/dwellings to be passed by the FTTH-network, i.e. Homes Passed. The requirement is that the customers can be connected by adding a drop cable of maximum 30 meters. The difference between Homes Passed and Homes Connected is illustrated in *Figure 11.* The trenching from Secondary Distribution Point to the demarcation point between the premises and the road are included in the cost of reaching Homes Passed coverage, excluding road-crossing. The additional costs when connecting the home consists of deploying a drop cable in the trench, necessary road-crossing, drop cable from road to house, in-door cabling, and home gateway. The exclusion of road-crossing in the cost of deploying Homes Passed makes it possible to reach Homes Passed coverage by digging in only one side of the road.

Based on the above we have excluded the final drop cable and the CPE at the customer premises in the calculation of the costs of reaching coverage with Homes Passed. For apartment buildings, the cost of drop cable to the building and a small ODF in the basement is included in the Homes Passed cost estimate, whereas the costs of connecting each flat to the ODF is a part of the cost of obtaining Homes Connected.

Figure 11, Homes Passed digging and additional digging needed to connect the homes



In *Figure 11* the solid line illustrates the trenching done as part of our calculation of reaching Homes Passed coverage. The dotted line illustrates the additional trenching needed to connect the individual home. For multi dwelling units (apartment buildings) the ODF in the basement coincide with the Secondary Distribution Point (SDP).

Passive infrastructure:

The primary cost driver for FTTH-deployment is digging and trenching, particularly for the last 118.000 homes located in geotype Rural (b). To estimate the digging length, we have estimated the different parts of the network in accordance with both *Figure 9* and *Figure 10.* The distance from SDP to demarcation point between the premises and the road is named EF, the distance between SDP and PDP is named CD and the distance between POP and PDP is named AB. The digging length of the different parts depends on the type of area and the geotype.

In Urban areas, the distance EF is estimated based on the assumption that the not covered addresses are either located in groups or located close to already covered addresses and can therefore be reached by minor digging. The distance is assumed to depend on whether the uncovered address is a SDU or a MDU. In case of a SDU, SDPs are placed in the area, using the dimensioning of one SDP per 10 houses. In case of MDUs the SDP is placed in the basement of the building and the distance from PDP to SDP is thus the sum of CD and EF using the terminology from *Figure 9.*

In urban areas, it is assumed that to move from 0 to 100% coverage, digging along 90% of the roads is needed. Based on the assumption that the uncovered addresses are placed in groups it is assumed to be sufficient do dig along x% of 90% of the roads if the uncovered addresses represents x% of the households in the square. Based on this assumption and the total length of roads in each square the following estimates have been used:

Table 12, estimated digging length per area type, urban areas

Area	SDU/MDU	Distance AB[15]	Distance CD	Distance EF[16]
City	SDU	20 m/PDP	18 m/SDP	10 m/SDU
City	MDU		15 m/building	10 m/building
Provincial town	SDU	30 m/PDP	20 m/SDP	12 m/SDU
Provincial town	MDU		20 m/building	10 m/building
Town	SDU	50 m/PDP	35 m/SDP	15 m/SDU
Town	MDU		20 m/building	10 m/building

In Rural areas, the digging estimate depends on the actual number of uncovered households. If the area is a village or on the countryside and if more than 50 uncovered households are in the area, we assume that the classification is wrong and the area is in a town and the square is thus moved from being rural to being urban. In the remaining rural areas, all households are estimated to be SDU and in the situation with more than 10 uncovered households, the estimated digging is based on figures calculated in the same way as in the urban case. Only if less than 10 households are to be covered

[15] The digging length listed in this column covers digging within the square. If fibre is not already available in the square additional digging is included.

[16] For MDU the 10-meter distance EF is covering drop cable from road to ODF in building (vertical cost).

the estimate is more theoretical, based on the assumption that the uncovered households are distributed widely over the area with no clustering. The figures can be seen in *Table 13* below:

Table 13, digging length per area type, rural areas

Area	Number of homes	Distance AB[15]	Distance CD	Distance EF
Village	≥ 10 homes	50 m/PDP	30 m/SDP	22 m/SDU
Recreational area	≥ 10 homes	50 m/PDP	60 m/SDP	30 m/SDU
Countryside	≥ 10 homes	50 m/PDP	30 m/SDP	22 m/SDU
Rural	First 2 homes additional homes < 10	50 m/PDP	60 m/SDP	125 m/SDU 30 m/SDU

In rural areas, the number of SDP's are estimated based on the number of households not covered - with a figure of one SDP covering 10 households. In areas with less than 10 uncovered addresses only a fraction of a SDP is included in the calculation. This assumption is reasonable when looking at the costs of the cabinet and the splitter but to get the right length of cabling, the digging corresponding to one SDP must be included in the squares with less than 10 households.

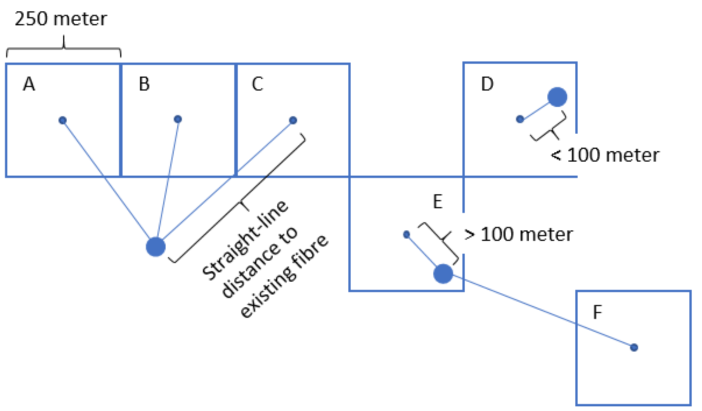
In both urban and rural areas, one PDP is estimated per 250 homes passed.

Besides the digging estimated by using the figures mentioned in *Table 12* and *Table 13* additional digging must be included to connect the square with existing fibre. If the straight-line distance from the centre of the square to addresses already covered by NGA is less than 100 meter the square is assumed already to be connected to fibre and no additional digging is included.

In other cases, additional digging is added to the distance AB. For each square the distance from the centre of the square to either another uncovered square or existing fibre is used as basis for this additional digging.

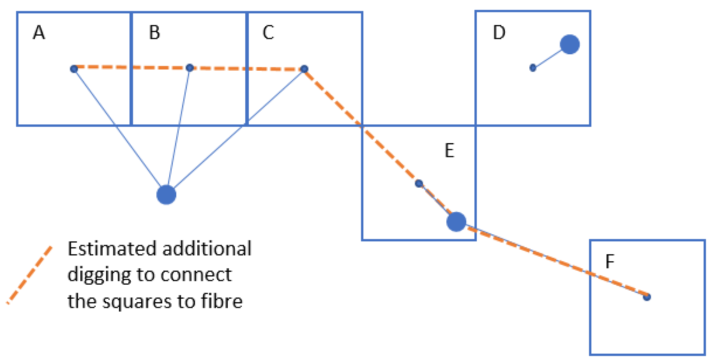
The method used is theoretical, based on straight-line distance and not on actual road-distance. Experience shows that as an average of 1.2-1.4 times straight-line distance is a doable estimate for digging length. We have used an estimate of 1.2 times straight-line distance which is most appropriate with longer distances. The exact cost calculation method is based on graph-theoretical methods and a small example is illustrated in *Figure 12, Figure 13* and *Figure 14*.

Figure 12, squares with uncovered households supplemented with distance from centre of square to existing fibre



Based on the distance from the centre of the square to either existing fibre or to the centre of another square representing uncovered households, the additional digging corresponding to deploying fibre in each square is calculated. In the example shown in *Figure 12* the corresponding additional digging is illustrated in *Figure 13*.

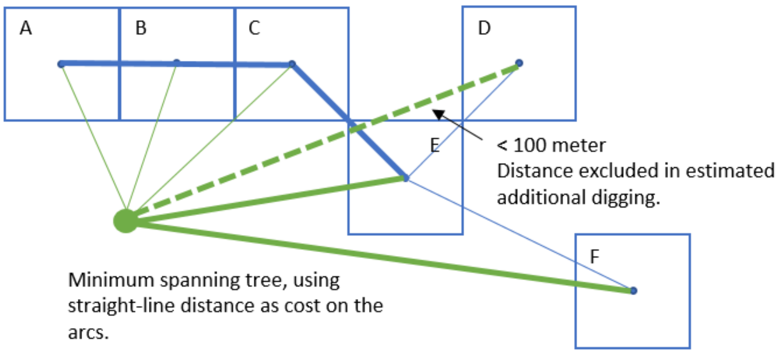
Figure 13, illustration of estimated additional digging needed to connect the uncovered households from *Figure 12* with existing fibre



In the example, square D does not need additional digging since existing fibre is less than 100 meter from the centre of the square. Squares E and F are connected to the closest existing fibre whereas square C is connected to square E, square B to square C and finally square A is connected to square B. The distance described here is used as approximation to the additional digging, i.e. for square A, an additional digging of 300 meter (1.2*250 meter) is included in the calculation.

To be sure to get a connected network, i.e. avoid a situation where square A is connected to square B and vice versa, additional conditions must be included in the calculation. The graph theoretical method is based on the minimum spanning tree algorithm used on a graph in which the centre of the square are nodes and the nodes are connected by arcs issued with costs that equal the straight-line distance between the nodes. In addition to this, an artificial node is added to the network. This node represents the possibility to connect the square to the closest existing fibre and in the graph, there is an arc connecting all nodes to this artificial node. The cost of this arc is the straight-line distance from the square to existing fibre. The minimum spanning tree corresponding to the solution illustrated in *Figure 13* is shown in *Figure 14* below.

Figure 14, graph illustrating the introduction of an artificial node to secure connectivity



The total graph needed to complete the calculations consists of approximately 102.000 nodes (the number of squares) and 102.000^2 arcs. If the calculation is performed on the complete graph the calculation time is substantial and probably not feasible without additional calculation engineering which is out of scope for this thesis. To reduce complexity, we have therefor made a small graph corresponding to each exchange area used in the LRAIC model, and made independent calculations for each exchange area. We expect this segmentation of the calculation to be of little consequence to the final estimated digging costs.

Based on the methods and figures described the following amount of digging have been estimated:

Table 14, estimated digging length

Geotype	House-holds	Trench AB (km)	Trench CD (km)	Trench EF (km)	Trench per Household
Urban (a)	121.000	270	390	2.000	22 meter
Urban (b)	500	14	2	8	43 meter
Rural (a)	77.000	7.000	700	5.500	172 meter
Rural (b)	118.000	25.600	1.400	11.600	326 meter
Total	**317.000**	**32.900**	**2.400**	**19.100**	**172 meter**

Active infrastructure:

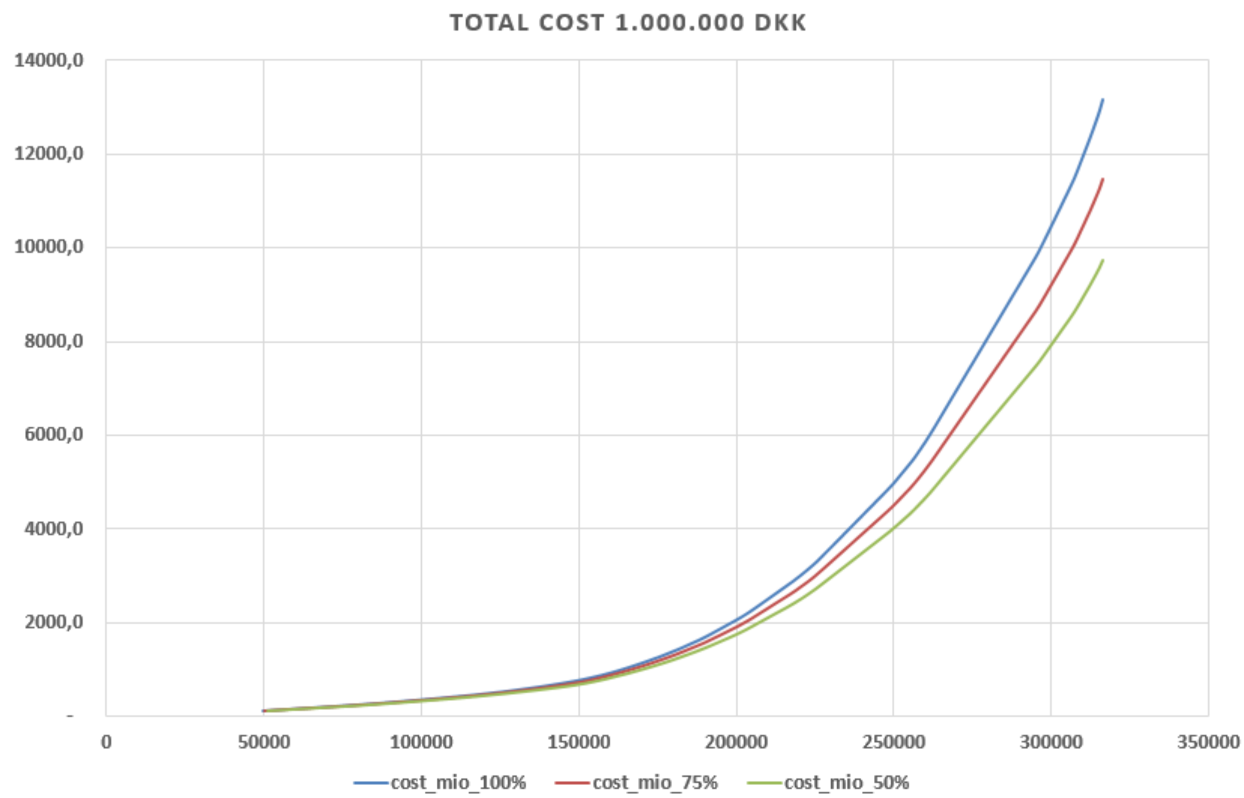
The primary driver with respect to active infrastructure is number of connected customers. Since we are only estimating the cost of achieving Homes Passed it is possible to argue, that these costs should be left out. We have however decided to include a minor part of the active equipment, as described in *section 8.3*.

8.5.Results

The cost-calculations are extremely sensitive primarily to the cost of digging. In the LARIC model substantial co-digging is assumed which is not viable in our case. With the chosen design deploying drop cables in trenches, the possibility of sufficient trenches for section EF (see *Figure 9*) already being available based on existing deployment in the neighbourhood is small. In the remaining part of the distribution network – sections AB and CD – some reuse of existing trenches is likely. To reflect this, we have made calculations with 50%, 25% or 0% of the digging in sections AB and CD being replaced by reuse of existing ducts owned by the operator deploying FTTH in the area, and thus free of charge.

The results are illustrated in *Figure 15* showing a total cost of 9.7-13.2 billion DKK.

Figure 15, estimated total cost with no 0%, 25% or 50% reuse of existing ducts



This estimate of total cost is the same magnitude as the estimate made by Dansk Energi & Netplan (2016). In (Dansk Energi & Netplan, 2016) an estimate of 7,3-8,6 billion DKK is stated to be the level of investment needed in order to cover the remaining part of Denmark with FTTH. Dansk Energi & Netplan (2016) only includes cable infrastructure, i.e. digging, trenches, cables as well as a part of the POPs (the cabin). The method used by Dansk Energi & Netplan (2016) builds on an analysis made by Jensen et al. (2015) used on specific cases and applied to Denmark in general. It is not possible to compare the result from (Dansk Energi & Netplan, 2016) directly with our estimates due to differences in method and amount of rollout. In our estimation, we include more cost elements, we exclude addresses already covered by 100/30 Mbit/s based on FTTC, and besides the foundation for our analysis is the specific uncovered addresses and not a generalization of cases.

9. Financing the gap

According to Mønsted & Nielsen (2014) and (Bauer, 2010) the level of investment in the broadband infrastructure depends on the NPV of the investment and thereby the Business Case seen by a potential investor. Factors affecting the Business Case are: costs, expected earnings, and risk, also described in the policy framework in *section 5.2*. Investing in broadband access is relative expensive per Homes Passed as we have shown in *section 8*. The expected earnings are dependent on the future demand for NGA-services and the number of competitors already present in the area. The future risk according to Mønsted & Nielsen (2014), can be both uncertainty about the future demand and uncertainty about future regulation.

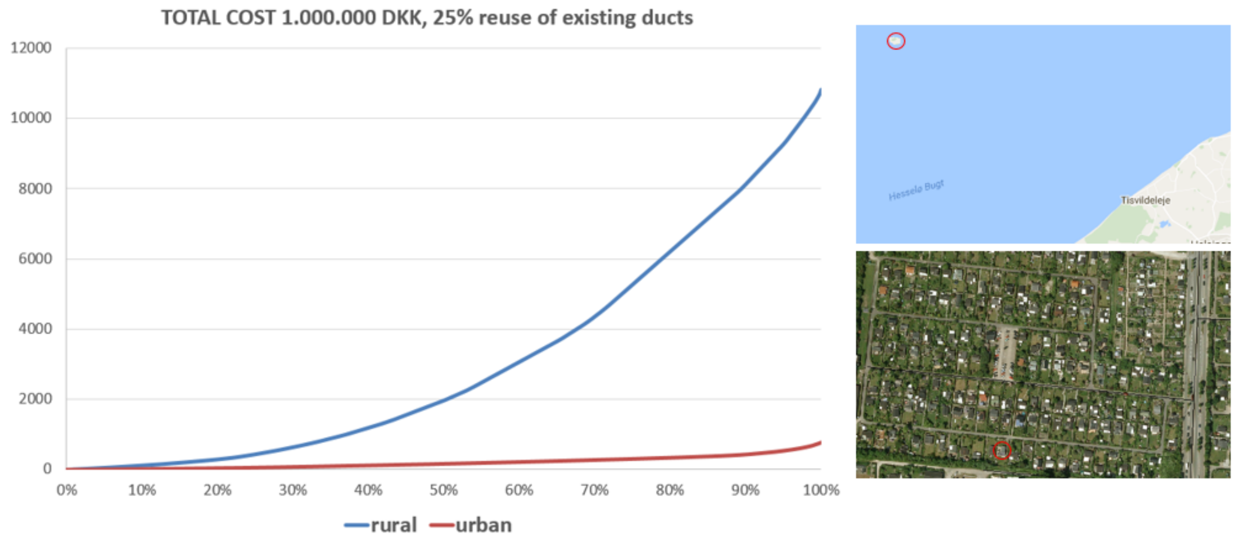
In *section 8* we have considered the expected deployment costs. Other costs like finance cost, costs related to rights of way, and costs of market entry are not estimated explicitly. The same goes for risk of investment. In *section 10* we will elaborate further on the possible effects on investment incentives in case of changes in the regulatory regime, or at least by looking at the different regulatory and non-regulatory tools that can be used to push a NGA-deployment.

In this section, we will look specifically into the question of how much a possible investor can expect to spend on Homes Passed to get a positive NPV on the investment. In this calculus, the demand for NGA-services is highly relevant and one of the key parameters affecting the Business Case. Besides, the demand is one of the parameters that can be affected by eg. the citizens and we have thus included this effect as a tool that can be used both by the dedicated citizens as well as municipalities and Government institutions.

One part of the Business Case is cost of deployment but after deployment the cost of running a broadband network is highly relevant. The costs of running the network is not included in the analysis made by Mønsted & Nielsen (2014) and even though particularly capacity cost and interconnection costs are expected to increase with an increase in demand and particularly with capacity use, we have decided not to include this aspect in our thesis either.

The cost curve derived in the previous section and focusing on the scenario with 25% reuse of existing ducts, can be divided in two, one curve representing rollout in rural areas and one curve representing rollout in urban areas. This is illustrated in *Figure 16*, and from this it is seen that the 122.000 uncovered households in urban areas can be covered for a total of 760 million DKK. The cost of covering the 195.000 uncovered households in rural areas is 10.8 billion DKK, which corresponds to an average investment pr. household of 55.500 DKK in the rural areas.

Figure 16, total cost separated in urban and rural areas



In *Figure 16* the most expensive address in a rural area (Hesselø) is show to the right of the graph as well as one of the most expensive address in an urban area (Haveforeningen Stjernelund, Kastrup). Some of the most expensive addresses in urban areas are recreational garden areas, the majority of the small houses in these areas are of recreational use and therefore not a part of the data-set we have received form TjekDitNet.dk. If recreational or business addresses are included in these areas, it is possible to get a decrease in the average cost of deploying FTTH to a part of the most expensive addresses in the urban areas. In rural areas, the most expensive households are extremely expensive even with the inclusion of recreational or business addresses.

Looking at the LRAIC price for unbundled fiber[17], and assuming it is possible to achieve positive return on investment in backbone if access is rented on LRAIC terms, we can use this as an approximation on the level of investment acceptable to experience positive NPV on investment. Off course the need for financing and other factors mentioned by both Mønsted & Nielsen (2014) and (Bauer, 2010) need to be present in order for the deployment to be part of a positive Business Case.

The current price on raw fiber is including the drop cable, which in LRAIC is estimated to cost 6.800 according to (Larsen, 2016). With a yearly fee of 1.185 DKK, a 35 year depreciation on the FTTH-network and using a WACC of 5,8% this leaves 11.000 DKK to be used on Homes Passed deployment. With a penetration of 40% this leaves 4.500 DKK to be used per Homes Passed whereas 9.000 DKK can be used per Homes Passed in case of 80% penetration. If the households

[17] https://erhvervsstyrelsen.dk/sites/default/files/media/prisafgoerelse_lraic-fastnet_2017_0.pdf

subscribing to the service pays a 2.000 connection fee, the figures are adjusted to 5.000 DKK and 10. 500 DKK respectively.

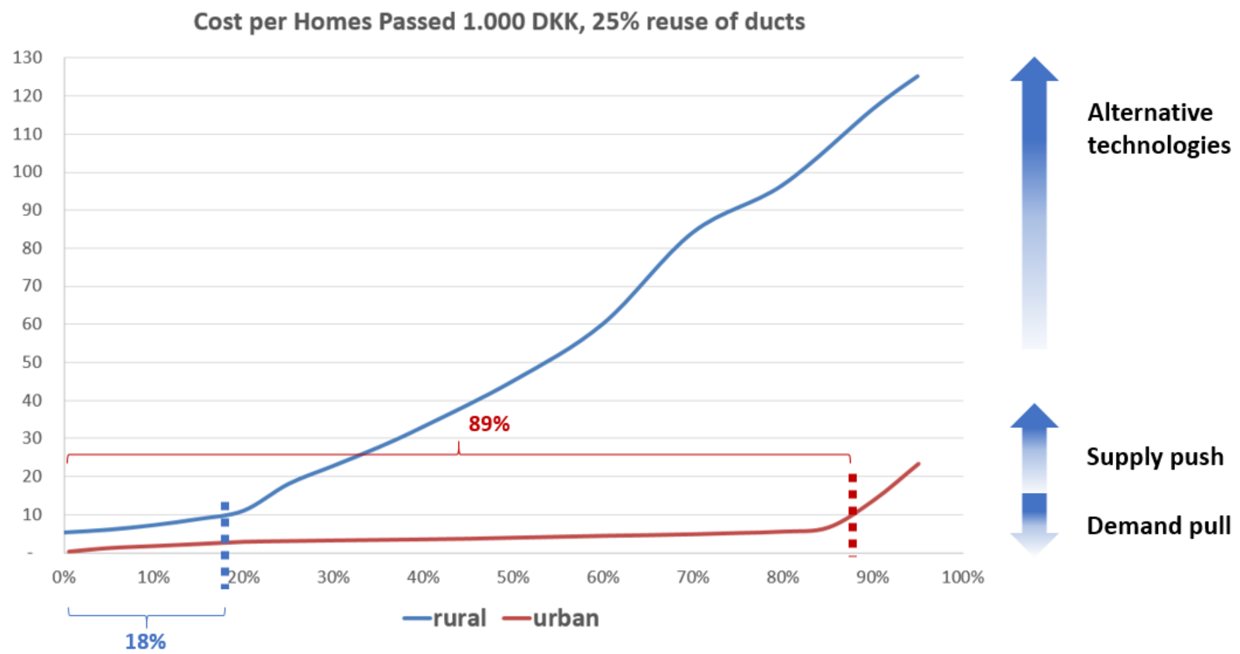
Since the LRAIC prices are based on an already existing network it can be expected that slightly larger deployment costs per household can still be basis for a positive Business Case. In the interview with Netplan (01052017_Netplan) Mette Dalsgård states that she has heard a utility company mention the amount 11.000 DKK as still being doable to get a positive NPV on the investment.

Based on the above argument and a few additional assumptions, we expect a deployment cost of up to 10.000 DKK per Homes Passed to be acceptable to secure a positive long-term return on investments, depending on the level of penetration.

The above calculations also show, that when comparing NPV on FTTH-deployment, it is a better case to deploy a parallel infrastructure in urban areas, even with a very low penetration, if it is compared to deploying FTTH-network in expensive rural areas, even with a very high penetration.

In *Figure 17* the unit cost per Homes Passed is illustrated for both rural and urban areas. In the illustration, the 5% most expensive addresses in both rural and urban areas are left out.

Figure 17, cost per Homes Passed excluding the top 5%



Source: Our own calculations based on data from TjekDitNet.dk

With the assumption that up to 10.000 DKK per Homes Passed can give in a positive Business Case if sufficient commitment from citizens are present, approximately 18% of the remaining addresses in rural areas and 89% of addresses in urban areas can be covered by pure demand pull. Whether the exact penetration needed to get a positive Business Case is 40%, 60% or even more depends on the specific parameters affecting the Business Case for the operator in question.

Even though costs of deploying fiber exceeds what can be covered on commercial terms it is still possible for the citizens to affect the Business Case met by the potential operator. An example is if the citizens accepts an additional setup fee. The line between what can be covered by pure demand pull is thus floating and no matter how expensive the deployment is, the citizens can make a strong influence on the Business Case.

Based on the above arguments it seems reasonable to conclude, that almost all households in urban areas can be covered by NGA-network based on traditional commercial terms – at least if the households within a specific area join forces and make a joint agreement with an operator to secure high penetration and thereby acceptable return on investment.

If the cost is too high to be covered by the subscribers, additional activities must be initiated to make an appropriate Business Case. In *Figure 17* we have gathered these activities under the label supply pull, which means that supply incentives must be present to supplement the demand side activities. The specific political tools and initiatives are described more thorough in *section 10.*

In *Figure 17* we have indicated, that the most expensive addresses are probably easiest to cover by alternative technologies to decrease the deployment costs. Approximately 60.000 of the households in rural areas are isolated with only one household in each square, and additional 35.000 households are in squares with 2 households. In total 95.000 of the households in rural areas are in areas with less than 32 households per square kilometre. If it is possible to place an antenna and reach line of sight from the households to the antenna a wireless solution seems like a solution worth investigating to obtain NGA-coverage. These 95.000 most isolated households in the rural areas account for 8,5 billion DKK or 90.000 in average per household.

To conclude this section, we expect 45% of the remaining addresses to be potential to be covered by commercial rollout, if sufficient demand is present. In case of willingness from the customers to pay a substantial deployment fee, this percentage will be even larger. The problem as to whether the market will ensure the rollout within the set time limit, is thus very dependent on the actual demand and if the 45% in scope of market driven rollout must succeed before 2020 it is expected that some kind of intervention must be introduced.

10. Policy dimension

In this section, we will look at some of the political instruments described in *subsection 5.3*, that can be used to close some of the coverage gaps described in *section 9*. In *section 9* the different coverage gaps were classified depending on the potential Business Case. The first gap consisting of approximately 45% of the uncovered addresses was assumed to be possible to cover by a deployment having a positive Business Case if sufficient demand is present. This requires that the citizens are demanding the services, hence the political option is to stimulate the demand generation that will drive the service uptake. Theses political options are discussed below in *subsection 10.1*. In the case where the demand itself is not enough to generate a positive Business Case for the provider, the rollout will require that parts of the initial investment can be subsidised to make it attractive for the providers. This and other supply side instruments are discussed in *subsection 10.2*.

In *Table 15* below the different political tools supporting either an increase in demand or an increase in supply is repeated.

Table 15, available policy tools (reprint of *Table 5*)

Instruments affecting Demand:	
Vertical Instruments	e-government, e-health, e-education, Consumer awareness and information
Non-regulatory instruments	Subsidies, Tax credits, Voucher programs, Low interest financing, Public Private Partnerships
Instruments affecting Supply:	
Horizontal Instruments:	Unbundling, Access to rights of way, Colocation, Interconnect, Wholesale, Licensing policies, Universal Service Obligation, Technology neutrality
Vertical Instruments	Separation between network and content, Limiting exclusivity between players, Network neutrality, Common Carrier
Non-regulatory instruments	Tax credits on investments, Subsidies, Public Private Partnerships, Deprecation on investments, Low interest financing

Finally, in *subsection 10.3* we look at alternative ways to meet the NGA-coverage target, i.e. in case of demand and supply side intervention not being sufficient.

10.1. Commercially reachable coverage

If the presence of adequate demand will generate a positive Business Case for the operator to deploy NGA, the Government can increase the **opportunity** (see *Figure 2, [1]*) for the suppliers. This can be done by applying some of the tools listed in *Table 15,* categorized to affect demand.

First the Government can increase the demand by generating a need for broadband to be part of the digital Denmark. So far, the Government has been digitalising the communication between the citizen and the public sector with initiatives like borger.dk, e-boks, and online tax registration. This public digitalization requires the citizen and companies to use digital channels when interacting with the public sector, and thereby increases the demand for broadband.

The Government is using digitalization in the educational sector, nudging the students to use and interact with the educational and public institutions using the Internet. The municipalities provide common access to Internet and public service support on the public library and all agencies public or private that provides further education or retraining unemployed includes training in using digital medias. The None Government Organizations (NGOs) are offering training for groups with special needs like elderly people, blind people etc. for everybody being able to be part of the digital Denmark. This is activities used to increase the use and knowledge of digital medias.

The Government also raises the awareness on digitalization by promoting services like e-health, and by providing a legal framework that allows relevant public and private players to operate fully digitally. This legal framework aims at providing the same protection to the citizens doing online shopping as if it they were shopping locally in a physical shop. Public and sector specific agencies provide certification of e-commerce sites that should reduce the barriers to use online digital services and e-commerce by ensuring the security, privacy and equal terms between online trading and physical stores.

The speed needed to communicate with the public sector is not enough to carter for NGA-deployment, but by increasing digitalization and thereby introducing Internet services to a broader part of the society can eventually lead to increased use and thereby need for higher bandwidth.

The mentioned activities all raise the public awareness and facilitate a demand, but the demand needs to be gathered in order to drive a positive NPV for the operator considering NGA-deployment in the area. To make this demand visible the Government has made a guide and a toolbox (as described in *section 7.6*), informing the interested or dedicated citizens how the local community can get together and reach the critical mass to be commercially attractive for the operator, and how the community should approach the operator with their projects in order to be positioned as an area with attractive NPV on the NGA-investment. At the municipality level, some municipalities have employed staff to support the dedicated citizens in creating the needed local support for a broadband project, (01052017_Netplan), see also *Figure 5*.

Looking at the non-regulatory tools from *Table 15,* only one of the tools have already been applied in Denmark, which is the possibility of introducing tax credits. To remove any initial financial barriers for the citizens, the Government has provided the citizens to deduct the cost of establishing broadband[18] (fixed, fixed wireless and mobile) up to 12.000 DKK. This tax credit possibility has only been available during 2016/2017, hence the popularity of this fiscal instrument is not known (10052017_Energistyrelsen, 27:14-27:20), but it is not perceived to be widely used by the providers in their campaign material (01052017_Netplan, 01:15:40-01:16:00). To drive more demand, it would be an idea to extend this tax credit until 2020 and to track its utilization to determine if there is a need to extend the knowledge of its existence.

The more direct support by providing direct subsidies, or voucher campaigns where the citizens get a voucher with a certain amount that are earmarked for the broadband installation, has not yet been applied in Denmark, most likely due to the financial climate in Denmark. The only exception is the broadband fund which must be applied by the citizens even though the subsidy is forwarded directly to the operator, and is therefore more seen like a supply generating subsidy.

Another option is to give access to low interest financing to stimulate demand, like mortgage loans, using the argumentation that the broadband installation is of the benefit of the house and not the persons living in it at the time. This fiscal instrument has currently not been used as a demand stimulating tool, it is however used as a tool to decrease cost of money to stimulate supply.

The final tool listed in *Table 15* to stimulate demand is Public Private Partnerships. To support demand the Government and public sector can facilitate a version of Public Private Partnership where the public players are responsible for supporting the dedicated citizens in gathering enough interested potential customers to make it commercially attractive for the operators to commit to a rollout. In this Public Private Partnership, the industry is responsible for providing information about actual coverage, rollout plans etc. to support the local communities in formulating projects, e.g. via Tjekditnet.dk. There are no actual financial transactions between the public and the private players in this type of collaboration, but there is a common interest in promoting local demand generation, making it attractive to rollout infrastructure for the operators.

A tool not directly mentioned as a tool in *Table 15* is the possibility for the Government or others to promote the idea of the citizens accepting a larger deployment fee to get their address covered by

[18] https://www.skat.dk/SKAT.aspx?oId=2534

NGA-network, like the fees that applies for other utilities like water and sewer. This task is a delicate matter, but the main problem is that broadband in Denmark is perceived as a commodity people are not willing to pay for. This means that the public opinion is that broadband ought to be available at all addresses. Looking e.g. to our neighboring country Sweden, the citizens are willing to pay a substantially part of the NGA-deployment. In the case of Almhult, (Falch, Henten, Tadayoni, & Williams, 2016, p. 11), each household paid approximately 2.500€ to get connected.

10.2. Coverage that needs intervention

If it is not possible to get a positive Business Case for the operators by increasing demand the next set of tools listed in *Table 15* can be used to stimulate supply.

The horizontal instruments are instruments affecting players operating at the same level in the value chain – in this case, we are focusing on instruments affecting operators considering deploying NGA-network. Unbundling, interconnect, wholesale access and colocation is primarily tools affecting service providers. Indirectly they can also serve as tools making it easier for a local operator to get a national service offer and thereby getting scale advantages. An example is the small company Gigabit, who is primarily operating as service provider on TDCs network. Based on this nationwide network Gigabit has already scale and they are considering deploying NGA-network themselves in small areas where TDC is not present with ultra-high-speed access, and if they can get a good NPV of the investment[19]. The effect is however only indirect and it will increase the **competitive intensity** among the operators, and it can work opposite the intension. John Strand mentions that if the utility companies were obliged to offer wholesale access it is expected that they will argue that their opportunity to get pay back on their investment will decrease, (28042017_John Strand). Ie the **competitive intensity** will cause a decrease in revenue and affect the NPV of the operator deploying NGA-network in a negative direction.

The instruments 'access to rights of way' and 'technology neutrality' can work to increase the **opportunity** for operators deploying NGA-network. Of special relevance to the operators offering wired NGA-network is the obligation to offer co-digging to other operators, if public or private companies are digging. With the latest change in the law related to digging along public roads, one operator can claim access to the passive infrastructure (e.g. ducts) owned by other players, see *subsection 7.2*.

[19] https://gigabit.dk/projekter.html

From our interviews, internal knowledge and case investigations we have got the impression that the tool of enforcing ‘technology neutrality’ has not been granted sufficient attention. In both the different tenders facilitated by the municipalities as well as the national broadband fund, the speed limit and general formulation have been in favor of fiber. If less focus is on the guaranteed bandwidth and more focus is on low costs in these tenders it is possible that this could serve as a kick start to the rollout of wireless high-speed networks in rural areas. An extremely costly part of creating wireless high-speed networks is getting masts or antennas, here the access to other operators and service providers poles, masts and antennas – which is included in ‘rights of way’ – is both a possible **opportunity** as well as a way for the Government to reduce **costs** for the wireless operator.

The Government has the regulatory instrument of using the spectrum licenses to appoint specific network deployments requirements. Today the technologies are converging hence there is less reason to keep the traditional distinction between mobile, fixed, cable, wireless etc. In several countries they are allowing unified, multi service and technology independent licenses (Blackman & Srivastava, 2011) which makes it possible to support a wide range of market players.

The last instrument listed in *Table 15* that works horizontally is to issue a Universal Service Obligation. It is not possible to issue a USO for NGA-products, but it is possible to issue USO on basal broadband which is sufficient to use e-mail, correspondence with the public, e-boks, net-banking etc. In the interview with Netplan Anne Mette Kruse Møller was addressing this point asking the question: “… de kræver at borgeren er digital, men hvor er modforpligtigelsen”, (01052017_Netplan, 01:17:00-01:17:04). As mentioned in *subsection 7.2*, it has been rejected by the authorities to issue a USO on basic broadband in Denmark primarily due to expected high costs and based on the assumption that TDC would be the Operator holding the USO. H. Jussi (2011) has estimated the cost of i) reaching nationwide coverage in EU on basic broadband, ii) upgrading to 30 Mbit/s coverage, and iii) having 50% of the eupeans subscribing to more than 100 Mbit/s broadband. Of the three calculations, the most expensive is i) and the upgrade to ii) and iii) is almost cheap in comparison. This observation could be a lever for reconsidering USO on basic broadband in Denmark.

The vertical instruments listed in *Table 15* are primarily tools that affects the innovation and product development among players acting at a higher level in the value chain, and thereby indirectly driving demand and thereby increasing **opportunity** for the operators deploying NGA-network. These tools have focus on ensuring equal free access from the application and content providers. This will drive the service innovation and development of new services that will lead to increased bandwidth requirements from the customers. Net neutrality is the regulatory tool that ensures that the infrastructure providers are not keeping the service developers outside their network. The need for bandwidth, as described in (Thimmer & Hansen, 2014) and (Falch et al., 2013), are driven by the uptake of new service like streaming, video conferencing etc. A tool similar to net neutrality is to force the operators to strictly separate their infrastructure business from their service business, not giving any specific benefits to own produced services like guaranteed service speed, specific QoS, service priority etc.

The last tools listed in *Table 15* affecting the supply are non-regulatory tools. In Denmark the Government has introduces one this year, with the introduction of using mortgage loans to finance infrastructure rollout and thereby decreasing the interest on financing and potentially making it more attractive for smaller companies to invest in infrastructure (10052017_Energistyrelsen, 44:59).

A tool extremely usable to affect the NPV of the investment by directly decreasing costs is the possibility to issue subsidies. These subsidies must be in accordance with the EU guidelines on state aid, as already described in subsection 7.3. As opposed to the low interest rate via mortgage loans or other tools that are affecting the NPV calculation more generally the direct subsidy can be targeted specific areas and according to the EU guidelines on state aid, (Commission, 2013), it must support the rollout of infrastructure in areas where it is not commercially viable for the private sector to rollout. The Commission allows support in white areas, where no broadband is provided except for satellite or leased lines. In grey areas, where some broadband is provided, a thorough examination is needed to allow subsidizes, whereas state aid is not allowed in black areas with existing competition.

Direct supply side subsidies such as direct public payment is reducing the overall cost of a project for the operator, and has the advantage compared to other supply side instruments that they can be made depended on a long range of criteria like actual address, speed provided, technology used, the size of the operator etc. this allows the regulator to be able to ensure competition in a specific region, but it also requires a high degree of administration (Bauer, 2009). The main risk is that subsidies might be used to finance development that would have happened anyway. This is the same concern that John Strand expresses (28042017_John Strand, 1:04:23) that when the Government is placing an address in a category that are eligible for subsidies, then the market will not do any development on their own initiative.

Indirect subsidies like access to low interest financing, deprecation on investments, and tax credits are instruments that overall reduces the cost of money for the operators. The effect of these measures depends highly on the design and the context in which it is given as to whether it is effective or not. If the investment is depended on external capital, then the cost of capital is of great importance. These instruments tend to favor established companies that are financial liable. However, these instruments carry the same risk as the direct subsidies, that they are given to investments that will happen anyway without public intervention (Bauer, 2009, 2010).

The last instrument we will comment on is the use of Public Private Partnerships (PPP). A Public Private Partnership (PPP) initiative involves the corporation between public and private players. The private players are either doing tasks on behalf of the public sector to fulfill a public policy goal or public sector perform activities that supports private sector initiatives (Falch & Henten, 2010). According to Falch, Henten, Tadayoi, & Williams (2016), PPP in the ICT area can support the development of infrastructure in three different scenarios: 1) development of infrastructure, 2) stimulating service development, and 3) projects that include investments in ICT, but has a broader scope.

The primary problem with Public Private Partnership is that the projects must comply to both national and EU legislation. A possibility we discussed with Netplan (01052017_Netplan), that in their opinion ought to be doable is the following: The municipality and the dedicated citizens or local organizations joins forces with local business to get sufficient future demand to create the foundation for a positive Business Case. If the total cost is too high, the municipality can contribute by facilitating the trenching. For the municipality to legally contribute to the project, they must be sure that no rollout will take place on commercial terms within the coming three years, and the ducting must be offered to other operators as well.

A tool not mentioned in *Table 15* is a tool, that was mentioned by Netplan and which according to Mette Dalsgaard (01052017_Netplan) would be extremely valuable, is if the Government or the Agency takes a responsibility in interacting with the European Union to create a set of recommendations on how to structure the tenders or Public Private Partnerships without conflicting with the European law.

10.3. Coverage that needs extraordinary funding or alternative technology

The general problem with households with very high deployment costs is, that unless the citizens are willing to pay a substantial deployment fee, the tool most effective is to grant direct subsidies from the Government. If no direct intervention is affecting the specific project, the NPV of an alternative NGA-deployment, e.g. deploying infrastructure competition in an urban area, will probably be more profitable. And the extended NPV as illustrated in *Figure 2*, is thus turning negative.

The only known governmental or regulatory tool, except subsidies, that addresses this issue is to issue a USO. Even though the USO can only be on basic broadband we have argued in subsection 10.1 that this could clear the way for deployment of broadband of higher speed. The USO can be based on a set of geographical separated areas, and the USO can then be auctioned out in these areas. This requires that the operators and the Government will establish a universal access fund that will subsidize the licensed operator for the cost of covering the very remote addresses.

Enforcing and promoting technology neutrality, and particularly in a way as not to discriminate wireless solutions, as mentioned *subsection 10.2,* is another option that the Government can pursue to increase NGA-coverage. This would allow new wireless technologies to be deployed to cover the majority of the remaining households, that cannot be covered without extraordinary subsidies.

We expect some of the most expensive addresses to be out of reach even by use of wireless technologies. This group of addresses out of reach with ordinary tools will probably be households in hilly areas, in areas with forest or on islands. To reach this remaining probably 1% of the households the government must be willing to either grant extraordinary subsidies or finally issue a Universal Service Obligation.

10.4. Summary

To summarize we find that intervention is probably needed to cover both the households that are within reach for commercially NGA-deployment as well as the households that cannot be covered on ordinary commercially terms.

To cover the commercially reachable addresses, the Government should put forward a mix of public policy instruments to generate the necessary demand. These instruments are i) pushing the public digitalization further, ii) prolonging the tax credit that allows citizens to deduct up to 12.000 DKK used on getting broadband access, iii) increasing information on possibilities and particularly iv) use resources within the municipality to facilitate the dedicated citizens.

To cover the addresses outside commercially reach the Government has two drastic choices, either use substantially amounts of money on subsidies or issue a Universal Service Obligation on basic broadband. Other less drastic alternatives are a) make it easier/less expensive to get access to other operators' poles/masts/cell towers, b) make tenders that are targeted wireless solutions, as opposed to fiber solutions, - even if this means decreasing the targeted bandwidth, c) explore new forms of Public Private Partnership, or d) contribute by making a set of recommendations on how to structure the tenders or Public Private Partnerships without conflicting with the European law.

11. Validating the findings

In *section 4* we held interviews with 3 industry experts/organizations to get their view on the matter as well as getting some kind of validation of our findings. The first interview was held with John Strand who is an independent telecommunication analyst, who has worked within the industry for about 25 years and has a broad knowledge of both the regulation and the different operators offering services within the field of broadband services. The second interview was held with Anne Mette Møller (CEO) and Mette Dalsgaard (senior consultant) at Netplan A/S. Netplan has been an independent consultancy specializing in telco solutions since 1994, and recently Netplan A/S have been involved in designing the tender material for some of recently held tenders in which municipalities ask for additional coverage. The last interview was with three employees at the Danish Energy Agency: Peter Johnson, Hans Teglhus Møller, and Rikke Rosenmejer. Peter Johnson has coverage issues as one of his primary work tasks, Hans Teglhus Møller is responsible for TjekDitNet.dk, both data and functionality, and Rikke Rosenmejer is leader of the team responsible for the broadband fund.

In the following three subsections, we have highlighted the points from the different interviews, the audio files can be acquired upon request.

11.1. Interview with John Strand, April 28th 2017

John Strand describes himself with the following words: "*Jeg er free market man, min holdning er, lad konkurrencen køre derudaf, lad vær' med at regulere det her*", (28042017_John Strand, 6:01-6:06), and this is naturally reflected in his views and opinions.

The Danish regulatory strategy "Best and Cheapest" has been a great success and have positioned Denmark in the same league as USA and Canada regarding investments levels in broadband development.

The problem today is the demand for high-speed broadband. Today around 86% of the Danish population can get 100 Mbit/s, but when the utility companies deploy fiber in a new area, they are struggling with a penetration rate of 5-37 %, leaving 7 out of 10 to say no-thanks to high-speed broadband. The current political agenda is driven by the utility companies and various NGO's and focuses on fiber as the only infrastructure able of solving the future demands for speed. This is a myth, particularly because the current technology and service development has a focus on mobile first due to a change in the way that we are using services like streaming, gaming etc. This development will allow customers to get more content and service with less need for speed.

John Strand believes it will be possible to deploy nationwide coverage of 100/30 Mbit/s. The current investment rate in infrastructure in Denmark is around 6 billion DKK a year, and the technology development is happening at a rapid pace that should solve the capacity constraints on technologies like wireless or cobber. It will require technology neutrality, and realistically it will be a mix of fixed and fixed wireless that will ensure the complete coverage.

Technology neutrality in combination with a free and unregulated market is the key to keep ensuring infrastructure investments without public subsidies, according to John Strand. It should be possible for companies to invest in infrastructure, and to capitalize on this investment without being forced to give others access to their network. if one company will be dominant in one geographical area then the completive law has the instrument of – open access – to handle this. John Strand believes that the utility companies will gradually open their networks, providing a BSA-product, that compared with a regulatory wholesale product will allow them to have a positive Business Case on the open access.

If the public decides to intervene in the market either by providing infrastructure or by appointing addresses to be eligible for subsidies, they will remove the Business Case for other companies to invest in covering the supply gap. Today the focus on providing the cheapest broadband has removed the profit that the operators need to invest into new infrastructure and technology. The current price level is not allowing the operators to get their historical investments payed for. Allowing the prices to increase with 20-40 DKK pr. month would be the best support to ensure technology and infrastructure development in the future, as it will increase the NPV for the operators.

11.2. Interview with Netplan A/S, May 1st 2017

Netplan is an independent advisor to larger companies and municipalities. they provide analysis of existing telecom solutions and performs public tenders regarding telecommunication services on behalf of their clients. Netplan finds that there are many locally based actors on the broadband market. There are many small wireless actors, there are one or more utility companies providing fiber infrastructure in their supply area, and there is TDC as the only provider that are present in all municipalities. The experience is that normally there are only room for one fiber provider in on geography, when we are looking at residential broadband, since there is not enough volume to pay for the high deployment cost.

The utility companies are very loyal to their supply areas when deploying fiber. They are very cautious that they have a basic penetration in place before rollout in order to get a positive Business

Case. This was not the case a few years back, where the utility companies were deploying fiber without ensuring that the business case and penetration were in place.

The government has given the municipalities the responsibility of deploying an NGA infrastructure, but except for a toolbox with some useful advice, it is limited what tools the municipalities have to make things happen, besides what the market does by itself. Netplan is expecting that the new Telecom Act. will include new tools to support the municipalities. The government has initiated the national broadband fund ("bredbåndspuljen"), but it will not really give anything on the coverage part. It has however raised the awareness in the local community to the fact that if people are signing up, then it is possible to be attractive for the operators to rollout on commercial terms.

The Energy Agency has initiated the broadband fund, which to a larger degree should have been targeted to the rural areas as the urban areas will almost always be a better Business Case for commercial deployment, but speed was selected as the objective parameter. The suggestion from Netplan would be to use the average cost to serve as a lower and higher marker. If the lower limit is 11.000 DKK and the higher limit is 70.000 DKK, then it would have ruled out most of the projects in the urban area, focusing the project on the rural Denmark.

The municipalities are trying to support the citizens by employing broadband coordinators, that in close dialog with the operators and the local communities are trying to raise awareness and ensure that things happen. Today maybe a handful of the municipalities that has done this. Guldborgsund is an example on such a municipality. Besides these activities, there are no other initiatives under way.

Netplan believes that in principle should openness be built in from the beginning, but in reality, it is limiting the competition in the market. The utility companies and smaller wireless based operators cannot handle the degree of openness that are required in the public tenders. This is a requirement from European Commission, but it is not clear how openness should be implemented, what services, what terms, and at what price. The utility companies prefer a model where they can deploy fiber broadband, and the capitalize on this over a period of time, and then increase penetration by opening up the network using a bit stream access product. Currently it is only TDC that can meet the requirements from the European Commission. The utility companies SE and Fibia have compensated by creating their own broadband fund, that uses the same model regarding citizens involvement.

Speaking of technology, then fiber is the only real option, due to it being future proof. Complementary technologies, like wireless, mobile and cable (coax) are to be considered less future proof.

However, the technology development is moving fast and there are wireless providers that are delivering gigabit speed over a long range.

It is limited what tools that are available for the municipalities that can be used to increase NGA-deployment. The municipalities have to balance a tender between numerous laws like the EU guidelines for state aid, competitive law, and "erhvervsfremmeloven" an there is no coordination between the law areas. The agencies and ministries are not able to support the municipalities in creating the clarity.

Netplan views the transition of the IT & Telestyrelsen into several public agencies as a down prioritization of the area. Digitalization is important for the government, but they have not given any requirements of a minimum speed that the citizens can require. There is no action behind the political goal, as Anne Mette Kruse Møller states: "…*mener man det? Det tror jeg ikke*." (01052017_Netplan, 1:03:50-1:04:02).

11.3. Interview with the Energy Agency, May 10th 2017

Since the Agency delivered coverage data to us from Tjekditnet.dk, it has been updated with new data from the operators. Now 89% of the household addresses in Denmark are covered with 100/30 Mbit/s broadband, compared to 88% in February when we received the dataset. This accounts for around 8-9% of the total pool of uncovered addresses.

The European Commission target of 30/30 Mbit/s is not something that are being monitored or reported on by the Agency, they are only reporting on the Danish political goal of 100/30 Mbit/s.

There has been a development over time from where the end-uses expected that a rollout would automatically happen to a situation where they need to collaborate for things to happen. An example is the Midtvest Jysk mobile tender, where 6 municipalities joined forces to increase buying power to reduce prices and increase coverage. At the institutional level the municipalities have been much more strategic in terms of pushing for more coverage when buying something. For private and enterprise customers, the only option is to complain to the public authorities, or they can join forces to drive the operators to provide coverage. The model is still not widely used, but operators, utility companies, and municipalities are using it more and more. The Agency issued a campaign 2-3 years ago to inform municipalities and dedicated citizens about the possibilities. The national broadband fund is an outcome of this campaign to establish contact between end-users and operators, and to bridge the perception in people minds that there are only a few operators to choose from.

The operators and utility companies are using this model to prioritize their investment budgets, so if they get guaranteed a sign-up of 60% in one location compared to 10% in another (other factors the same), they will select the one where they get most customers for their investment. There are several examples of locations that were eligible to apply for subsidies at the broadband fund, but didn't apply as they were enough to be covered commercially.

As part of the broadband fund there has been a lot of thoughts on how to ensure that rural areas get most attention, but it has been difficult to create a set of well-defined and objective criteria's without having to evaluate each and individual address.

There are many different players in the NGA-market, but there is no real difference in what the Agency can do to support them. The main task is to ensure that there are good frame conditions like: ensuring that the companies can dig and establish mobile masts, removing unneeded laws and regulation, ensure access to low interest rate, tax reduction for specific services ("håndværker-fradrag") – in short solve general market barriers in a technology independent way. If it is not expected that the market will solve a demand within a certain timeframe, then the Agency will see if additional founding can help (like the broadband fund).

The way the Government is ensuring a demand for broadband is initially to ensure that people need it to engage with the public sectors through digitalization of all services. There need to be focus on this as part of all educational studies. In the future the demand for more bandwidth will come from a wide area of services like the intelligent home, streaming etc.

The Government has not defined any new instruments to support the NGA-deployment, this awaits the new political agreement Telecom Act that can contain many or few instruments. Over the past years only a few new regulatory instruments have been introduced based on existing legal frameworks. These new regulatory instruments include the possibility to use mortgage loans for financing infrastructure development, changes to the planning act, and Danish guidelines for planning and design, construction and maintenance of roads to make it easier to get digging permits and permits to deploy new masts. These regulatory instruments have been introduced to reduce the operators cost of deploying broadband. Furthermore, the Energy Agency has been working with the municipalities to digitalize their internal processes, to make it easier and quicker for the operators to get their various permits, to increase speed and reduce cost of applying.

The municipalities are trying to speed up the development in their locations in two ways: 1) Where it is for their internal use, and where the traditional EU tender rules apply or 2) when they are trying to include support for specific local areas or businesses, where it then includes “erhvervsfremme-loven” that is the domain of The Danish Minister of Industry, Business and Financial Affairs. The legal framework is the EU guidelines on state aid, that is very complicated to understand. It is only the European Commission and the European Community Court that can determine if a tender is legal, and it is the tendering authority that are responsible. Hence the Agency cannot provide any guidance into how this should be done in Denmark, so that it would be legal, an example is the requirement of open access to the network, but at what price?

The Agency have tried to use two different models: at Bornholm, the wholesale price was based on LRAIC, and in the national broadband fund a fair price based on commercial negotiations are used. If the commercial negotiations fall apart, The Danish Minister of Industry, Business and Financial Affairs will set a wholesale price.

In the current legal framework, it is possible to create geographical separated markets if there is evidence for it in the competitive environment. It is the Danish Business Authority that will make this assessment, and it will be further investigated as part of the new Telecom Act. In this updated Telecom Act it will be evaluated if there are missing legal instruments to keep up with the development. The Agency doesn’t expect the term Universal Service will be part of this discussion as it only accounts for basic speeds. In the future, the Universal Service term will specify a basic set of services, and not an actual Mbit/s target. It might be a more viable solution to use the Bornholm model of defining geographical area and ask if any operators are interested in building out. There is a chance that this will ruin the business case for many of the small operators that are locally founded and are building out using a mix of wired and wireless technologies. These companies are typically not geared for large public tender processes.

12. Conclusion

In our theses, we have looked at the current NGA-coverage, the ongoing political initiatives, and the viability of a market driven rollout of NGA-network. A significant input to the analysis is the estimated cost of deploying FTTH to ensure a nationwide coverage of 100/30 Mbit/s to all residential households in Denmark. Based on the calculation, the status and the current initiatives we conclude that to reach the goal of nationwide coverage something additional must happen.

In *subsection 7.1* the status of the 100/30 Mbit/s coverage as well as the development is illustrated. It is obvious that the pace at which the coverage is increasing is decreasing and simple extrapolation of the development will result in approximately 95% NGA-coverage by 2020.

In *section 8* we have estimated the total cost of reaching nationwide NGA-coverage based on FTTH/GPON to be approximately 9.7-13.2 billion DKK, a sum it is not expected that the government will fund, nor a sum that we expect that the industry will finance on normal commercial terms. We have divided the uncovered addresses in rural and urban areas, and the conclusion is that almost all the uncovered households in the urban areas can be covered on commercially terms, at least when the needed demand is present. Particularly for the households in the rural areas smart subsidies or other activities needs to be initiated. In *section 9* we estimate the commercially reachable part of the households to be approximately 45%, leaving 55% or 175.000 households to be in scope for intervention. Looking at the target of nationwide coverage the 175.000 households corresponds to 6,5%.

Seen from the side of the operator the Business Case of investing in parallel infrastructure in the highly populated areas are far better than investing in rural areas even with a 100% commitment from the citizens in the area. This means that the extended NPV calculation for deploying NGA-network in the very expensive areas are negative. The only way the operators can be expected to finance the remaining rollout is by deploying alternative infrastructure technologies, by altruism from local operators, the utility companies, or by force or regulation.

To cover the total cost of deploying fiber to the remaining uncovered households the government must be willing to pay for a larger part of the investment either by direct subsidies or by supporting the municipalities in exploring new forms of PPP that will drive the rollout of high-speed broadband, if the political vision shall come true.

The policy tools that can be used to increase coverage is divided in three groups: 1) The tools that can be used to accelerate the coverage of the commercially reachable addresses, 2) tools that can be used to facilitate the coverage of the addresses outside commercially reach, and finally 3) tools that can help NGA-deployment for the last addresses that can only be covered by extraordinary means.

Coverage of commercially reachable addresses can be accelerated by i) pushing the public digitalization further, ii) prolong the tax credit ("håndværkerfradraget"), iii) increase information on possibilities and iv) use resources to facilitate the dedicated citizens.

Coverage of addresses outside commercially reach can be facilitated by a) make it easier to get access to other operators' cell towers, b) make tenders that are targeted wireless solutions, c) explore new forms of Public Private Partnership, or d) contribute by making a set of recommendations to the municipalities on how to conform with the European law.

To cover the last addresses – the addresses not reachable by wireless solutions, and located far from other households – the Government has two drastic choices, either subsidies or issue a Universal Service Obligation on basic broadband.

We conclude our thesis by stating that we find it unlikely that Denmark will reach a nationwide coverage of 100/30 Mbit/s broadband access to residential areas by 2020. We find however that if demand and willingness is present the goal is reachable and there is no true access gap, that cannot be met by using existing political instruments, pushing for new technologies, and the engagement of the citizens.

13. Discussion and reflection

In this section, we will end our thesis with some reflections on our method, and discussion on some of the topics described in the thesis. The topics we will elaborate on is the field of public intervention versus free market forces coved by the following headlines:

1) The potential of setting the market free and allowing the prices to increase,
2) The potential conflict of public tenders favouring the larger players,
3) The possible negative effect of appointing an area to be entitled to subsidies,

13.1. Method of analysis

In our choice of method of analysis, we have decided to build the analysis on desk studies of existing literature – both scientific articles, government reports and legislation – and combining this with a bottom up calculation of deployment costs to get a quantifiable foundation for the size of the different coverage gaps. To validate our findings and get inspiration in our analysis we held interviews with three different industry experts. Except from the Energy Agency, the interviewees were not active partners in the market, neither representatives from the operators, nor the municipalities or dedicated citizens. It would have been valuable for our conclusions if we had discussed the different suggestions with the industry. We had a small email correspondence with Jens Jönsson from Skywire, and it would have been interesting to have an interview with some of the representatives from the wireless players, to get information on their business opportunities and ways to upgrade their existing infrastructure. The role and business opportunities seen by the utility companies, and the different options and possible actions seen by the municipalities would also be relevant to get first-hand view on. This is probably sufficient material for another master thesis, and to get the foundation right we consider our choice of using time on cost calculations as a valid first step. Getting interviews with the operators was out of scope – but still an interesting task to have included.

13.2. Setting the market free

As mentioned in *subsection 11.1*, John Strand is a market man, and naturally he had some points on the possible development of the ICT-market. With respect to the possible evolution of the market after the utility companies opens their infrastructure to other players, he had the point of view, that this will probably be on bit-stream-access terms and expectedly at a higher cost than the regulated bit-stream-access to TDCs infrastructure. John had the opinion that the prices on broadband in Denmark is too low to drive a decent innovation and rollout. His observation of the prices being low coincide with a press release from the European Commission[20] in which the different prices for broadband services across EU is illustrated. According to this overview, prices in Denmark are about average in EU and this will not change dramatically if ex. the price is enlarged with 3-4 € per month for all broadband subscriptions.

John has the opinion that this increase in prices will give the infrastructure owners the possibility to increase deployment and it will also increase the revenue margin for alternative operators, e.g. operators offering wireless broadband. All in all, John Strand concludes that a price increase of e.g. 20-30 DKK per month is reasonable and will be of great benefit to the development of ICT-infrastructure and services.

If we accept this precondition a price increase of 20-30 DKK adds up to 600-900 million DKK per year. Money that in another political framework could be used to finance either a Universal Service Obligation on basic broadband – or be used to subsidise NGA-deployment even further.

13.3. Public tenders and the small players

In *section 7* we have illustrated some of the pitfalls with particularly public tenders targeted at increasing broadband coverage in a specific geographical area. The tender must be in accordance with EUs guidelines for stat aid if it involves subsidies or payment from e.g. the municipality. This means that the infrastructure must be open, which is difficult to handle for most of the operators as it involves complex IT systems to support multiple interfaces to other networks. Smaller operators will not have the administrative competences or investment budget to handle a complex public tender based on European law. They can also have difficulties in covering all the specified addresses. This could be the case for a wireless operator who are dependent on being able to get housing on relevant masts or cell towers, or otherwise get permission to build new mast. For the wireless operator, even perfect location of masts is not a guarantee to be able to cover all addresses in a specific area.

If a municipality is doing a tender where a large number of addresses must be covered with ultra-high-speed infrastructure, then they are potentially removing the business case for many local small providers of alternative technologies like fixed wireless that have an existing business opportunity. This could be the case if a part of the area is covered by small providers who cannot meet the required speed. This could be a small wireless operator that are only able to provide 20/20 Mbit/s and

[20] http://europa.eu/rapid/press-release_IP-14-314_da.htm

the tender is requiring 100/30 Mbit/s with seamless upgrades to 1/1 Gbit/s. In this case the public tender will destroy the existing business opportunity for the small operator.

So the municipality will promote the larger operators effort in deploying fibre, but are reducing the numbers of competitors in the area in doing so.

13.4. Areas appointed to be entitled to subsidies

A foundation for the application for subsidies in the national broadband fond is the available broadband speed for the addresses in question. A part of the material in the broadband fund is thus a list of all addresses in Denmark entitled to apply for subsidies from the broadband fund. A potential risk of this appointment is that whenever an address is entitled to receive subsidies the business opportunity for operators who are working on commercially terms are decreasing.

Elaborating on this John Strand has the opinion that even addresses close to the subsidy zone will not be attractive as part of a commercial project as the operators will expect this address to be included in the subsidy zone over time, or the subsidised operator will increase coverage to include these addresses over time.

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Appendix A, validation of coverage data

Based on a list from the BBR-register containing all addresses in Denmark, a random uniform distribution is used to make a very small sample of 20 addresses. The addresses are first checked against the data-set from TjekDitNet.dk containing not covered addresses, and if the address is present it is removed from the sample and a new address is chosen. All the sample addresses are then looked up on the online version of TjekDitNet.dk, and the operator offering the highest bandwidth is checked on the operator homepage for actual product offers on the address. This process resulted in the following 20 sample addresses and associated information from TjekDitNet.dk, and the corresponding operators:

Address:	TjekDitNet.dk	Operator
Sjællandsgade 40 st tv, 8900 Randers	300/60 Mbit/s: YouSee, Hiper	Hiper: 100/25 Mbit/s YouSee: 300/60 Mbit/s
Solbakken 91, 2840 Holte	300/60 Mbit/s: YouSee	YouSee: 300/60 Mbit/s
Hasselvej 6, 8300 Odder	750/750 Mbit/s: Aura	Aura: 500/500 Mbit/s
Dronningemaen 13c 2, 5700 Svendborg	300/60 Mbit/s: YouSee	YouSee: 300/60 Mbit/s
Hornborgvej 23, 8762 Flemming	500/500 Mbit/s: eniig	Eniig: 500/500 Mbit/s
Konsul Beÿers Allé 22 1 th, 4300 Holbæk	300/60 Mbit/s: YouSee	YouSee: 300/60 Mbit/s
Pedersholms Allé 10 2, 7100 Vejle	250/250 Mbit/s: Stofa, YouSee, DK TV	Stofa and YouSee: address not covered DK TV: 250/250 Mbit/s
Murergården 8, 2635 Ishøj	360/360 Mbit/s: DK TV	DK TV: 250/250 Mbit/s
Nolsvej 10 st 0001, 9493 Saltum	1/1 Gbit/s: Bredbånd Nord, Nyfors	Bredbånd Nord and Nyfors: not covered
Skovvejen 48 2 mf, 6000 Kolding	300/50 Mbit/s: Stofa	Stofa: 300/50 Mbit/s
Skagerraksvej 4, 9700 Brønderslev	1/1 Gbit/s: Bredbånd Nord, Stofa	BN: not able to deliver Stofa: "technical problems"
Aarø 92, 6100 Haderslev	300/300 Mbit/s: Stofa	Stofa: 600/600 Mbit/s
Sibiriensvej 236, 5300 Kerteminde	500/500 Mbit/s: Nef fiber	Nef fiber: 500/500 Mbit/s
Nødager 42, 4000 Roskilde	500/60 Mbit/s: YouSee, Hiper	YouSee: 300/60 Mbit/s Hiper: 100/25 Mbit/s
Foderstofgården 91, 3600 Frederikssund	300/60 Mbit/s: YouSee, Hiper	YouSee: 300/60 Mbit/s Hiper: 100/25 Mbit/s
Marselis Boulevard 22 2 th, 8000 Århus C	300/60 Mbit/s: YouSee, Hiper, Stofa	YouSee: 1000/100 Mbit/s Hiper: 100/25 Mbit/s Stofa: Information not available
Vildtbanestien 7 3 tv, 2635 Ishøj	300/60 Mbit/s: YouSee	YouSee. 300/60 Mbit/s
Henrik Ibsens Vej 1 2 tv, 1813 Frederiksberg C	300/60 Mbit/s: YouSee	YouSee: 300/60 Mbit/s
Vrenderupvej 42, 6818 Årre	300/300 Mbit/s: Stofa	Stofa: 600/600 Mbit/s
Spættevej 20, 2680 Solrød Strand	300/60 Mbit/s: YouSee, Hiper	YouSee: 300/60 Mbit/s Hiper: 100/25 Mbit/s

The sample size is too small to make any statistically valid conclusions, but it seems like the information on TjekDitNet.dk is in accordance with the data-set we have received. Ie. if the address is not in the data-set of not covered addresses, an operator is offering a broadband service with speed above 100/30 Mbit/s.

The information on the homepages of the operators is however not always in accordance with the information on TjekDitNet.dk. This can be due to changes in the coverage of the individual operator, misinterpretation of the specific address or mismatch within the databases of the different operators or within the Agency.

The second part of our validation has been to check the 317.000 uncovered addresses against TDC internal data, to see if the addresses are covered by YouSee. The result is that in total 7.450 addresses are covered by YouSee, 4.100 by YouSee coax, 850 by YouSee FTTH and the rest, 2.500 by copper. The additional coverage can be explained by time difference between the time at which TDC reported information to TjekDitNet.dk and February 2017 which is the date of the comparison of the two sources of information.

The number of addresses covered by 100/30 Mbit/s by YouSee corresponds to 2,5% of the uncovered addresses or 3‰ of the total number of households in TDC. At the interview with the Engergy Agency Hans Teglhus Møller (10052017_Energistyrelsen, 5:55-6:06) informed us, that the coverage based on the latest updated reporting shoved a small increase in coverage – approximately 1%. This supports the theory that the primary source of differences is the time having passed and the rollout thereby having increased.