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Financial requirements for nationwide fibre access coverage

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Jay, Stephan / Plueckebaum, Thomas (2011)

Financial requirements for nationwide fibre access coverage

Abstract

It is common knowledge that Next Generation Access (NGA) networks require significant investments and that for many regions, especially in more rural areas, there is no viable business case. Taking note of the broadband strategies formulated by European governments the deployment cost is analysed to assess options for extending the profitable coverage of FTTH.

In this paper a bottom-up cost model is applied to determine the investment and cost of deploying and operating a FTTH network in Germany on a national level. The monthly cost per subscriber at rising penetration is compared with the Average Revenue Per User (ARPU) to determine the required penetration level or the required revenue for profitable operation in a steady market state. Those regions for which there is no business case are analysed with regard to the level of required subsidies. All modelling is based on differentiated geotypes reflecting urban and rural areas. The basic cost model used has been applied to numerous case studies before and was adapted to determine different forms of subsidies.

The research questions addressed are

- What is the limit of profitable FTTH coverage in Germany?
- What is the level of prices, internal subsidisation or investment subsidy necessary to increase the coverage of FTTH in Germany?

These results inform policy makers and operators of the relevant investment deltas and/or price levels needed to increase the coverage of next generation broadband access infrastructure.

JEL codes: L96 – Telecommunications, L5 - Regulation and Industrial Policy, L51 – Economics of Regulation

Keywords: Next Generation Access, FTTH, cost modelling, GPON, P2P, broadband strategy

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1 Goal and methodology

The German government has set concrete goals for broadband development in Germany. Among them is the coverage of 75% of households with 50Mbps until the year 2014 with the vision of making such bandwidth available nationwide by 2018. However, economic analysis and statements of investors have shown that a nationwide rollout of fibre access networks is not profitable at the current revenue level.

In order to increase the profitable coverage of Germany with fibre access networks some options are conceivable and addressed here: 1) End users can pay a higher monthly price. 2) The operators can use profits from profitable areas to subsidise customers in non-profitable areas. 3) The network investment could be subsidised to the point that makes network operation profitable for the investor. Such subsidisation could e.g. be one-time connection fees from end-users or subsidised funds from the state.

The goal of this paper is to analyse the investment requirements for rolling out fibre networks nationwide in Germany, to determine the range of profitable operation and to assess the level of subsidies needed for extending the range of profitable operation.

Previous research by the authors for Germany did neither incorporate geodata nor determination of subsidy requirements.¹ Subsidy requirements were already calculated by the authors in a 2009 cost study for Switzerland.²

For this exercise detailed geodata of Germany was available, such as the location of Main Distribution Frames (MDF), location of buildings, geo-referenced road networks, statistical data of households and businesses. The work was conducted in five steps

1. Extensive processing of geodata: At the end of the process geo-coded data for MDFs, buildings, streets etc. was prepared as input into our network optimisation tool.
2. Delineation of access areas, determination of street cabinet locations and trench lengths: With the processed geo-data a network optimisation tool was applied taking the MDF locations as given ("scorched node") and endogenously determining the trenches and street cabinet locations to connect all customers (~43mn lines). For each of the 7731 MDFs trench lengths, customers, buildings, street cabinets, etc. were determined.
3. Aggregation of MDF data into 20 clusters: For simplification results were aggregated to 20 clusters of equal size in terms of number of customers defined by customer density.

¹ Elixmann / Ilic / Neumann / Plückebaum (2008): "The Economics of Next Generation Access", Doose / Elixmann / Jay (2009): "'Breitband/Bandbreite für alle': Kosten und Finanzierung einer nationalen Infrastruktur".

² Ilic / Neumann / Plückebaum (2009): "Szenarien einer nationalen Glasfaserausbaustrategie in der Schweiz",

4. Determination of invest, cost and profitability for each cluster.
5. Determination of subsidies.

We analysed three FTTH architectures, namely Ethernet Point-to-Point (P2P), FTTH GPON and GPON over P2P. A brief description of these architectures is included in the assumptions section in the following chapter.

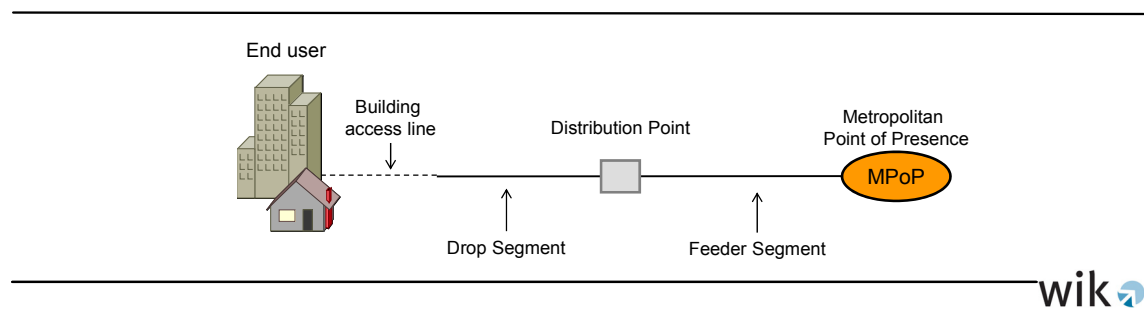
2 Key assumptions

2.1 Delineation of access areas, determination of street cabinet locations and trench lengths

MDF-locations of the German incumbent operator have been treated as scorched node. Delineation of access areas was conducted with a network optimisation tool that associated all 10 mn German street segments to the nearest MDF and determined access area polygons on top of the street layer. The algorithm was configured to respect distance criteria. Street cabinet locations were determined endogenously so they are not comparable to the real location and number of the cabinets in the German copper access network. Accordingly MDF locations are those of the German incumbent but MDF areas and street cabinet number and location have been determined in the model. All buildings / customers were connected to the network deploying trenches along the German road network. The optimisation tool determined the following key outputs for each of the MDF:

- Number of customers
- Number of customers per km²
- Number of buildings
- Number of street cabinets
- Trench length of the feeder (from MDF to street cabinet or distribution point), drop (from the street cabinet to the street in front of the building) and building access line segment (from the street in front of the building to the building entry point). See Figure 1 for a visualisation of the access network segment differentiation (see below for distinction between MDF and MPoP).
- Length of shared trenches between feeder and drop segments

Figure 1: Access network segments



All MDF with less than 2000 customer were reduced to passive nodes to reap scale benefits. A detailed analysis of the optimal number and location of MDFs has not been conducted. All remaining MDF become Metropolitan Points of Presence (MPoP) of the Next Generation Access (NGA) Network. The MPoP is the first point where active equipment lights the fibre towards the end user³.

The following table details the source of the geodata used in this study.

Table 1: Geodata sources

Data	Source	Comments
MDF locations	"BMW Breitbandatlas" (Broadband Atlas of the Federal Ministry of Economics and Technology)	8351 data sets with duplicate addresses generated 7731 unique MDF locations
Road network	TeleAtlas 2008/04	External procurement and processing of the national street layer
Buildings	Federal Agency for Cartography and Geodesy	About 22,5 mn building locations
Delineation of municipal and administrative areas	Federal Agency for Cartography and Geodesy	"VG250-EW (Kompakt)" administrative areas of Germany with number of inhabitants (as of 1.01.2009)
Households	Federal Statistical Office	40mn households
Buildings and dwellings	State Statistical Offices	Data from 12.000 municipalities
Enterprises	State Statistical Offices	Data from 38 administrative areas

2.2 Cluster aggregation

MPoPs were sorted by customer density in descending order. Then MPoPs were grouped in 20 Clusters by first aggregating 5% of all customers per cluster and readjusting for even customer density thresholds. Therefore, clusters roughly include 2,1mn customers or 5% of the total national customer base (about 43mn potential customers composed of about 40mn households and about 3mn business users).

³ Except for FTTC/VDSL.

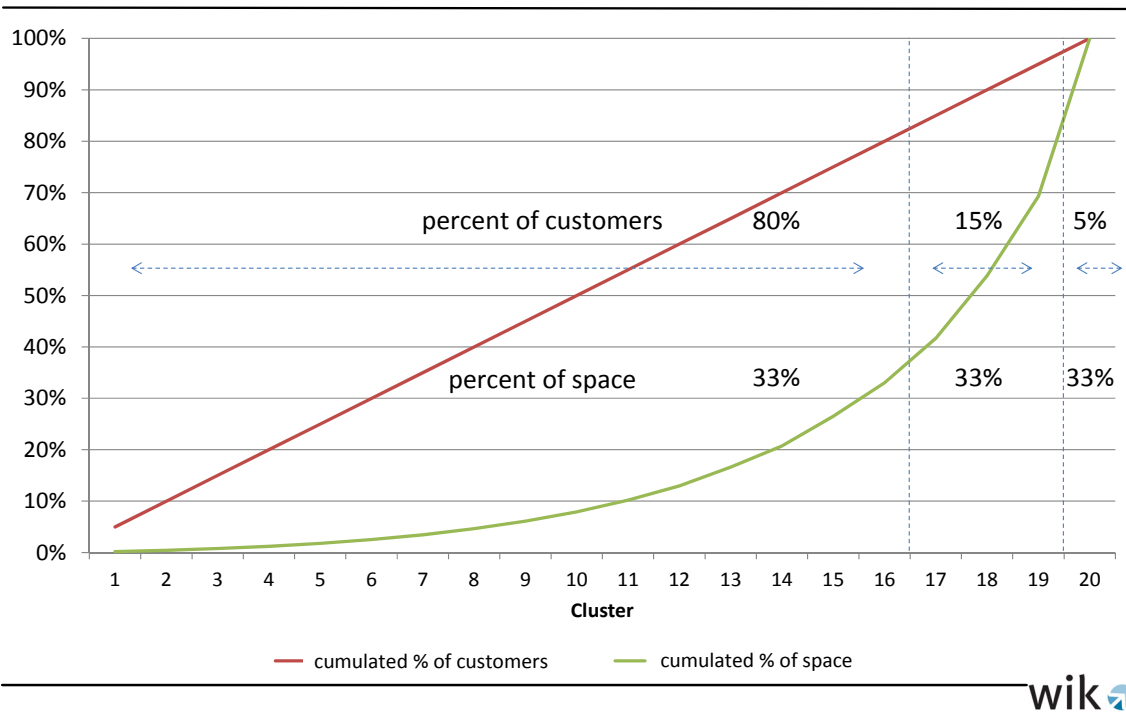
Absolute values were summed up over all MPOPs of a cluster (e.g. total number of MPOPs, street cabinets, customers, buildings, and trench meters). Relative values were determined as average for this cluster (e.g. customers per MPOP equals total customers divided by total number of MPOPs in a cluster).

Table 2: Cluster composition

Cluster ID	Potential customers	Share of customers	Cumulated share of customers	Minimum customer density (customers per km ²)	Area in km ²
1	2,209,338	5.1%	5%	2,750	620
2	2,167,961	5.0%	10%	1,950	950
3	2,131,407	4.9%	15%	1,500	1,248
4	2,142,703	5.0%	20%	1,200	1,603
5	2,158,128	5.0%	25%	952	2,045
6	2,165,555	5.0%	30%	740	2,636
7	2,168,541	5.0%	35%	575	3,323
8	2,211,345	5.1%	40%	455	4,400
9	2,112,800	4.9%	45%	360	5,209
10	2,074,980	4.8%	50%	290	6,487
11	2,124,501	4.9%	55%	235	8,189
12	2,114,832	4.9%	60%	190	10,016
13	2,252,308	5.2%	65%	155	13,133
14	2,051,986	4.7%	70%	125	14,824
15	2,317,848	5.4%	75%	100	20,874
16	2,086,509	4.8%	80%	80	23,569
17	2,185,291	5.0%	85%	62	31,214
18	2,305,738	5.3%	90%	46	43,780
19	2,144,569	5.0%	95%	32	55,792
20	2,153,552	5.0%	100%	1	110,641
Total	43,279,892				360,554

A comparison of the spatial distribution of customers reveals a strong concentration: The 80% densest customers (clusters 1-16) inhabit about 1/3 of Germany. The next three clusters 17-19 also account for 1/3 of the area and the last cluster alone accounts for another third.

Figure 2: Concentration of customers and space



The overall concentration of customers can also be noted from the relatively small patches of red and yellow MDF areas that symbolize high customer density compared to the dominant low density green on the map of Germany in Figure 3.

Figure 3: MDF area clustering in Germany⁴

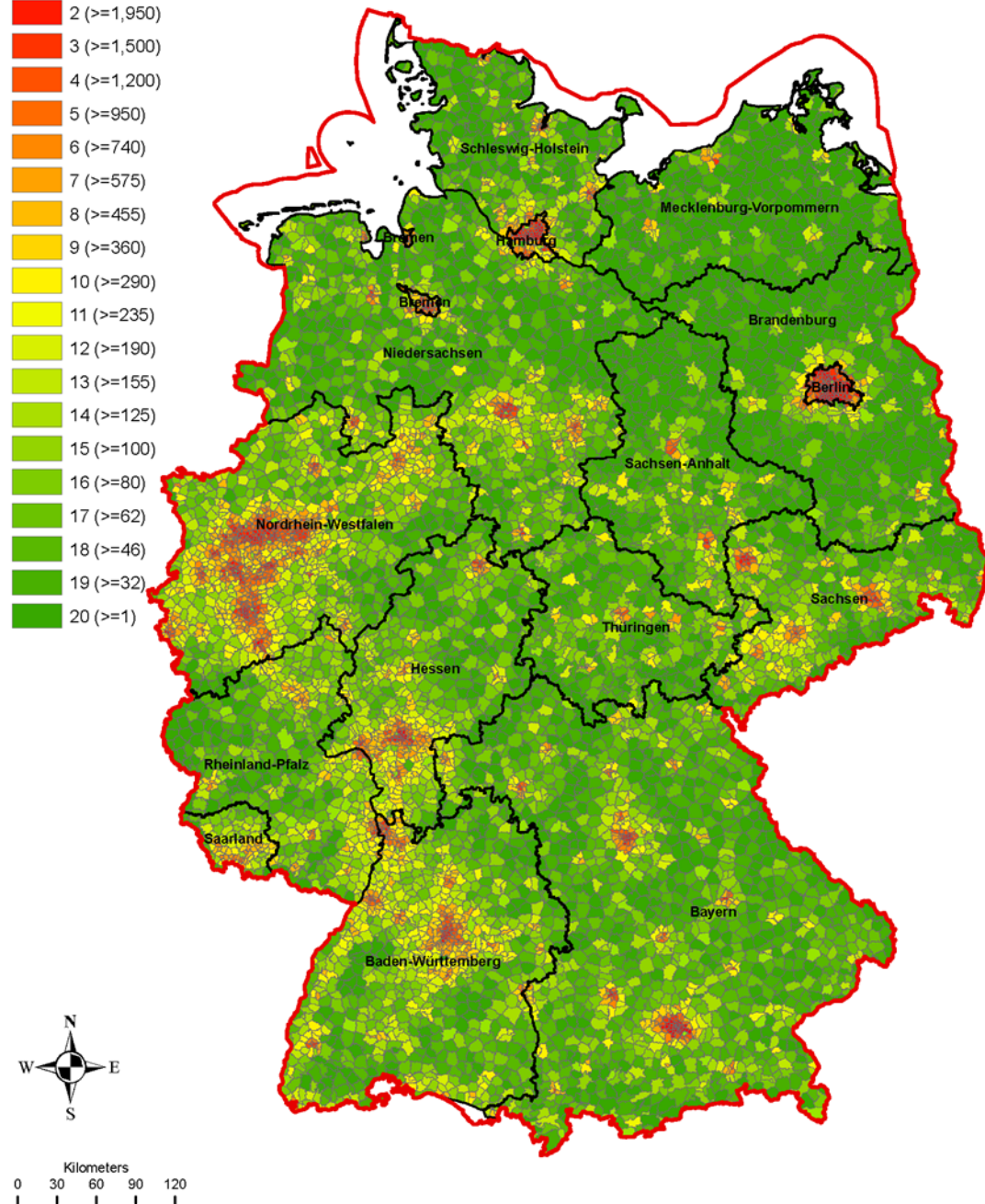
HVT Clustering Deutschland

 BRD Grenze

 Bundesland Grenze

Clustertyp (Teilnehmer pro km²)

-  1 ($\geq 2,750$)
-  2 ($\geq 1,950$)
-  3 ($\geq 1,500$)
-  4 ($\geq 1,200$)
-  5 (≥ 950)
-  6 (≥ 740)
-  7 (≥ 575)
-  8 (≥ 455)
-  9 (≥ 360)
-  10 (≥ 290)
-  11 (≥ 235)
-  12 (≥ 190)
-  13 (≥ 155)
-  14 (≥ 125)
-  15 (≥ 100)
-  16 (≥ 80)
-  17 (≥ 62)
-  18 (≥ 46)
-  19 (≥ 32)
-  20 (≥ 1)



⁴ HVT Clustering Deutschland = MDF clusters Germany
 BRD Grenze = Germany border, Bundesland Grenze = State border
 Clustertyp (Teilnehmer pro km²) = Cluster type (customers per km²)

2.3 Investment, cost and profitability determination

A bottom-up cost model for fibre based access networks was applied (the "WIK NGA model"). It determines investment of the access network components in detail while approximating the cost of concentration and core network through cost functions. We have assumed a green field fibre deployment rolling the network out as Fibre-to-the-Road for every building/customer (100% of homes are passed independent of assumptions on subscriber penetration). However, the building access line from the street in front of the building to the building entry point and the inhouse cabling are only deployed for active subscribers, i.e. the cost depends on the penetration rate.

The large majority of cables are deployed underground and all of these trenches are deployed ducted. We assumed a small part of aerial cabling (5% each in the last 5 clusters) for which lower investment but higher OPEX is required. The following tables show key parameters for invest, cost and other elements.

Table 3: Assumptions for key investment positions

Item	Investment per unit	Lifetime in years
Ethernet CPE	100€	5
GPON CPE	115€	5
ODF port	23€	35
OLT port	1000€	7
Ethernet port 1Gbps / 10Gbps	120S€ / 2000€	7
Total investment per meter for trench, duct and cable	120€ Cluster 1 ... 40€ Cluster 20	35

The model converts investment⁵ into monthly cost (CAPEX) by taking account of asset lifetime and Weighted Average Cost of Capital (WACC). Accordingly, the cost determined includes the risk-adjusted weighed average cost of capital. Profits are therefore profits that exceed the return on interest of capital.

Operating Cost (OPEX) is primarily determined through mark-ups on investment. Some positions such as floorspace rental and MPoP energy costs are also calculated bottom-up as direct cost. Common Cost is also considered as mark-up on CAPEX and OPEX. In addition to the access network we accounted for investment into an IPTV platform and retail costs for customer acquisition, marketing, billing etc.

The model assumes a steady state in the future where the existing copper network has been completely substituted by the new fibre network. This is a long-term view towards market structure and does neither incorporate additional cost of parallel operation of fibre and copper networks nor the cost of migration. The latter also includes the cost of running the network at low penetration rates, i.e. at high costs per user, initially. It

⁵ In addition to the direct investment determined bottom-up, indirect investments for assets such as buildings, vehicle fleet, workshops etc. is calculated as mark-up on direct investment.

should be noted that the cost of migration are likely significant and as such would reduce the profitability deduced in this paper. On the other hand, having a large customer base that can be migrated is probably a very important asset when it comes to quickly realising high penetration rates.

Table 4: Assumptions on direct costs and other parameters

Parameter	Assumption
Concentration network cost per month	22,5 Mio € + 0,7€ per subscriber
Core network cost per month	6 Mio € + 1,08€ per subscriber
Retail Cost (customer care, billing, sales & marketing, customer acquisition) per month	5€ per subscriber
WACC	10%
OPEX mark-up on investment	8% for active and 0,5% for passive equipment
Indirect investment mark-up on investment	0,5%-3%
Common cost mark-up on CAPEX and OPEX	10%

When checking for profitability the monthly Average Revenue per User (ARPU) is compared with the monthly cost per user. The maximum take-up of the NGA is assumed to be lower than 100% of passed homes since a share of all potential customers for which the network is deployed will select cable or mobile-only services (or not use telecommunication services at all). Today the fixed network penetration in Germany is about 80 %. In this analysis a maximum penetration of the fibre access network or the market share of the fixed network (without cable networks!) within a given cluster is assumed to be 70 %.

2.4 Considered NGA architectures

Three FTTH architectures were considered in our calculations. Their main characteristics are shown in Table 5.

Table 5: Modelled NGA architectures

Abbreviation	Passive network topology	Active technology that lights fibres in the MPoP	Comments
FTTH/P2P	Point-to-Point	Ethernet	One fibre for every customer between the customer and the MPoP.
FTTH/PON	Point-to-Multipoint	GPON	Decentral splitters between MPoP and customer. Individual fibres for every customer in the drop segment, shared fibres in the feeder segment.
GPON over P2P	Point-to-Point	GPON	Individual fibres for every customer between the customer and the MPoP. Fibres lead to splitters located centrally at the MPoP (also see Figure 4).

The combination of a Point-to-Point topology with GPON active technology in the MPoP is also visualised in Figure 4. The advantage of this architecture is that it has a high degree of flexibility regarding customer bandwidth management. By adjusting the splitting ratio right down to 1:1 customers can be provided with different levels of (guaranteed) bandwidth and GPON active electronics can always be run on high levels of efficiency independent of the actual penetration. In addition this retains the option of unbundling individual customers at the MPoP location. A more detailed description of FTTH architectures can for example be found in Hoernig / Jay / Neumann et al. (2010).

Figure 4: GPON over P2P

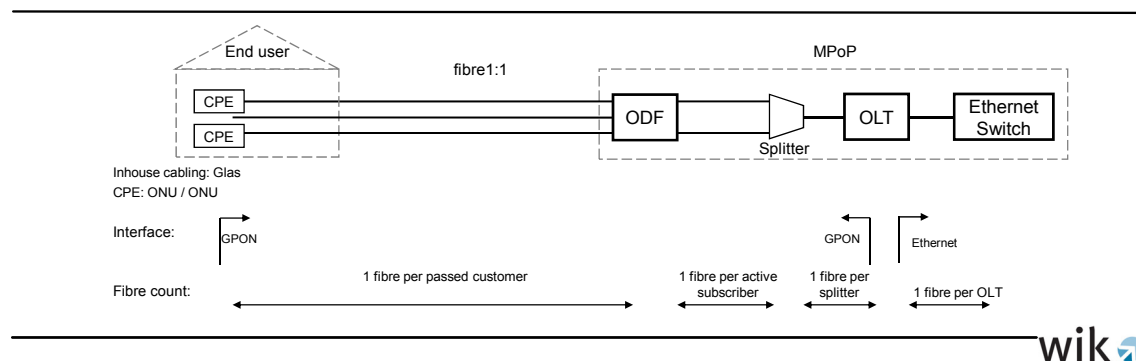


Table 6 provides an overview of considered network segments and elements of the access network between MPoP and customer. With few exceptions (energy, floorspace rental) these positions are direct investments.

Table 6: Overview of considered network segments and elements of the access network

	FTTH/GPON	FTTH/P2P Ethernet	FTTH/GPON over P2P
Customer modem	X	X	X
Fibre inhouse cabling	(X)	(X)	(X)
FTTB- Mini DSLAM in the basement			
Fibre deployment in the drop segment	X	X	X
Distribution Point	Splitter		
Fibre deployment in the feeder segment	X	X	X
MPoP: ODF, active technology, floorspace, energy	X	X	X

X – considered; (X) for FTTH a scenario with and without the inhouse cabling is set up

For every FTTH architecture scenarios with and without inhouse cabling cost were calculated since it is a still debated issue who will bear these costs.

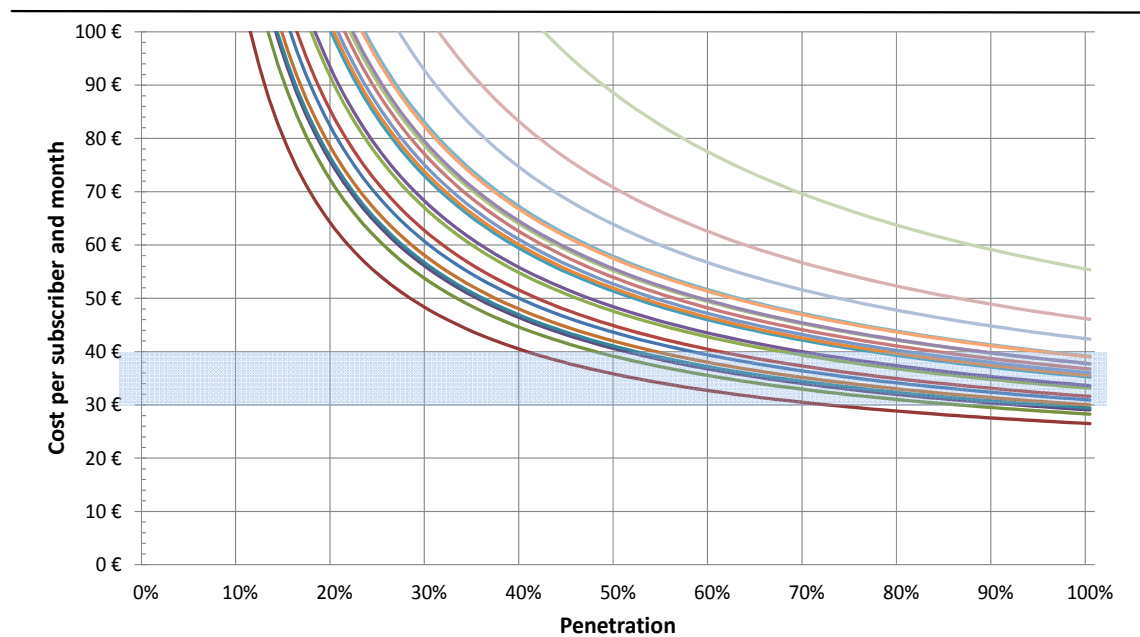
3 Investment, cost and limits of profitability

In this chapter investment, cost and profitability of rolling out NGA to all of Germany through 20 clusters is determined. The analysis is conducted in detail for one architecture (FTTH/P2P w/o considering the cost of inhouse cabling) but results for all scenarios are shown.

3.1 Impact of penetration on cost per customer

The total monthly cost per subscriber is strongly dependent on the take-up rate because of the high degree of fixed cost in the access network. This is shown clearly in Figure 5 in which every line represents one cluster with cluster 1 (most dense) being bottom left and cluster 20 (least dense) top right. The cost shown here is the total cost including the passive access network, the active equipment, concentration and core network cost, marketing, customer support etc.

Figure 5: Monthly total cost per subscriber (example FTTH/P2P w/o considering the cost of inhouse cabling)



The level of current averaged revenues in Germany is estimated to lie between 30 € and 40 € which has been visually highlighted in Figure 5. This allows two different analyses: First, one can fix an ARPU level and analyse the necessary penetration required to operate profitably, i.e. with lower cost than revenues per user. Second, one can fix a penetration level and determine the necessary ARPU that allows profitability at this penetration.

Considering for example the 40 € mark as ARPU Figure 5 shows that Cluster 1 needs at least 40 % penetration, cluster 2 a little bit less than 50 % and so on. Notably,

clusters 18-20 always have a cost per user that is above 40 € per month. At 30 € per month only some of the densest cluster ever break even.

At penetration rates below 40 % revenues would need to be very high to sustain profitable operation. Considering the maximum penetration of 70 % for the NGA suggested by the authors, prices of many clusters lie above the perceived 30 € - 40 € range.

3.2 Investment and profitability

For the following results penetration was fixed at 70 %. With the penetration set at this level the total investment to deploy and operate a nationwide fibre access network is in the range of 70 – 80 bn €. Splitting the total investment volume in three one can deduct from Figure 6 that the first nine clusters require only 33 % of investments but contribute 45 % of customers. Conversely the last 5 clusters also require 33% of total investments but contribute only 25 % of customers. As expected less dense clusters contribute relatively more to the overall investment volume.

Figure 6: Concentration of investment and customers

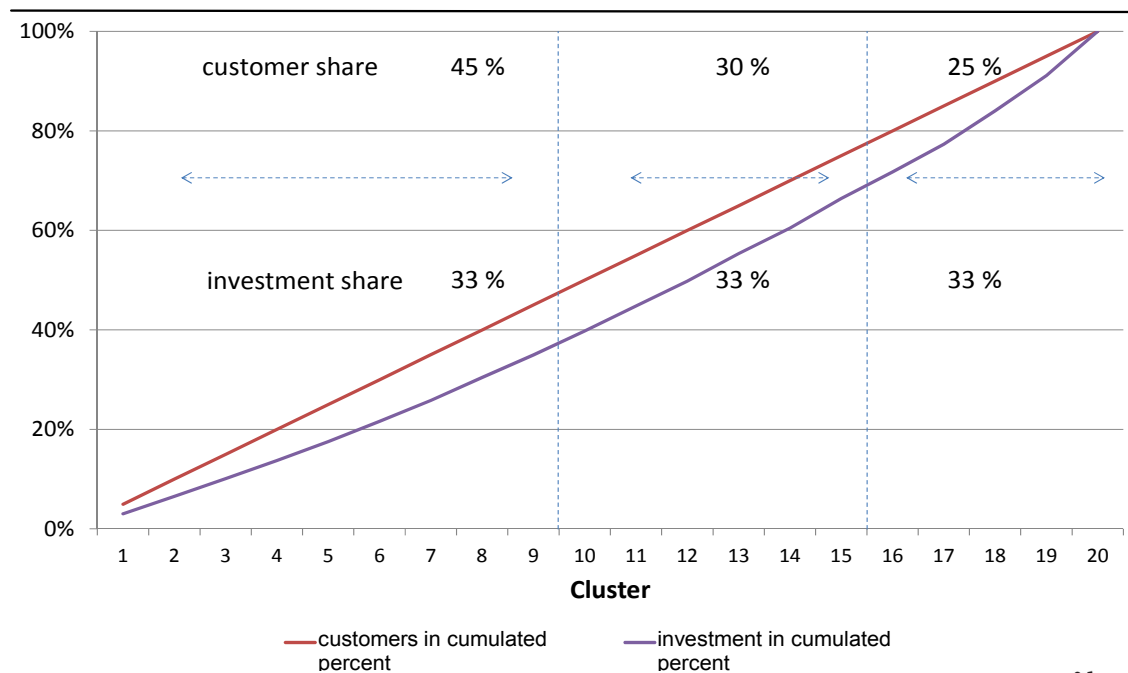
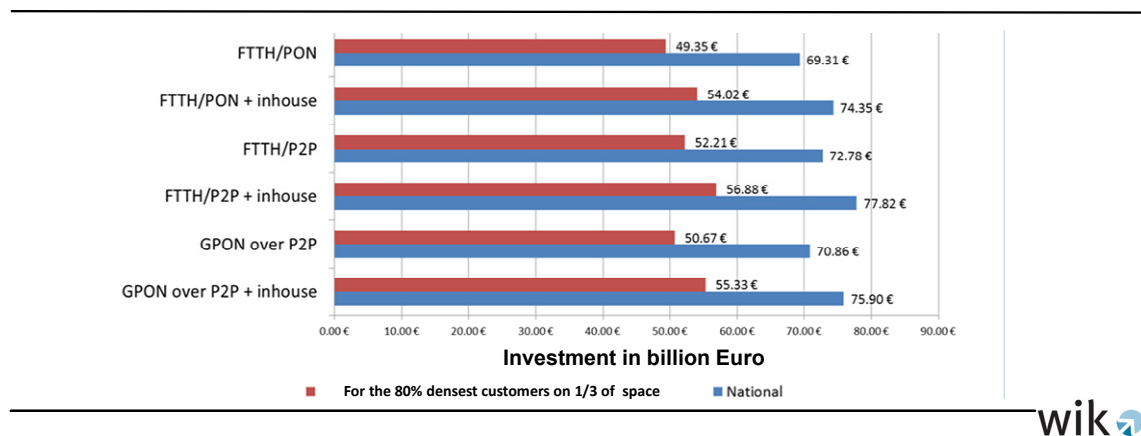


Figure 7 shows the total investments for all architectures at 70 % penetration. It also shows that if one only covered clusters 1-15 (the 80 % densest customers that make up only 1/3 of Germany's space) the investment reduction is about 30 %.

Figure 7: Total investment in bn € at 70 % penetration for covering all clusters or only clusters 1-16



Comparing investments per customer, these range from about 1.300 € in dense areas to 4.800 € in less dense areas. It is shown for all architectures in Figure 8. Since the overall investment totals are relatively similar between architectures so are the investments per customer.

Figure 8: Investment per customer at 70 % penetration (cluster 1-20)

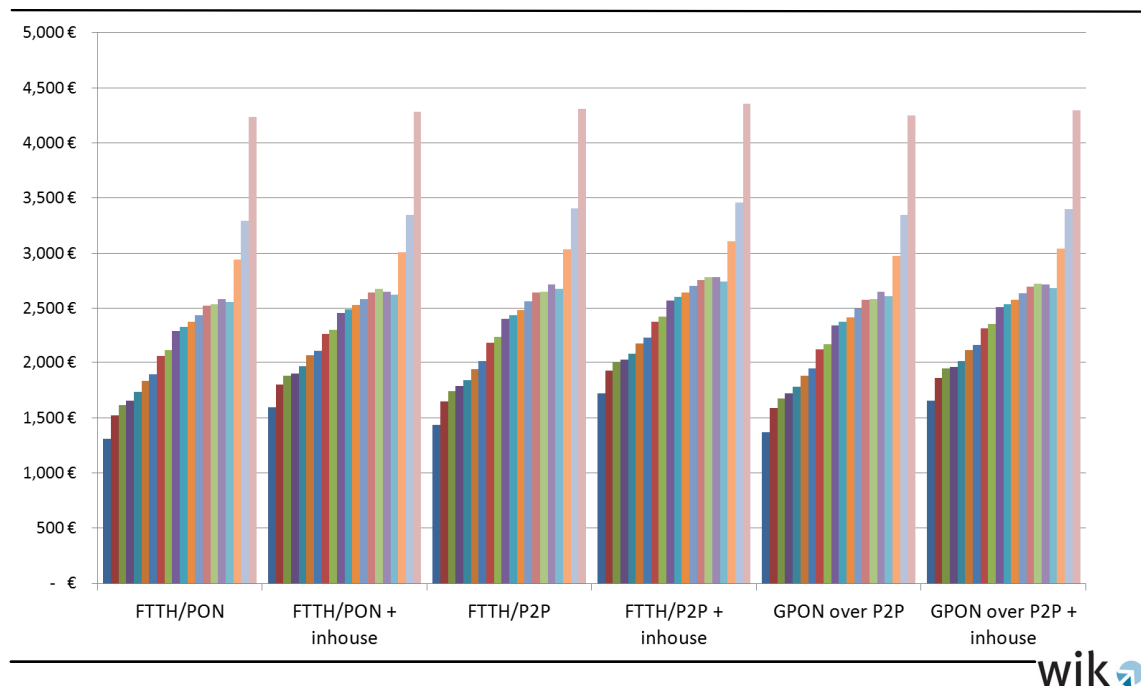


Table 7 holds those investment components that together account for 97% - 99% of total investments. It is immediately evident that the passive network from the ODF-port at the MPoP to the sleeve at the street in front of the building accounts for by far the largest share of total investments (at least 2/3). The building access accounts for about 15 % and inhouse cabling (where applicable) for about 7% of total investments.

Together the passive network detailed here (FTTR, building access, inhouse cabling) accounts for roughly 80 % - 90 % of total investments.

There are relatively small differences in investment, considering e.g. P2P and GPON the difference for a nationwide roll-out and operation at 70 % penetration in Germany is only 5 %. The reason is that most items of the dominant investment positions are identical for all architectures in a greenfield deployment. Inhouse cabling, building access and the drop segment between the building's street and the distribution point are identical for all FTTH networks. The differences between point-to-point and point-to-multipoint topologies lie in the distribution point, the feeder segment and the ODF at the MPoP which are all part of the line FTTR in Table 7. The splitter at the distribution point is only required for the PON case. In the feeder segment PON requires fewer fibres. However, in most cases this does not lead to smaller trenches so civil works cost remains comparable in a greenfield deployment.

Table 7: Key investment components for nationwide rollout in 20 clusters at 70 % penetration

	PON	PON + inhouse	P2P	P2P + inhouse	GPON over P2P	GPON over P2P + inhouse
Total invest (bn €)	69.31 €	74.35 €	72.78 €	77.82 €	70.86 €	75.90 €
<i>FTTR</i>	76 % 52.95 €	71 % 52.95 €	73 % 52.78 €	68 % 52.78 €	74 % 52.78 €	70 % 52.78 €
Building access line	16 % 11.18 €	15 % 11.18 €	15 % 11.18 €	14 % 11.18 €	16 % 11.18 €	15 % 11.18 €
Inhouse cabling		7 % 5.04 €		6 % 5.04 €		7 % 5.04 €
CPE	5 % 3.81 €	5 % 3.81 €	5 % 3.31 €	4 % 3.31 €	5 % 3.81 €	5 % 3.81 €
Active equipment at MPoP	2 % 1.12 €	2 % 1.12 €	5 % 3.99 €	5 % 3.99 €	1 % 0.68 €	1 % 0.68 €
Rest*	0 % 0.26 €	0 % 0.26 €	2 % 1.52 €	2 % 1.52 €	3 % 2.41 €	3 % 2.41 €

* network sided ODF ports, space for active equipment at the MPoP, central splitter for GPON over P2P, IPTV platform.

In a brownfield environment where existing ducts can be used the situation is a little different. The most favourable case would be the free access to ducts.⁶ In this case one can consider the different probability that ducts exist in a desired location and that they have enough free space and sufficient remaining asset lifetime to host the fibre cables of the FTTH network. This probability will be the same for all architectures in the drop segment but differ between Point-to-Point and Point-to-Multipoint topologies in the feeder segment due to the difference in fibre count. In this study it was assumed that the degree of ducted cabling of the German copper infrastructure (which is assumed to be the basis of potential existing ducts) depends on the cluster and that in less dense clusters the degree of ducted copper cabling is very low. This leads to brownfield results

⁶ If duct access was priced at cost access charges would probably be at a similar level of deploying new ducts.

that do not change the profitable reach very much but only make the business case more attractive in those dense clusters that are profitable anyway. Total investments of PON are reduced by about 3 % when considering all clusters (2 % for P2P). When considering only the first ten clusters the investment reduction for PON is about 7 % (5 % for P2P).

Expectations about the willingness to pay of end users are another critical pillar of the profitability analysis. So far analysis was conducted in a band between 30 € and 40 € were German revenues would likely be.⁷ For the following calculations a mix of single, double, triple play and business customers was chosen that leads to an ARPU of 38€ per subscriber and month. For the German market this is probably at the upper end of achievable revenues. The intersection of cost curve and ARPU leads to the minimum penetration required for profitability. These critical penetration rates are shown for all architectures in Table 8. If the critical penetration rate is higher than 70 % the relevant cell in the table was highlighted in red. Similarly one may consider a different maximum penetration rate such as 60 % and check the critical penetration rates cluster by cluster to determine the limits of profitability likewise, e.g. at 60 % maximum achievable penetration P2P only reaches 5 clusters.

Table 8: Critical penetration rate at 38 € ARPU

Cluster	Cumulate share of customers	FTTH/PON	FTTH/PON + inhouse	FTTH/P2P	FTTH/P2P + inhouse	GPON over P2P	GPON over P2P + inhouse
1	5 %	40 %	47 %	45 %	54 %	40 %	48 %
2	10 %	47 %	55 %	53 %	63 %	48 %	56 %
3	15 %	50 %	58 %	56 %	67 %	51 %	59 %
4	20 %	51 %	58 %	58 %	67 %	52 %	60 %
5	25 %	54 %	61 %	60 %	70 %	54 %	62 %
6	30 %	57 %	65 %	64 %	75 %	58 %	66 %
7	35 %	59 %	67 %	68 %	78 %	61 %	69 %
8	40 %	66 %	73 %	75 %	86 %	67 %	76 %
9	45 %	68 %	75 %	77 %	88 %	69 %	78 %
10	50 %	75 %	82 %	86 %	96 %	77 %	85 %
11	55 %	76 %	83 %	87 %	97 %	78 %	86 %
12	60 %	78 %	86 %	90 %	100 %	80 %	88 %
13	65 %	81 %	87 %	93 %		83 %	91 %
14	70 %	85 %	91 %	99 %		88 %	95 %
15	75 %	86 %	93 %	99 %		88 %	96 %
16	80 %	91 %	94 %			95 %	99 %
17	85 %	91 %	94 %			95 %	99 %
18	90 %						
19	95 %						
20	100 %						

Comparing P2P and GPON, GPON has lower critical penetration rates than P2P (or any other architecture) in every cluster because it is the cheapest technology. Assuming the 70 % threshold its profitable reach is 9 clusters of Germany which represents 45 %

⁷ Confirmed by a survey of German retail prices in August 2011.

of all customers. P2P only reaches 7 clusters (35 % of customers). Interesting to note is that GPON over P2P has very similar requirements regarding the critical penetration rate as GPON. When comparing the total investments of GPON and GPON over P2P in Table 8 the investment requirements are also very similar (2 % difference). Considering that the latter architecture is much more flexible regarding future bandwidth requirements and in addition enables unbundled access to fibre at the MPoP this appears to be a strong argument in favour of such a hybrid concept.

A sensitivity was conducted for P2P that includes cost increases for CPE (+25 %) as well as house access line investment (+33 %) and assumes that all deployment is underground (in the base case there was a small share of overhead cabling in the last five clusters). This increases the cost by about 2 € per customer and month. Compared to the results in Table 8 the critical penetration rates increase by 3 – 10 %-points depending on the cluster. This reduces the profitable reach from 7 to 6 clusters considering a threshold of 70 % maximum take-up. At a threshold of 60 % maximum take-up the profitable reach decreases from 5 to 2 clusters.

Results show that NGA deployment in Germany can only be profitably realized for less than half of all customers. Depending on whether the inhouse cabling is also considered in the cost for the investor this decreases to about 25 % of the densest customers.

The primary key issue for profitability is the penetration rate. Network operators must realise high penetration rates. In order to e.g. produce at total cost below 40 € per customer and month the penetration even in most dense areas has to be higher than 50 % (see Figure 5).

Especially the passive access network is characterized by high fixed cost that is driven purely by coverage requirements and not by the number of actual subscribers (usually more than 70-80 % of total cost is related to the passive access network). In the greenfield investment situation assumed here the cost difference between architectures is therefore relatively small.

All results shown here are based on the assumption that the investor passes all customers with the network in any given cluster. However, an investor could also select his roll-out area on the basis of street segments with a preference among other factors for multi-dwelling units with a high willingness to pay. Such an investor who "cherry picks" areas and therefore does not pass 100 % of the customers in a cluster will produce at significantly lower cost per customer. He will therefore also be able to operate profitably at lower critical penetration rates and might be able to extend the limits of profitability to less dense clusters, too.

Still the assumption of full coverage reflects requirements of the market. At least in denser clusters operators will have to strive for copper network substitution in the long run in order to reduce the cost of parallel network operation and to be able to apply marketing as homogeneously as possible. Furthermore, the primary goal of public broadband strategies is the area-wide rather than the spotted availability of broadband access.

4 Measures for increasing the profitable coverage

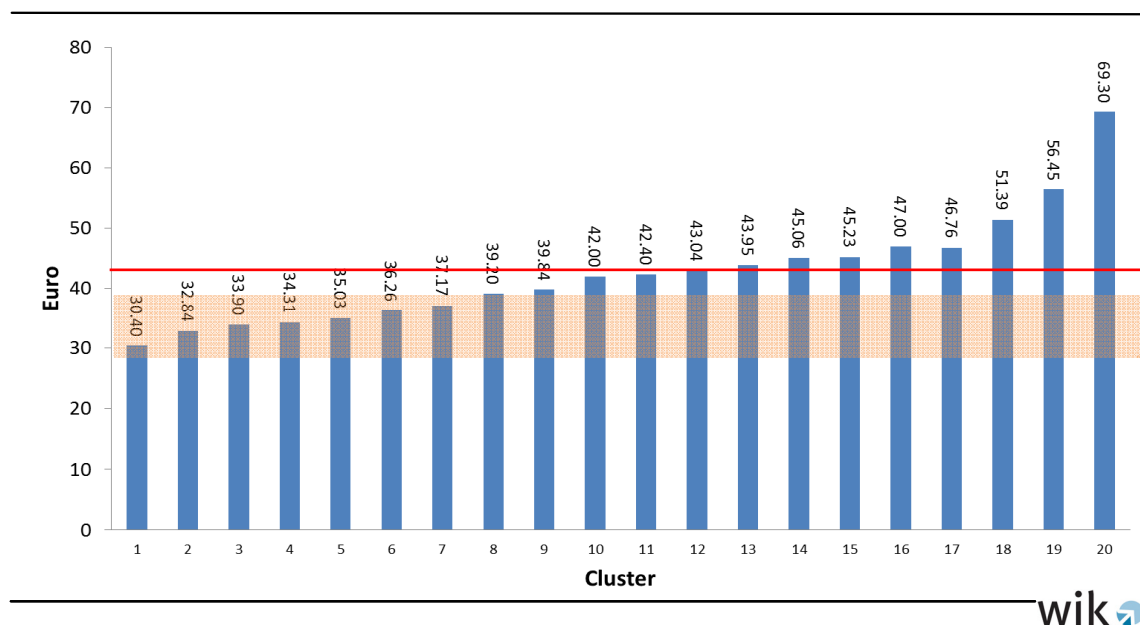
In order to increase the profitable coverage of Germany with fibre access networks three options are addressed here. 1) End users can pay a higher monthly price. 2) The operators can use profits from profitable areas to subsidise the fibre roll-out in non-profitable areas. 3) The network investment could be subsidised (externally) to the point where the network can be operated profitably by the operator. Such subsidisation could e.g. be one-time connection fees from end-users or subsidised funds from the state.

Calculation is shown in detail exemplarily for FTTH/P2P without cost of inhouse cabling first but results for all architectures are given.

4.1 Prices

The basis for identifying the price level required for profitability is the cost per customer and month in the 20 clusters. If prices were set regionally differentiated they would lie between 30 € and 70 € per customer and month at 70 % penetration. If prices would be set at that individual cluster-specific value there could be nationwide coverage of a fibre network. If a single national price was to be set based on average cost of all customers this price would have to be about 43 € per customer and month (horizontal red line in Figure 9).

Figure 9: Cost per customer and month at 70 % penetration: FTTH/P2P w/o cost of inhouse cabling

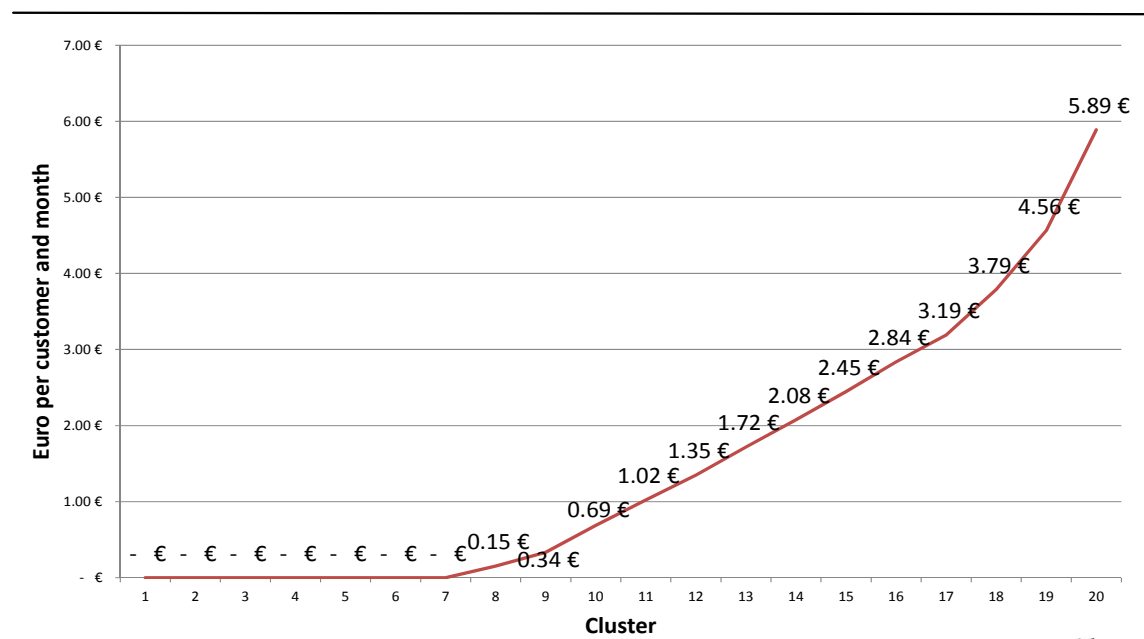


Again Figure 9 highlights the area of 30 – 40 € as likely ARPU range. At 40 € ARPU monthly prices need to be subsidised by 2 € (cluster 10) to 29 € (cluster 20). At 30 € ARPU no cluster remains profitable.

With an ARPU of 38 € the total loss in non-profitable clusters (clusters 8-20) is divided by all subscribers to identify the premium all customers would have to pay to support the non-profitable clusters while leaving profits in profitable areas to the operator. This leads to a premium of about 6 € which increases the end-user price to about 44 € per customer and month at 70 % penetration.

Figure 10 analyses this issue on a cumulative basis and states the price increase from 38 € that is required to allow profitable operation in clusters 1 to the considered cluster. Since clusters 1 to 7 are profitable on their own the curve starts with cluster 8. The value at cluster 11 shows that in order to support the loss making clusters 8 to 11 all subscribers in clusters 1 to 11 have to pay about 1 € per month in addition to the base ARPU of 38 €. The curve shows a relatively sharp increase in required subsidy in the last 3 clusters reflecting the relative weight of these clusters in terms of cost. About 6 € from all subscribers are additionally required to enable profitable operation in all clusters

Figure 10: Monthly premium for all customers at successive roll-out to the considered cluster: FTTH/P2P w/o costs of inhouse cabling at 70 % penetration and 38 € ARPU.

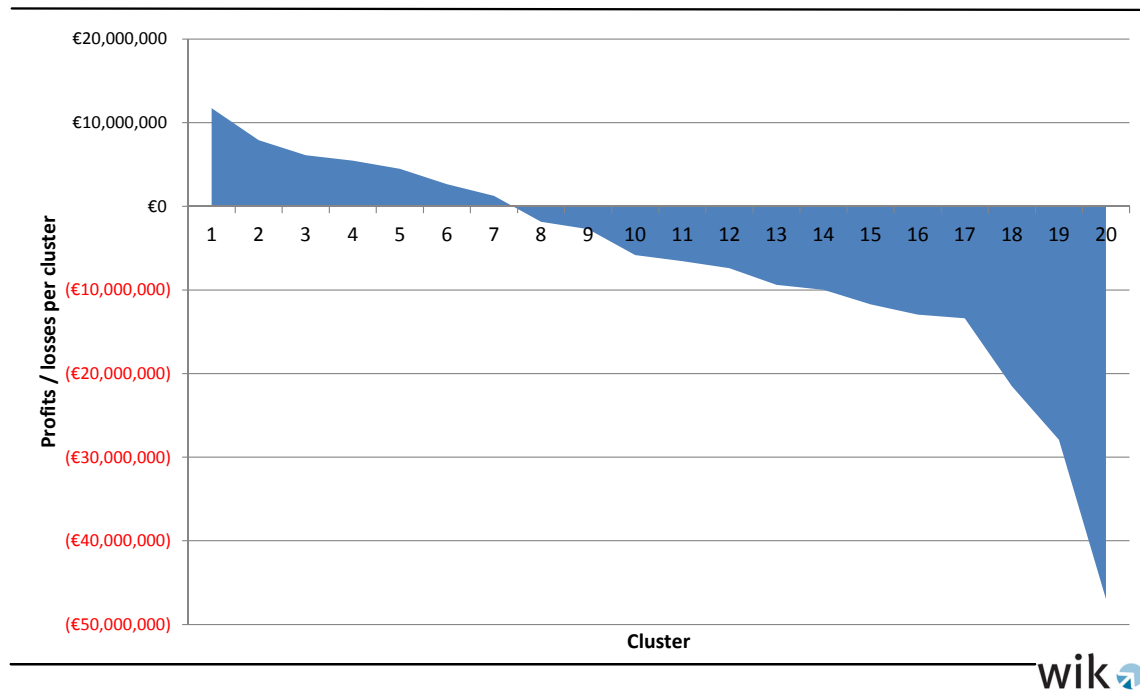


4.2 Internal subsidy between profitable and non-profitable clusters

So far the investment decision was based on profit maximising investors. Such an investor will maximise his profits by deploying the network as long as a profitable return (in this calculation in excess of return on capital) is achievable. Figure 11 shows the profits and losses per cluster where Cluster 7 still shows a slight profit while cluster 8 is the first loss making cluster. Accordingly, the profit maximising investor would invest only in clusters 1-7.

Now, it is hypothetically assumed that operators would be willing to use profits in excess of return on capital to subsidise clusters that are non-profitable. This assumes a welfare-maximisation goal in the sense that higher coverage with fibre access is welfare enhancing. Clearly the sum of all profits is smaller than the sum of all losses across all clusters. If one used all the profits from clusters 1 to 7 the profitable reach could be extended to cluster 13 and losses in cluster 14 could be reduced by about half. The situation in clusters 15 to 20 would not change.

Figure 11: Profits and losses per cluster and month: FTTH/P2P w/o cost of inhouse cabling, 38 € ARPU and 70 % penetration



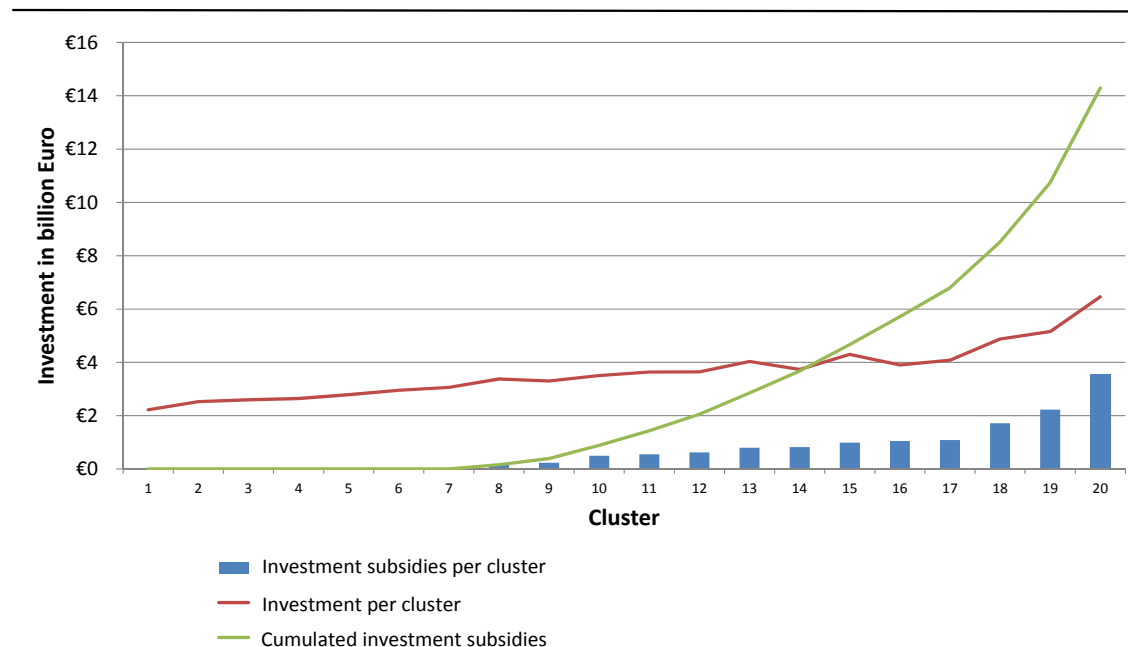
4.3 One-time investment subsidy

To increase the profitable reach of fibre access networks in Germany investment subsidies are conceivable, e.g. in the form of investment sharing with the building owner. The total investment per customer for FTTH/P2P without considering the cost of inhouse cabling ranges from about 1.500 € in cluster 1 to about 4.300 € in cluster 20. In clusters 8 to 13 moderate investment subsidies of up to 500 € per fibre access line would be sufficient to make the case for the investor profitable. In the last cluster, however, subsidies would need to be in the range of 2.300 € per customer.

Figure 12 shows total investment per cluster (red line), the required subsidies per cluster (blue columns) and the cumulated subsidies (green line) at 70 % penetration and 38 €. The line of cumulated subsidies shows e.g. at cluster 15 that the investor needs around 5 bn € from other sources to make the investment in clusters 1- to 15 profitable. In the same way the value for cluster 20 shows that a national roll-out would require about 14 bn € subsidies to make all clusters profitable at 70 % penetration and

38 € ARPU. The figure also reveals that the last three clusters account for over half of all required subsidies.

Figure 12: Total investment and required subsidy per cluster as well as cumulated subsidies in bn €: FTTH/P2P w/o inhouse cabling at 70 % penetration and 38 € ARPU



4.4 Sensitivity with increased cost and reduced penetration

For the alternative case with increased cost described in chapter 3.2 (CPE +25 %, house access line +33 %, no overhead deployment) an additional sensitivity was conducted with a decrease of the penetration rate from 70 % to 60 % and in addition a decrease of the ARPU from 38 € to 35 €.

Under this scenario all customers would have to pay 48 € per month (an increase of 13 €) in order to enable a profitable reach of FTTH/P2P nationwide. This compares with 44 € and a 6 € increase in the base case. Under regional price differentiation cost orientated prices would range from about 34 € (cluster 1) to 80 € (cluster 20). This compares with a range of 30 € (cluster 1) to 70 € (cluster 20) in the base case. With these assumption the total subsidy volume based on one-time investment subsidies nearly doubles from 14 bn € to 27 bn €.

4.5 Summary of all architectures

So far only results for FTTH/P2P without considering the cost of inhouse cabling were shown. Table 9 shows the high level results for all architectures. First the number of profitable clusters is shown. Then, the total loss accumulated in all non-profitable clusters is shown for the base case scenario with 38 € ARPU. Based on this loss the

uniform price is given and the broadband premium to be paid on top of the 38 € by all NGA customers. The fifth row shows that the investment subsidy required for profitable national coverage at 70 % ranges from about 11 bn € to 17 bn € depending on the architecture considered. In case of investment subsidy, the table also shows monthly operational cost that need to be subsidised as well.

Table 9: Overview of key results for all architectures (base case): PON and P2P at 70 % penetration with baseline ARPU of 38 €

	FTTH/PON	FTTH/PON + inhouse	FTTH/P2P	FTTH/P2P + inhouse	GPON over P2P	GPON over P2P + inhouse
Number of profitable clusters	9	7	7	5	9	7
Total loss per month in non-profitable clusters (bn €)	0.13 € (bn)	0.15 € (bn)	0.18 € (bn)	0.21 € (bn)	0.14 € (bn)	0.16 € (bn)
Necessary uniform price per month for profitable national coverage	42.29 €	43.11 €	43.89 €	44.98 €	42.56 €	43.44 €
Monthly broadband premium paid by all NGA customers to achieve profitable national coverage	4.29 €	5.11 €	5.89 €	6.98 €	4.56 €	5.44 €
Required investment subsidy for profitable national coverage (bn €)	10.54 € (bn)	12.49 € (bn)	14.21 € (bn)	16.89 € (bn)	11.15 € (bn)	13.32 € (bn)
Necessary monthly operating cost subsidy for profitable national coverage (bn €)	0.02 € (bn)	0.02 € (bn)	0.02 € (bn)	0.03 € (bn)	0.02 € (bn)	0.02 € (bn)

5 Conclusions

The coverage of all German customers with FTTH and the operation of the network at 70 % penetration requires greenfield investments in the range of 70 to 80 bn €. The differences in investment between the architectures are relatively small in the range of a few per cent. The reason is that most investments into the passive access network that make up 80-90 % of total investments are identical for the considered architectures (inhouse cabling, house access line, drop cable segment). Even in the feeder segment between distribution point and MPoP GPON only has limited cost savings in a greenfield environment because civil works have to be conducted anyway and do not scale much with the observed fibre count.

Sensitivities show that even with free access to ducts the profitable reach cannot be significantly extended because especially the rural areas of Germany are assumed to have limited ducted copper infrastructure in the first place. With (free) access to other infrastructures (e.g. other telecom networks, electricity, gas, etc.) the potentials of brownfield could be increased though. Here, initiatives such as infrastructure registers could aid in identifying potentials and increasing the profitable reach.

However, nationwide coverage with fibre is not economically possible without a form of subsidy since results have shown that the limits of profitability are about 20 to 45 % of the densest German customers. The profitability of fibre access is critically dependent on the penetration. Investors must realize high penetration rates for ubiquitous deployments (all homes in a cluster are passed) such as assumed in this study. In this case penetrations rates have to be above 40 % and often above 60 % even in the more dense areas. On the other hand, investors that do not roll out the network to all customers of a given cluster but only focus on e.g. 80 % of all potential customers will very likely be able to save (much) more than 20 % of the cost of deploying the network to all customers. This is because in practice it becomes increasingly expensive to pass more customers. An investor who "cherry-picks" on a street segment base should therefore be able to produce at lower cost, require lower critical penetration rates and potentially extend reach to other clusters. In this study however, the fibre network is rolled out to the road in front of the customer buildings for all customers, so there is no "cherry-picking". This approach was necessary for the goal of this study even though it does not reflect the initial deployment phase of a real life investor. It is still valid though for analysing the long-term competitive situation of the fibre access network.

Two aspects follow from the finding that penetration rate is so critical: First, wholesale business is important to increase the load of the network (quickly). Second, it appears next to impossible to realize ubiquitous coverage at the required high penetration levels in a parallel operation of the old copper and the new fibre network. In the long-run the substitution of the old copper infrastructure is therefore a key requirement for the fibre investor. However, in reality opportunity cost, cannibalization of copper profits, reduce the incentives for going into fibre.⁸

But even at the high end of penetration rates (70 % was assumed to be the maximum achievable penetration level for the new fixed network excluding cable and LTE) the cost is too high to be profitable at current price levels. Accordingly, users would have to pay a higher price in order to bring broadband to less denser areas of Germany. In the last cluster customers would have to pay an average price of 70 – 80 € per month. Alternatively, users could participate in the investment to connect their home. Depending on the degree of losses occurred in a non-profitable cluster this would range between a few hundred € and over 2,000€ in the last cluster. The total volume of such one-time investment subsidy is between 11 and 17 bn €.

In most of the detailed results shown the cost of the inhouse cabling was allocated to the sphere of the building owner. If the investor has to bear it himself this will increase the total investments by at least 5 bn €. This value is probably conservatively low since the deployment not only includes the technical realisation that was considered here but also the legal and administrative cost of preparing the deployment. This was not considered in this calculation and would reduce the profitable reach of fibre access. In all scenarios the investor fully paid the building access line. If building owners were to bear this cost the investor would be relieved of a volume of around 11 bn € so this could

⁸ See Hoernig, S. / Jay, S. / Neu, W. / Neumann, K.-H. / Plückebaum, T. / Vogelsang, I. (2011)

potentially be an important starting point for sharing the investment as it is already common practice in new building areas.

To realize nationwide coverage with fibre access regionally differentiated prices and investment subsidies were discussed. Finally, all NGA customers could also pay the same price including a broadband premium that is sufficient to cover the losses incurred in the non-profitable clusters. The level of such a premium critically depends on the penetration and the base line ARPU because they define the level of profitability throughout all clusters. In the base case with 70 % penetration and 38 € ARPU an additional fee of 1 € extends profitability of P2P from 35 % to 55 %, 2 € reaches 65 % and 3 € reaches 80 % of customers. To equalize losses in the last three clusters this would have to be 6 €.

6 Bibliography

- Doose, A. / Elixmann, D. / Jay, S. (2009): "Breitband/Bandbreite für alle": Kosten und Finanzierung einer nationalen Infrastruktur; WIK Diskussionsbeitrag Nr. 330; Bad Honnef. URL:
[http://wik.org/index.php?id=diskussionsbeitraege&details&tx_ttnews\[cat\]=4&tx_ttnews\[year\]=2009&tx_ttnews\[tt_news\]=1091&tx_ttnews\[backPid\]=93&cHash=b0e78ad18bdb75ea17b2aad1cef80cec](http://wik.org/index.php?id=diskussionsbeitraege&details&tx_ttnews[cat]=4&tx_ttnews[year]=2009&tx_ttnews[tt_news]=1091&tx_ttnews[backPid]=93&cHash=b0e78ad18bdb75ea17b2aad1cef80cec)
- Hoernig, S. / Jay, S. / Neumann, K.-H. / Peitz, M. / Plückebaum, T. / Vogelsang, I. (2010): "Architectures and competitive models in fibre networks". URL:
[http://wik.org/index.php?id=studiedetails&tx_ttnews\[tt_news\]=1269&tx_ttnews\[backPid\]=85&cHash=8208bc049759e82e9e26e6da79a7e7f4](http://wik.org/index.php?id=studiedetails&tx_ttnews[tt_news]=1269&tx_ttnews[backPid]=85&cHash=8208bc049759e82e9e26e6da79a7e7f4)
- Hoernig, S. / Jay, S. / Neu, W. / Neumann, K.-H. / Plückebaum, T. / Vogelsang, I. (2011): "Wholesale pricing, NGA take-up and competition". URL:
[http://wik.org/index.php?id=studiedetails&tx_ttnews\[tt_news\]=1284&tx_ttnews\[backPid\]=85&cHash=33d27148b68810af975e0dd0c41d266d](http://wik.org/index.php?id=studiedetails&tx_ttnews[tt_news]=1284&tx_ttnews[backPid]=85&cHash=33d27148b68810af975e0dd0c41d266d)
- Ilic / Neumann / Plückebaum (2009): "Szenarien einer nationalen Glasfaserausbaustrategie in der Schweiz". URL:
[http://wik.org/index.php?id=studiedetails&tx_ttnews\[pointer\]=2&tx_ttnews\[tt_news\]=1227&tx_ttnews\[backPid\]=85&cHash=2e90eb5db163aec3a755be86cba7c706](http://wik.org/index.php?id=studiedetails&tx_ttnews[pointer]=2&tx_ttnews[tt_news]=1227&tx_ttnews[backPid]=85&cHash=2e90eb5db163aec3a755be86cba7c706)