A Comparative Analysis of Selected National and Regional Investment Initiatives that Seek to Achieve Broadband Expansion by Deploying NGA Networks

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A COMPARATIVE ANALYSIS OF SELECTED NATIONAL AND REGIONAL INVESTMENT INITIATIVES THAT SEEK TO ACHIEVE BROADBAND EXPANSION BY DEPLOYING NGA NETWORKS

Fernando Beltrán, Marlies Van der Wee, and SofieVerbruggen

ABSTRACT

Expectations about higher economic growth and the ever-increasing demand for higher bandwidth are driving the worldwide deployment of Next-Generation Access (NGA) networks. The paths followed to achieve this goal markedly vary, however, across different countries. This article offers a comparison of a handful of leading NGA deployments that rely on different investment models. We study the broadband national initiatives of New Zealand and Australia and a group of selected regional NGA deployments in Europe. While New Zealand's approach partially relies on a public–private partnership model of investment, Australia's National Broadband Network is a wholly government-funded initiative and the European local initiatives in Sweden, Spain, the Netherlands, and Portugal use a range of mixed models of investment. We use a common technology–policy–market framework that allows for a clear mapping of the incentives, goals, and actions of those involved in network deployment. Our main interest is the identification of the drivers for investment as well as the description of main risk factors in each case. By applying this framework to those selected deployment cases our work draws relevant conclusions about the impact of investment decisions on performance criteria such as coverage and uptake.

Keywords: Next-Generation Access networks, Fibre-to-the-Premises, public investment in broadband, public–private partnership, New Zealand, Australia, Europe

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Current trends in increasing demand for faster and more reliable broadband (BB) connections stimulate the deployment of Next-Generation Access (NGA) networks. However, deploying new infrastructure, especially Fibre-to-the-Premises (FTTP), requires significant levels of investment. Different economic investment models are currently being used worldwide to steer the deployments, ranging from no government intervention (fully private deployment), to a collaboration of private companies and public actors in a public–private partnership (PPP), to public procurement or even fully government-driven and publicly operated rollout. Furthermore, variants in scale of deployment can be identified: small rural town initiatives, regional solutions, or nationwide projects.

The nationwide PPP Ultra-Fast Broadband (UFB) network initiated by the government of New Zealand and the fully government-owned and-funded Australian NBN contrast sharply with the European local initiatives, which use mixed models of investment and are subject to constraints imposed on public money spending. Whereas the public partner (governments and local authorities) focus on increasing BB coverage and stimulating the BB ecosystem, private partners seek to establish a successful business case to the satisfaction of their shareholders. However, a common aspect of the mixed deployment types is the alignment of goals by both public and private parties.

The cases identified in this article not only cover different sizes in the scale of deployment but insightfully cover the spectrum of public and private modes of participation in infrastructure deployment. With the latter in mind, we aim to reveal the relationship between indicators of goal achievement and the characteristics of the investment vehicles. For example, qualitatively finding and assessing a relationship between the estimated amounts of risk shifted onto a private partner and the speed of deployment. Thus, the article defines a common framework for effective comparison of the abovementioned country and regional cases.

Inspired by (Melody, 2013) a technology–policy–market interaction framework[1] is proposed that allows for a clear mapping of the incentives, goals, and actions of the different players in the field. Looking on the investment model used from a multidomain perspective (technology, policy, and the market) broadens our view and allows us to reach richer conclusions. This framework is applied to the following NGA

1. Melody.

deployment cases: New Zealand's UFB, the publicly owned dark fiber infrastructure provider Stokab in Stockholm (Sweden), the fully government-funded NBN project in Australia, a PPP under the Market Economy Investors Principle in Amsterdam (the Netherlands), a PPP initiated by the community in Catalonia, Spain, and a private initiative undertaken by the different providers, mainly the incumbent, in Portugal. These cases were chosen because they represent different types of investment mechanisms and so they cover the range of investment models of interest.

The goal of this article is to investigate, on a case-to-case basis, the links between the choice of investment model, including the level of public and private involvement, and several factors that speak about the success of a NGA deployment. Then the article identifies the drivers for investment in each case and the investment mechanism and looks into indicators relating to the main goals of the infrastructure deployment such as coverage and speed of deployment. As an important factor in the creation of incentives for private investment, the article also identifies the risk types shared between the partners across cases, whenever a partnership is the preferred vehicle for deployment. Placed on a straight segment with one end representing full government stewardship of a next-generation BB access deployment and the other end representing fully private investment, the cases studied in this article would sufficiently and variedly cover the space in between. Besides, their low number does not allow for a statistical approach to identifying correlation between factors and the measurement of interest.

The article unfolds as follows: after providing an introduction to PPPs and government intervention in BB deployment, the technology, policy, and market aspects are brought together in the interaction framework presented. Next, the UFB program in New Zealand, the NBN in Australia, and regional initiatives in Europe are respectively described and analyzed. Following that comparison criteria are used to highlight the commonalities and differences in how those cases have performed thus far. Conclusions and recommendations are formulated as a closure to the article.

PPPs and Government Intervention in BB Deployment

This section presents a definition of the mechanism that allows a government to enter a partnership to undertake an infrastructure construction project and an overview of the range of options a government may rely

upon when private participation is needed or preferred. In addition, it introduces concepts, key to the assessment of performance of those NGA deployments examined here.

Although acceptance of FTTP as the preferred type of NGA deployment is not universal, the political decisions that have favored deploying fiber to the customer look forward to future-proof the access network with the most reliable and capable technology available today. Politics aside, when a type of *greenfield* NGA is to be deployed in urban or suburban areas, technology and demand factors have shown that FTTP is preferred.[2] As investment incentives for private operators to upgrade their networks to full fiber networks[3] have been absent, some governments have tried alternative financial initiatives. These initiatives have included both private and public investment (financing structure), as well as different forms of "authority aid," mainly in the form of laws or regulations. In this article, we will mainly focus on the choice for and impact of the financing structure. Where deemed useful and to make the analysis relevant to policy makers, the article also links the financial aspects to relevant regulatory decisions.

Forms of Public and Private Participation in Infrastructure Project

Figure 1 gives an overview of the five main financing structures that can be identified for large projects[4] (not limited to telecommunication networks deployments). They range from 100 percent public investment to 100 percent private investment:

- In the *complete government production and delivery*, a public institution is responsible for the planning, deployment, and maintenance of the project.
- When a public party invests the funds, but outsources the execution (and possible operations or maintenance) of the project to private partners, the investments mechanism is referred to as *public procurement*.
- A *PPP* is characterized by both public and private investment, and hence, both public and private risk. This investment mechanism will be described in more detail.

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2. Van der Wee et al., "Identifying and Quantifying."

3. With full fiber networks, we refer to Fibre-to-the-Premises (FTTP), also referred to as Fibre-to-the-Home (FTTH). We argue for this type of networks over upgrades on copper (DSL) or coaxial cable (DOCSIS) networks, as these upgrades gradually bring fiber closer to the home, but still leave a last part of legacy infrastructure.

4. Adapted from OECD, "Public-Private Partnerships."

- The fourth mechanism is a *concession*, frequently also referred to as a *tender*. In this case, the public party grants a private partner the rights to deploy and operate an infrastructure (or to execute and maintain a project). The private partner relies on revenues from the project's users, to recoup its investment. In this case, the private investment (and risk) is higher than in the case of a PPP.
- *Full private investment* is the final financing structure, and involves no public investment.

Depending on the level of government involvement, different legal frameworks allow or forbid some of these investment mechanisms. In general, European policy holds that government intervention should only be allowed in cases where the market is not delivering the right quality and/or quantity. Lemstra and Groenewegen[5] argue that governments should only intervene in case of a market failure, where it has been proven that the private market players have tried to correct the failure without any result. In this situation, the authorities can either use competition law to correct the abuse of market power, or set specific regulation on standards (quality of service) or impose price corrections through the use of taxes and subsidies.

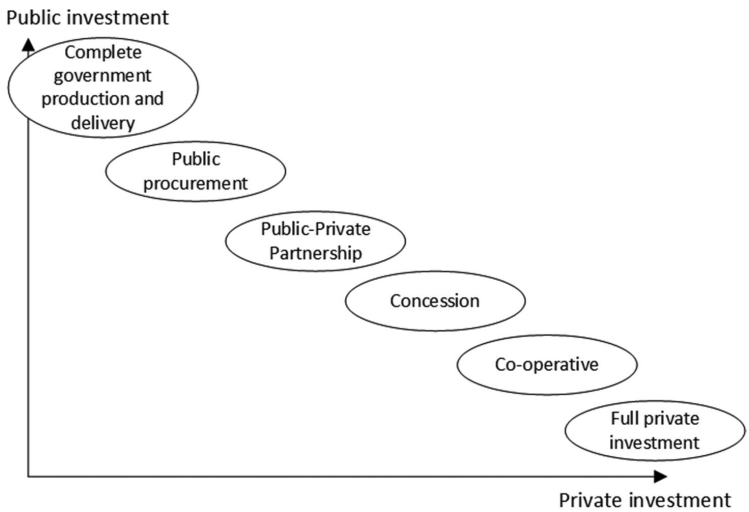

FIGURE 1 Overview of Types of Public–Private Collaboration.

5. Lemstra and Groenewegen.

Here, it should be noted that the European regulation on public involvements is specified in specific terms, and hence significantly different from other parts in the world. More precisely, we refer to the distinction between white, gray, and black areas[6]; in principle, only in white areas is public subsidy in network allowed. As an exception, there are two scenarios in which public investment is not regarded as State Aid in accordance with the Case-law of the European Court of Justice ("ECJ"):

- If the part of the investment that falls under the responsibility of the State can be used (in)directly by an undertaking in circumstances which correspond to normal market conditions
- If a Member State considers the provision of BB as a service of general economic interest (SGEI), known as SGEI as qualified by the Altmark[7] criteria.

Defining PPPs in the Context of BB Expansion

PPP finds the middle point between public and private investment, and is defined as a contract between an authority (e.g., the national government or a municipality) and one or more private partners.[8] By including both public and private money, the alignment of objectives can be achieved: that is, the service-delivery objective of the public parties along with the profit maximization of the private parties,[9] making the agreement mutually beneficial and economical.[10] Another approach toward PPPs is seeing it as lying between the government and the market,[11] with the

6. European Commission. "Commission Communication 2009/C 235/04."

7. The four conditions to meet in accordance with the Altmark criteria, as defined in Article 86(2) of the Treaty of the European Community, are (a) The beneficiary of a State funding mechanism must be formally entrusted with the provision and discharge of a SGEI (b)The parameters for calculating the compensation must be established beforehand to avoid an economic advantage over competing undertakings (c) The compensation cannot exceed what is necessary to cover all or part of the costs, taking into account the relevant receipts and a reasonable profit for discharging those obligations (d) The level of compensation granted must be determined on the basis of an analysis of the costs which a typical undertaking, well run, would have incurred in discharging those obligations, taking into account the relevant receipts and a reasonable profit.

8. Ibid., 3.

9. Fourie and Burger.

10. Tylee.

11. Howell.

government representing centralized control of transactions and the market representing decentralized control.

One key aspect that differentiates PPPs from traditional procurement models is the fact that the agreement involves a risk transfer mechanism; that is, the private partners in a PPP must bear an agreed share of the (financial) risk, and as such are incentivized to deliver the product as efficiently as possible. Thus PPPs are expected to deliver higher value-for-money by achieving the same goals as public procurement models, but at lower cost.

On the other hand, the involvement of public money is also key and provides the main differentiator to privatized projects. Public money ensures that government can impose their coverage targets and can provide a type of "subsidy" to ensure the economic viability of the entire project.

Organisation for Economic Co-operation and Development (OECD)[12] states that a well-established BB deployment PPP must balance out four factors: (1) connectivity (in terms of universal service), (2) competition (by requiring enough private risk), (3) innovation (as the deployment of a new network generates opportunities on services and applications level), and (4) social benefit (benefit for other sectors of society). To ensure this, four elements should be included in the mechanism: the clear and long-term relationship between public and private partners, private equity as part of the funding, main objectives defined by the public actor, whereas implementation decisions left to the private one(s), and clear sharing of risk.[13]

Assessing the Success of Deployments

The most straightforward way to evaluate the success of a project is to verify to what extent its goals and targets have been reached upon completion. Even in cases where the deployment has not been finished yet, if information that monitors the construction pace is available, measurements of the quality of progress can be obtained. In all cases, the project goals, partial or whole, can be assessed.

12. OECD, "The Role of Communication."
13. Falch and Henten.

Where government participation is present, the drivers for investment are grounded on expectations of social return and economic benefit in the medium term. Stakeholders in the deployment of an NGA network want to see construction deadlines met and targeted households reached. We are therefore relying on "coverage" (target and actual) as one indicator of the degree of success in meeting the goals.

It has also been recognized that private investment would not be able to provide a high-speed infrastructure before a desired point in time. In particular, due to the uncertain nature of NGA returns, the increasing demand for BB services, and government goals for the reduction of the digital divide[14] several regional European governments have invested in deployment of NGAs. Timing becomes then a pressing factor as government needs to deliver on their BB plans. In our assessment, such need is represented by the speed of deployment (relative to targets) as another indicator included in our analysis.

A third aspect in the assessment is the level of risk involved in the deployment of an NGA. When the vehicle to expand BB is a PPP one defining characteristic of the agreement is risk sharing and the type and amount of risk transferred to the private partner shape the contractual relationship. Risk transfer is inherently linked to PPPs as part of the investment risk that should be borne by the private party. Beltrán[15] argues that "it is the degree of risk transfer from the government onto the private party that determines the real nature of the contractual relationship between them."

Lacking accurate data about the financials of the cases analyzed here, our approach is the identification, not the calculation, of the risk type involved in each of the investment mechanisms used by the BB initiatives. We use a categorization of risk advocated by OECD,[16] which first divides risk between commercial risk, on one hand, and legal and political risk, on the other. In turn, commercial risk is further split into demand and supply risks. The former refers mainly to changes on the consumer side such as uptake and use of BB services, as well as other commercial offers of substitute and complementary services, and financial risks affecting demand. The latter, intimately linked to the "ability of the private partner to deliver"[17]

14. Nucciarelli, Sadowski, and Achard.
15. Beltrán, "Effectiveness and Efficiency."
16. Originally presented in Fourie, F. and Burger, P. Ibid., 7.
17. OECD, "Public-Private Partnerships."

and is divided into construction risk—risks mainly associated with the availability and costs of inputs—and operation risk. In our descriptive assessment, we address the components of commercial risks.

Technology–Policy–Market Interaction Framework

Although the development of new products and services is facilitated by technology, they only make it into the market when demand for them has built up. Similarly, if market dynamics do not provide enough incentives for operators to, for instance, adopt new technologies and upgrade the networks, government intervention in the form of acts, laws, or regulation could be justified. Finally, markets don't develop or evolve independent from policy decisions or technological innovations.

As such, the studied fiber deployment cases should be investigated within a framework that uses these three domains: technology, policy, and market. Following the research by Melody,[18] who identified the impact of technology through applications, the impact of markets through services, and the impacts of policy through the regulations, this article uses the interaction between technology, policy, and the market to describe how decisions on the financing structure of the new deployments impact their performance as measured by a variety of criteria both in New Zealand and European cases as displayed in Figure 2.

The *technology* pillar groups all innovations, both in network upgrades and applications and services development, not limited to the telecom sector only. Within the scope of Fibre-to-the-Home (FTTH) networks, it includes the choice of network topology (point-to-point, P2P or point-to-multipoint, P2MP), network architecture (Active Ethernet or Gigabit Passive Optical Network [GPON]), deployment method (aerial or buried), equipment innovations (e.g., on the Optical Network Terminal or Optical Line Terminal side), and so on.

The *policy* pillar comprises all laws, guidelines, regulations, and directives that impact the deployment of FTTH either directly or indirectly. They can be made on local, regional, national, or international level. Examples include wholesale price regulation, competition law, Digital Agenda guidelines, and so on.

18. Melody.

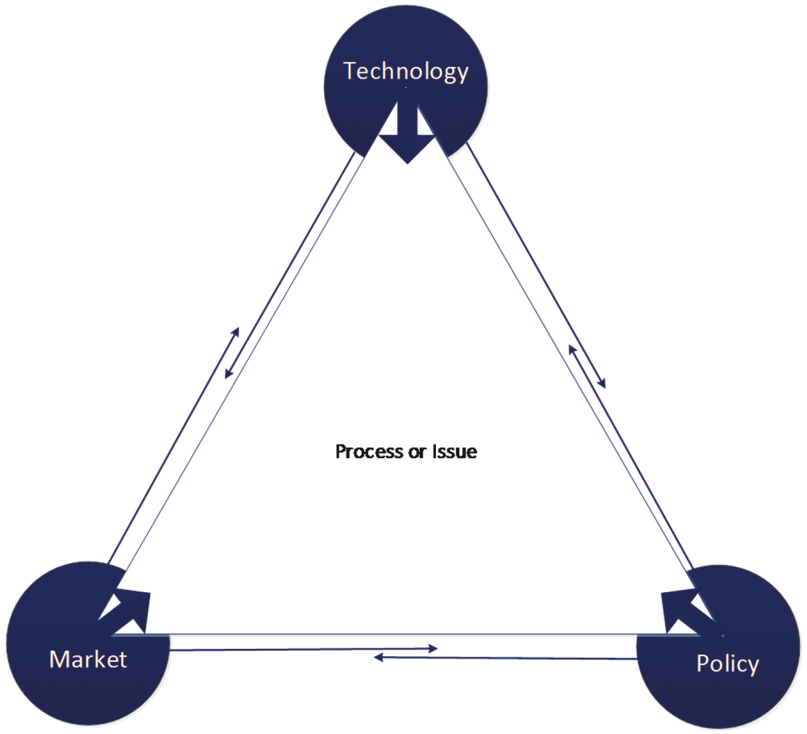

FIGURE 2 Technology–Policy–Market Interaction Framework.

The third and final pillar, the *market*, combines all commercial and strategic decisions, both by the end user and by the industry players itself. Examples include the customer's decision to take up on a fiber connection, the retailers' service offers in terms of speeds and caps and the NGA platform's wholesale tariff structure.

Next we will link the technology–policy–market interaction framework used for analyzing the cases to both factors of characterization and indicators of performance to evaluate the success of PPP in the deployment of fiber access networks. By focusing on the decisions made by actors in the three different pillars of the framework, the effect of their decisions on the other pillars can be studied, and possible interaction identified. Applying the framework on the financial decisive phase of different FTTH initiatives across New Zealand and Europe, allows analyzing both the drivers behind implementing a certain investment model, as well as the success of that model on the specific initiative.

A Nationwide PPP in New Zealand

New Zealand government committed NZ$1.5 billion to a FTHH network aimed to reach 75 percent of households and businesses, an initiative known as the UFB network.[19] The remainder is to be served mainly by the Rural Broadband Initiative, through investment in wireless connectivity and very-high-bit-rate digital subscriber line or VDSL connections. Crown Fibre Holdings (CFH), a publicly owned company, was created to manage the investment funds. In 2017, CFH denomination was changed to Crown Infrastructure Partners (CIP) Limited, expanding CFH's initial purpose.[20] A tender process saw four private companies win shares in the total investment funds to deploy the UFB. Three of these four partners are known as Local Fibre Companies (LFCs) and will eventually own and operate the network on a wholesale-only basis. They are NorthPower Fibre, UltraFast Fibre, and Enable Services. Chorus, the fourth and largest partner established from a demerger of Telecom New Zealand into a wholesale company owning the network (Chorus) and a retailer (Spark), is not a LFC but instead CIP invests directly in it in the form of nonvoting equity and debt securities.

The PPP was structured in two different models: the "funds-recycling" model with the LFCs and the "investment" model with Chorus. The contract with the LFCs is based on the recycling of capital in which CIP funds the fiber passing (the dark fiber, Layer 1 network deployed along the streets) and when a customer shows interest to subscribe to fiber services the LFC then funds the drop section (from the street to the customer's premises). A subscription-based retail commercial relation then starts between the customer and a retail service provider, which in turn pays for capacity to the LFC at wholesale prices. This income is then used by the LFC to buy a share in the UFB network (so far owned by CIP), gradually acquiring ownership of the entire network as services are deployed. CIP in turn can reinvest the regained funds in network deployments elsewhere. The government's UFB network initiative could be described as a "reverse PPP," where the government initially owns the PPP entity, takes risk, and

19. Sadowski et al.; Crown Fibre Holdings.

20. As read from https://www.crowninfrastructure.govt.nz, the redefined purpose includes "investigating and implementing commercial models, including those that will enable coinvestment from the private sector or any other sector, to achieve the Government's objectives for the deployment of water and roading infrastructure to support a timely increase in housing supply."

provides seed capital to private-sector partners to build the network, and then eventually sells out to private-sector partners.[21]

The contract signed with Chorus is different in the sense that CIP invests directly in Chorus as a company, but Chorus bears the main risks of the uncertain demand uptake. In return for this government loan, Chorus has to comply with specific coverage and uptake goals, set on milestone dates. Regulatory risks manifested in the changes to the regulation of the copper network, which led to a major change in Chorus composition of ownership with government investment funds replacing foreign capital.[22] In addition, the government has retained the power to exert control of Chorus if the provider does not meet its targets.[23]

Australia's NBN

NBN in Australia was originally conceived by the Labor government in 2008 as it sought to control Telstra's domination of the last-mile infrastructure in the emerging market of fixed BB, responsible for Australia's low rankings in the OECD charts on BB uptake and pricing throughout the 2000s. What was proposed as a nationwide, high-speed FTTP network with an initial estimate of AU$42 billion turned out to be grounds for a heavy political fight. In 2009, the government established NBN Co to build and manage the fiber deployment; as fiber was expected to be rolled out and copper decommissioned, NBN Co would eventually become the sole provider of wholesale services to retailers and other interested parties. NBN Co planned to offer speeds of up to 100 Mbps in towns with populations larger than 1000, comprising 93 percent of Australian premises, by 2021. In 2011, the cost of building the NBN was revised down to AU$37 billion and the purchase of Telstra's copper network for additional AU$11 billion was announced. The deal with Telstra would gradually shut down its copper infrastructure, moving almost 10 million customers to the NBN.

With mounting pressure from the opposition ever since labor announced its investment in the NBN, the largest infrastructure project in Australia's history, the landscape radically changed when labor lost the 2013 election to the coalition, a political force gathering conservatives and liberal

21. Howell and Sadowski.
22. Ibid 14.
23. Ibid.

democrats. Overnight, the coalition set itself to change the investment plan for NBN. The first 2 years of coalition-run NBN were spent in redefining the character of the network in terms of the deployed access technology. From the original 93 percent-covered FTTH network, in 2017 NBN coverage plan is a mix of the following technologies: 18 percent of premises with FTTP, 25 percent on Hybrid Fiber-Coaxial HFC, 18 percent served by Fibre to the Distribution point (like fiber to the basement of an apartment building), 33 percent with FTTN,[24] 3 percent with fixed wireless technology, and the remaining 3 percent with satellite. Minimum connection uplink rate is 25 Mbps, such as in satellite, with speeds going up to 1 Gbps on FTTP.

NBN Co's access service encompasses several classes of services; among those are the bit-stream services, traffic classes, telephony capability, multicast, service operation, administration and maintenance, and physical interconnection agreements. The network must provide wholesale access service to any retailer wanting to offer services to end user.

The Case of Stokab in Stockholm

Driven by the incentive to increase the economic attractiveness of the region of Stockholm, the city decided to invest in a FTTP deployment. Stokab, founded in 1994, is a public company, 100 percent owned by the city of Stockholm, and was established to deploy a dark fiber access infrastructure to all businesses and households in the Stockholm region. The company was founded as a public infrastructure company (comparable to other public firms responsible for road, railway, etc.); all the development, deployment, and operations are in direct hands of the company, no outsourcing is done. As the deployment started before the European Union (EU), State Aid regulation was established, its public involvement was not questioned.

In its initial phase, the network rollout was financed by publicly backed loans. As a first goal, the network aimed at connecting mainly public and educational institutions, but was quickly expanded toward private businesses, which requested to be connected on the dark fiber circuits. Although being a public company, taxpayers' money was never used. Instead, the initial €300 million investment was based on loans backed

24. FTTN corresponds to VDSL, but achieved bandwidth speeds depend on the area.

by the city of Stockholm, whereas the customers' revenues provided the necessary funds for a later expansion of the network. Note that about 50 percent of Stokab's revenues flows from direct business customers[25] (e.g., banks, schools). Stokab reached a breakeven point in 2001, and is now a profitable company, although the majority of their profits is still reinvested in maintenance and further expansion of the network.

As in the first years, the deployment was mainly focused on larger businesses and public buildings, the speed of deployments (in terms of buildings passed) was not very high. The rollout speeded up drastically when the focus shifted to connecting more residential users, in the beginning of the 2000s. In mid-2013, 90 percent of households and 100 percent of businesses in Stockholm had access to the fiber network. The goal of creating ultrafast reliable connections to the highly knowledge-intensive region that would "meet future communications needs, stimulate competition, promote diversity, offer freedom of choice and minimize the need for excavation,"[26] has definitely been reached. Stockholm is now home to a number of successful international companies (e.g., Skype, Spotify, and Transmode), all of which were attracted to the "most densely fibred city in Europe."

Deployments in the Netherlands: the Case of Amsterdam

In the case of Amsterdam, the city wanted to explore the importance of high-speed connectivity to the economic well-being of the city, and launched a formal investigation into the best way to proceed. Based on the outcome of several studies with and without the collaboration of the national incumbent, Koninklijke PTT Nederland or KPN, and the local cable operator, United Philips Cable or UPC, the municipality decided to create a PPP to invest in a passive fiber infrastructure. This PPP, GNA (Glasvezelnet Amsterdam BV) was incorporated with three groups of investors—the municipality itself, the housing associations, and the private sector—each investing €6 million in return for a one-third stake in the company. Another €12 million in funding was provided as debt financing, bringing the total investment to €30 million. Although GNA was

25. Broberg.
26. Stokab.

taken to court multiple times by the cable operators, the public investment was eventually allowed under the Market Economy Investor Principle:

- All shareholders should invest under the same conditions in a profitable business with an acceptable risk/reward ratio.
- The network should be operated using the "open network" concept, meaning that the wholesale specifies that all service providers must be able to purchase transport capacity on nondiscriminatory conditions.

This investment fund of €30 million was used to cover about 40,000 homes with fiber access, this process took about 2.5 years and finished in February 2009. Then, GNA announced plans to connect the remaining parts of the city (420,000 homes in total) by 2013, and estimated an overall budget of €300 million to do so.[27] Soon, however, the ownership structure in Amsterdam changed, as Reggefiber (a passive infrastructure provider set up by an investment company [Reggeborgh]), bought about 70 percent of the shares, in a partnership with KPN (the Dutch incumbent). This evolution made tracking the actual process of the initial project hard. Though the project evolved in a different way than it was initially started, it remains an interesting example of how a PPP can be set up, and proved an example of multiple other, smaller, regional initiatives.

In general, across the Netherlands, most of the early first Dutch FTTH initiatives were taken by municipalities. Later on FTTH deployment in the Netherlands was mainly driven by Reggefiber. Since 2014, the Dutch incumbent KPN acquired 100 percent ownership of Reggefiber.

A Community Network in Catalonia, Spain

Guifi.net presents an example of a totally different way of collaboration between public and private parties, by implementing a crowdsourced network.[28] In 2004, the initiative was started by a group of enthusiasts that wanted to create amateur networking infrastructure, in order to serve the more rural areas that were not on the strategic road map of the commercial operators. Because of its initial success, the group founded the Guifi.net Foundation and professionalized the offer. Four types of stakeholders participate in the network deployment and operations[29]:

27. FTTH Council. "2016 FTTH Case Studies Collection."
28. Guifi.net.
29. Baig et al. "Guifi. net."

- Volunteers, responsible for management of the project, as well as development and maintenance of the software tools for network operations.
- Professionals, who invest in the network in return for fair compensation, and/or use the network to offer services (i.e., service providers) in return for a fair payment for this network usage.
- Customers, who use the offered services for a fair fee.
- Public administrations, regulating the public goods, interactions between other stakeholders, and so on.

The network governance model is based on the Common-Pool Resources framework, which assumes that all partners involved agree to and follow up on the same standardized ruleset, yet ownership remains with the stakeholder that invested. A specific compensation framework is in place to ensure fair (cost-based) payment for invested effort in network deployment or operations.[30]

Though the network originally started as a small initiative in some towns in Catalonia, many regions in Spain now enter in the Guifi.net foundation for the deployment of their network infrastructure. The founders devote the success of the community network to its three underlying key principles: open, free, and neutral. The openness refers to the fact that everyone can gain insights on how the network is built and operated (e.g., all software tools are open source), the network is free because access is nondiscriminatory, and neutral because any technological solution is welcomed in network extensions.

Mainly Private Investment in Portugal

Although most European FTTH initiatives are based on some form of PPP, exceptional examples of other financing structures can be found. The main example for a pure private investment is to be found in Portugal, where the national incumbent, Portugal Telecom (PT), started a GPON rollout to face the fierce competition by the cable operator which could offer more attractive video-based offers using its HFC network. At the end of 2011, PT had passed 1.6 million homes,[31] in comparison to Vodafone Portugal, who has currently covered more than 700,000 homes with FTTH, whereas

30. Baig et al. "Making Community Networks."
31. FTTH Council, "Portugal Telecom."

aiming for the 1.5 million target by mid-2015.[32] They recently announced that their copper network would be replaced by fiber almost completely (93 percent of homes) by 2020.[33]

This decision to upgrade to FTTH was helped by the decision of the National Regulatory Authority ANACOM which adopted a segmented regulation after a market analysis in 2008. The decision determined that access to ducts and associated infrastructure (so-called market 4) should be an obligation for all infrastructures (DSL, DOCSIS cable, and FTTH), but that a wholesale offer (bit-stream access, market 5) should only be regulated in noncompetitive areas. In areas with sufficient competition (defined as areas where the percentage of passed homes by the main competitor—the cable operator ZON—is larger than 60 percent), there is as such no significant market power (SMP), and according to European guidelines, no need for access regulation.[34] In most of these competitive regions, the combined market shares of ZON and PT currently exceeds 85 percent.

The upgrade of PT's network started in 2007 and was a gradual process. First, the network was quickly upgraded to DSL and later the copper loop was shortened by Fibre-to-the-Node installations, with the final step deploying fiber to the actual homes with the GPON technology. The choice for GPON was largely based on its capability for broadcasting, as many Portuguese homes have multiple TV sets and thus require enough signals (the analogue TV signals could be carried over a third wavelength in the GPON system [RF overlay]). Although originally only open to PT's customers (see earlier, no enforced regulation), PT announced in 2016 that they would also launch a wholesale offer for other operators to use their FTTP network.[35]

Apart from the pure private GPON investment, PT also signed coinvestment sharing agreements with Vodafone for easy and cost-efficient upgrading of the mobile network to Long Term Evolution or LTE, providing PT with the opportunity of offering quadruple play for competitive prices.

Finally, in other areas of Portugal (the mainly rural, noncompetitive areas), the government opened public tenders for the deployment of a wholesale network that would cover 50 percent of the targeted population with a minimum download bandwidth of 40 Mbps. In these areas, PT deploys an open access network with a wholesale offer for passive access.[36]

32. Vodafone.
33. Alveirinho.
34. Anacom, "Mercados Grossistas."
35. Portugal Telecom.
36. Ibid., 24.

Comparison of Deployments

For all cases studied here, Table 1 summarizes the most important decisions as referred to each of the three aspects (pillars) considered by the framework. The chronology of the decisions is revealed by the bracketed numbers showing first on each table entry, with (1) indicating the oldest decision. Table 1 is complemented with Table 2, which assesses the extent to which the factors chosen as performance indicators have been met.

Table 2 displays in two parts: the upper section describes the aspects driving the deployment in each case, particularly what motivates governments to act, whereas the lower section displays data on construction targets. In addition, Table 3 summarizes the information used for estimating the speed of deployment, the measurement of comparison for which enough data is available.

Having summarized the main aspects of the country and region cases previously within the domains of the technology–policy–market framework, we turn now to draw a comparative assessment across the groups of international deployments. We first use the data available about deployment and time to achieve it to provide a quantitative approach to the speed of deployment, before turning to a more qualitative comparative analysis based on the information on Tables 1 and 2.

An estimate of the speed of deployment is obtained by taking account of the number of fiber connections reported over a period of time. Although several issues may arise, calculating such gradient provides a comparator that allows observing a difference across deployments. The difficulties with this approach lie on selecting a meaningful time interval over which construction is advanced under somewhat normal conditions (for instance, in accordance to plans). Also, when disturbances have arisen that impeded the steady delivery of connections passed, the duration of such time interval should be long enough to offset or amortize their effects.

Table 3 displays the values of the number of connections passed to total time of deployment ratio as a proxy to the speed of deployment for selected periods of time in most cases discussed here. The table also adds a measurement of speed of deployment per 1,000 people to take account of the size of the population target for each deployment.

In spite of the differences in the overall size of each initiative, all deployments are urban as far as FTTP concerns. Nationwide deployments take longer and achieve comparatively higher deployment rates than their city counterparts. The Australian and Stokab cases are presented in two stages,

TABLE 1 Overview of the Most Important Impacting Decisions Using the Three-Pillar Framework on Regional and Country Cases

Decisions	New Zealand	Australia	Stockholm, Sweden	Amsterdam, the Netherlands	Catalonia, Spain	Portugal
Policy pillar	(1) Government investment	(1) Initiative by government party (6) Major changes when coalition took power	(2) Foundation of Stokab	(1) Amsterdam City investment under market economy investor principle	(2) Initiatives from local citizens (3) Common-Pool Resources framework	(2) No unbundling obligation
Market pillar	(5) Demerger of Telecom (2) Wholesale only	(2) No competition on infrastructure (3) Wholesale only (4) Buy-out of Telstra´s network	(1) Demand from business users (3) Dark fiber only	(2) Taken to court by UPC (3) Dark fiber only	(1) Community initiative, competition on higher layers	(1a) Competitive threat from cable (1b) Vertical integration, later wholesale offer
Technology pillar	(3) GPON deployment (4) Bit-stream access	(5) 93 percent FTTP (6) Mix of 18 percent FTTP, 25 percent HFC, 18 percent FDp, 33 percent FTTN, 3 percent fixed wireless, 3 percent satellite.	(4) Technology-neutral passive infrastructure	(4) Technology-neutral passive infrastructure	(4) Technology mix, depending on the area	(3) Gradual upgrade of DSL network; no new network deployment
Type of public–private collaboration	Public–private partnership/ concession	Public procurement/ complete government delivery (operation) government-owned company	Complete government production and delivery	Public–private partnership	Public–private partnership	Private investment

TABLE 2 Factors Characterizing and Indicators Comparing the Different Case Studies

Factors and indicators	New Zealand	Australia	Stockholm, Sweden	Amsterdam, the Netherlands	Catalonia, Spain	Portugal
Initiative drivers	Societal value of BB Political incentive	Societal benefits of BB Expectations of higher growth	Economic attractiveness of the region (businesses)	Value of BB for households	Community and local citizens	PT's response to increasing competition from the cable operator
Investment mechanism	0 percent interest loan/public–Private Partnership with recycled shares	Federal government ownership	Public ownership and deployment	Public–private partnership	Common-Pool Resources framework	Private investment, ownership and deployment
Risk transfer	Mixed model of risk transfer	NBN Co is sole provider		Market Economy Investor Principle		
Supply-side risk	LFCs assume "drop" construction risk	No private risk	No private risk	Parties take risk by equal parts	Majority risk taken by localities with support from municipalities	Private investor takes 100 percent demand risk
Demand-side risk	LFCs not exposed to risk for the initial deployment (recycling funds model) Chorus risk reduced by 0 percent interest loan from government	NBN Co takes 100 percent demand-side risk	Stokab takes 100 percent demand-side risk	Parties assume risk by equal parts		Private investor takes 100 percent supply side risk.

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Coverage (achieved)	75 percent of target households, 100 percent of priority users (Mid-2017)	As of October 2017 3M connected out of 6.2 M ready to connect.	90 percent of HH, 100 percent of businesses (May 2013)	40,000 HH by 2009 (first project)	55,000 nodes and counting (2017)	2.2 million HH (60 percent of population) (December 2012) (Anacom, 2013)
Coverage (target)	1,340,000 HH, 75 percent of population mainly urban	76 percent of households to be connected with a mix or technologies	450,000 HH 100 percent of Stockholm (dense) urban	420,000 HH (dense) urban	No specific target, new project proposals are always evaluated	BB over NGN to >50 percent population by 2013 (European Commission, 2011)

with the split in each case corresponding to major policy changes either during construction or as a result of an expansion of the original plan, respectively, as Table 3 shows. These figures alongside the New Zealand ones show how progress in initial build up stages is slower than progress at later times.

Returning to the summaries provided by Tables 1 and 2, New Zealand's UFB initiative sets 75 percent—upgraded to 85 percent with the addition of the second phase of the project in 2016—as the targeted proportion of households with passing fiber; the coverage goal in New Zealand is

TABLE 3 Speed of Deployment in Selected Country/Region Cases

Country/ Region	Time period	Number of connections	Speed of deployment[(i)] (number of connections passed per day)	Speed of deployment per 1000 POP[(ii)]
New Zealand UFB	January 2011 to December 2012	131,000	272.9	0.058
	June 2014 to December 2017	750,000	872.1	0.186
Australia NBN[(iii)]	January 2010 to December 2013	207,000	215.6	0.009
All technologies	January 2014 March 2018	6,600,000	6470.6	0.268
FTTP (only)	January 2014 to March 2018	1,425,000	1397.1	0.058
Stokab	January 2007 to June 2009	95,000	158.3	0.167
	July 2009 to December 2012	300,000	357.1	0.376
Amsterdam	November 2006 to February 2009	43,000	71.7	0.094
Portugal	October 2015 to September 2017	1,500,000	3125.0	0.303

(i) work month is 20 days.

(ii) population is either country total or city total.

(iii) Australia's NBN has been a mixed-technology project. Fiber deployment switched from 100 percent FTTP to an assortment of FTTX in 2014.

Sources: New Zealand CFH; Australia NBN Co; Fibre to the Home Council Europe; Stokab.se; PT Portugal.

similar to that found in Portugal but in local (city) initiatives the targets are much higher. Australia's plan relies on a mix of technologies that aim at 76 percent coverage using fiber (in different standards).

Coordination and scale issues cause a nationwide project to face bigger hurdles as the geographic area to cover is much larger than in the city-wide cases.

City governments can plan for and target almost all premises, especially in conditions where population density is rather high, 4,892 and 3,597 people per square kilometers in Stockholm and Amsterdam, respectively.[37] An increase in population density leads in general to a decrease in network deployment cost.[38] In spite of its lower population density—17 people per square kilometers, and also because of that, New Zealand did not commit to a higher target. Neither is the rural part of the country targeted by the Portuguese plan, at least not at the present stage. New Zealand's UFB original decision to only reach 75 percent of population was based on a cost-coverage trade-off, one that a smaller scale deployment with less cost per home passed would not have to face. On the other hand, a governmental initiative would normally be expected to focus more on universal coverage, thereby making sure all households are offered the ability to connect. In the case of New Zealand, the Rural Broadband Initiative—a complementary deployment to UFB—targets this goal, albeit using less costly (VDSL and fixed wireless) solutions.

Though the Australian case is clearly steered from the policy corner (as all major decisions in the NBN project are initiated and managed by the government, leaving not much space to the market component), this also presents its most important hurdle. The political disagreement between major political forces changed the deployment plans several times, leading to ambiguity. The original plan recognized the geographical hurdles and decided that 7 percent of households would not get fiber; the 2013 election brought in a new government, which had been acutely critical of the original proposed NBN's targets, resulting in a major revision of the project's targets and technologies of choice.

In terms of the speed of deployment, New Zealand's CIP reports show that deployment has consistently surpassed the established targets and, overall, the project is on track to be finished earlier. In spite

37. Wikipedia.

38. Van der Wee et al., "Evaluation of the Techno-Economic."

of the controversial review of the price of unbundled copper lines by the Commerce Commission with expectations that such decision could impact the deployment in areas served by Chorus, reports indicate that no delays are now forecast.

In Amsterdam, the cable (DOCSIS) operator UPC took the municipality's investment plan to court, because it was said to distort a well-functioning market. Although granted in the end, this court processes delayed the entire project significantly, and as such had a massive impact on the termination dates. In Stockholm, the initial network deployment was not set at a target speed of deployment, but was rather adjusted to market demand. Now that the network is operational and mature, targets are being set to connect the remainder of the homes.

With the exception of Australia's NBN, the fiber deployments have proven effective when government was or has been involved. These cases show an on- or above-target speed of deployment, with a warning message about how regulatory uncertainties may have a delaying effect on the progress of the deployment. In the case of Portugal, targets are more than met, and before target date, but as private operators do not always disclose their goals, it is difficult to draw robust conclusions here.

Evaluating the links between the investment mechanism, the initiative drivers and the risk transfers reveals a strong relationship between the social-benefit driver and the investment of public money. In Australia, New Zealand, and Amsterdam, the drivers followed the results of reports denoting the importance of BB to society,[39] and in the latter two cases a PPP with significant private risk (equal private/public risk in Amsterdam) was used as an investment vehicle. In Stockholm, the city reacted to a request from businesses to be connected on a very high-speed, technology-neutral network. The investment there was fully public (publicly backed loans) but the deploying company, Stokab, was set up to achieve return on investment rather quickly. In Portugal, the driver was set by the market (emerging competition), and hence, the reaction to invest was also fully private. In conclusion, a competition driver is followed by a market response, a demand driver can be answered by a market or a public response, and a societal driver influences policy, the pillar that then leads the initiative.

As per the choice for either a purely public or a PPP investment, the link to the driver is less clear. Here, a significant influence of regulation on the policy pillar can be identified. For example, in the case of Amsterdam,

39. Department of Broadband; Amsterdam; The New Zealand Institute.

purely public investment was not allowed, whereas alignment of the investment and sharing of the risk was a necessary condition for public involvement. One can tentatively conclude that the driver is crucial for the choice of investment mechanism, but the magnitude of public involvement is largely defined by regulatory rules.

How the network is actually deployed and services are offered (technological pillar) is also impacted by the market and the policy pillars, as the cases show. The Australian approach fully publicly supported "open access," which means any retailer can purchase wholesale service from NBN and start to provide BB-supported services. It is also the case of publicly backed network deployments under a PPP scheme, which obliges in all cases an open-access network to be deployed, albeit on different layers. In all three cases (Stockholm, Amsterdam, and New Zealand), the company or companies deploying the network cannot offer services directly to residential end customers, but lease access (on a dark fiber or bit-stream layer) to service providers, who then trade with end users. In Portugal, the situation is completely different: not only is PT operating as a service provider as well (no open access), it is also fully vertically integrated, not even having to unbundle its network.

Considering the topology deployed (P2P or P2MP), it is harder to draw conclusions about impacting factors from the policy or market side. In general, open access is easier to be offered on a P2P network (one dedicated fiber per end user is available), and therefore public parties tend to support P2P deployment more. In New Zealand, however, cost considerations changed this initial idea toward a GPON deployment with a limited percentage of P2P access that should be granted upon request.

Of course, this topology decision also impacts the amount of risk incurred, as deploying P2P is more expensive, but does not generate significantly higher revenues from most (residential) users. The latter allows us to claim a link is found between the deployment decision and the investment mechanism. On the other hand, P2P allows for easy dark fiber access, which was a crucial factor in the topology decision in Stockholm, as up to 50 percent of Stokab's revenue comes from business customers (banks, media companies, etc.), who lease dark fiber directly (so bypassing service providers).

Conclusions and Recommendations

Although it is generally recognized that the next step in BB networks is the evolution to NGA, with a strong preference for FTTP networks, the investment required to actually deploy these networks is regarded as

too high by many current telecom operators. As the importance of fast and reliable BB to society and economic growth has been proven, more and more public actors decide to step in by investing in NGA networks; the ensuing projects, either local, regional or national, face multiple constraints, from capped budgets to regulatory norms to international trading and investment agreements.

This article provided an extensive descriptive analysis of six different NGA deployment cases worldwide and studied the investment mechanisms used in these cases, with a focus on PPPs, by investigating the technology, policy, and market interactions, and evaluates the success of the deployment in terms of deployment speed and coverage.

In general, our analysis showed the importance of the policy pillar in the deployments studied, be it as full investment, participation in a PPP or indirect aid in the form of regulatory holidays. The policy pillar furthermore showed to impact the technological pillar significantly, in obliging open access on a dark fiber (P2P topology) or bit-stream (P2MP topology—GPON architecture) layer. The impact of the market pillar is limited in case of a public investment or PPP, but significant in the case of a private deployment, as there, the competitive threat provided a driver for investment. In all cases, the initiative lies with the policy or market pillar, and the technology pillar follows. In cases where the market takes the initiative, the technology pillar is less restricted than in policy-led cases.

The coverage targets are higher (in percentage of households) in smaller scale deployments, as the range of cost per home passed is smaller and as such provides for easier planning. Although it could be expected that a government-driven deployment would target 100 percent of the population (as to cancel out the digital divide), cost-coverage trade-offs have reduced this target, at least for FTTH coverage. In terms of speed of deployment, publicly backed initiatives tend to achieve on or above targets.

Although the described cases here follow different approaches, PPPs are identified as a very promising option, implemented, for example, New Zealand, Amsterdam, and Stockholm. The main advantage of a PPP is probably that it combines the strengths and goals of public and private players. Public players reduce the risk for private players, and at the mean time make sure that the offers that are put on the market are fair and reasonable. Private players see a more reliable business case, but are still driven to employ their technical knowledge strengths to the

maximum in order to minimize their own risk and ensuring sufficient return on investment.

Evaluating the success of NGA and FTTH deployments of course goes beyond assessing the coverage and speed of deployment. The work in this article could be further extended toward including other evaluation characteristics, to fully investigate the efficiency and effectiveness of the cases. Effectiveness denotes whether the set goals are reached, and can span characteristics ranging from target coverage and speed of deployment, to uptake and envisaged return on investment. Efficiency measures the way the goals were reached, which includes budget evaluation and operational monitoring.

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