Corning Incorporated Response to Issues Raised in Consultation Paper No. 12/2014 Delivering Broadband Quickly: What do we need to do?

Q1. What immediate measures are required to promote wireline technologies in Access networks? What is the cost per line for various wireline technologies and how can this cost be minimized?

Please reply separately for each technology.

Attached is a detailed cost analysis conducted to analyze a specific case in Australia but many universal lessons are provided as well as relative cost comparisons.

Governments can help continue to reduce costs by minimizing reporting, forced build out requirements, non-essential network functionality and redundancy. Where new network infrastructure must be built the logical medium would provide the highest capability and lowest operating cost. The medium that best fits these criteria is most often optical fiber.

See attachment: The cost of deploying FTTP and FTTN in Australia

Specific to India: Clear and consistent (not changing over time) regulations that govern right of way, industry M&A and spectrum purchase/allocation

Q2. What are the impediments of the deployment of wireless technologies in the Access network? How can these deployments be made faster? Please reply separately for each technology.

Some of the issues associated with wireless deployment are:

- Power requirements: As wireless bandwidth requirements continue to escalate higher frequencies must be employed to achieve the bandwidth (data rate) targets. Higher frequency transmission reduces the acceptable distances for communication. Expect that more wireless antennas will be needed for the same coverage leading to densification of wireless equipment all of which will require an optical fiber backhaul and power.

- Availability of fiber backhaul: As described above the higher required data rates for wireless networks will require optical fiber backhaul. Planning and designing new networks should include the convergence of optical fiber and wireless to be provided by one cohesive network.

- Location of antennas: Due to higher number of antennas to provide similar coverage to today's network, identifying locations that provide both coverage and acceptable aesthetics is increasingly difficult. Governments can help by making available infrastructure such as lighting fixtures, signage, bus stops etc. for locating wireless antennas. Additionally, removing bureaucracy to deployment of infrastructure to support these deployments can drastically lower installation costs.

Corning: The TRAI consultation paper touches on a number of key issues in deployment of wireless technologies in the access network. Each technology has a set of benefits and challenges that makes it more/less beneficial than others based upon the use case considered. When looking specifically at wireless access technologies, we know that the transition from 2G to 3G took many years and that, although 4G technologies are becoming ubiquitous in some regions of the world, it's taking longer for many areas. Those regions that broadly implemented WiMax or invested in the upgrades from HSPA to HSPA+, have experienced slower movement to 4G/LTE and, as such, we believe that these networks will remain heterogeneous for many years to come.

Generally, wireless access networks are struggling to keep up with the explosive growth in mobile data traffic from users that are usually located inside large buildings. In the US, it is commonly stated that more than 80% of mobile connections are initiated from inside buildings. As the user experience continues to improve in both QoS and link speeds, the service providers are focusing on implementation of in-building wireless access networks that are technology agnostic wherever possible. As the networks shift from 3G to 4G and, eventually, 5G, these in-building wireless access networks must be built from infrastructure that is capable of changing and/or scaling to leverage the expected capabilities of an IP based LTE network. Rapid shift of the hybrid wireless access networks to IP based LTE networks is the best answer for meeting the flexibility and bandwidth challenges of the expected mobile data traffic growth.

LTE is designed to provide multimegabit bandwidth, more efficient use of the radio network, latency reduction, and improved mobility. LTE technology is now mature, chipsets widely available and can be deployed in both licensed and unlicensed bands. LTE-Advanced, adds a number of capabilities to further enhance the flexibility of the access network including improvements in interference mitigation which become important as network density increases and utilization grows as you get closer to the end users. For example:

- ICIC: The basic goal of inter-cell interference coordination (ICIC) in practice is the provision of a more homogeneous service to users located in different regions of the network, i.e. mostly to promote the cell-edge performance.

- COMP: LTE Coordinated Multipoint (COMP) is a range of different techniques that enable the dynamic coordination of transmission and reception over a variety of different base stations. The aim is to improve overall quality for the user as well as improving the utilization of the network.

One area to evaluate more closely is the in-building network where the largest barrier to entry is the time and cost to deploy infrastructure (cabling and electronics) that enable the wireless signals to propagate evenly throughout the building and, as such, provide a high quality user experience. To improve the speed at which new, more efficient wireless technologies are deployed in the access networks inside these multi-dwelling, multi-tenant and large commercial buildings, we recommend that network designers start with a fiber based network infrastructure that provides nearly unlimited bandwidth and will allow for nearly seamless upgrades from SISO to MIMO (2x2, 4x4, etc.) as well as support for hybrid deployments of small cells and Wi-Fi. Deployment of fiber optic cabling for in-building and access network infrastructure will allow for fast transition from 3G to 4G and onward to the all IP vision enabled by LTE and LTE-A technologies.

But, as the access network continues to improve, bandwidth growth will not slow and network planners must consider how to enable support for centralized capacity sources (C-RAN) and capacity routing to ensure best utilization of what will always be a limited amount of spectrum – ultimately, we must move toward a completely IP access network from the wireless core to the mobile device. A fiber based solution provides the best architecture for the transition from traditional in-building wireless access networks to LTE-A, C-RAN and beyond and should be implemented today to insure the ability of the networks to quickly add the capacity and capabilities of the technologies when available and/or needed.

Specific to India, the key bottlenecks are:

a. lack of a clear regulatory framework for Right of Way;

b. lack of viable framework to enable consolidation of industry participants;

c. availability of spectrum;

d. telecom operators not being held responsible for any standardized Quality of Service metrics

Q3. The recommendations of the Authority on Microwave backhaul have been recently released. Are there any other issues which need to be addressed to ensure availability of sufficient Microwave backhaul capacity for the growth of broadband in the country?

Overall, Corning agrees with the contents of Section 3 in the Consultation Paper - the co-existence of wireless and fiber technologies in mobile backhaul within the next few years is generally also supported by reports from the analysts [1]. However, we would like to point out that traditional microwave technologies may not work equally well across the whole of India. This is due to the fact that the signal loss within the wireless link is significantly affected by the atmospheric conditions, such as rain, ultimately leading to reach reduction in a backhaul link. Higher rain intensity means shorter reach. According to ITU rain region maps, most of India falls into high rain intensity zones K and N, which for 99.999% service availability corresponds to 100 and 180 mm/h, respectively [2]. Millimeter-wave E-band solutions will be even more reach-limited due to larger attenuation at higher frequencies.

Also, a number of discussions are presently being initiated by equipment vendors, carriers and governments around the world regarding future 5G mobile access technology. It is currently unclear what the final 5G specifications will look like, but initial suggestions indicate a potential factor of 1000 increase in speed to the user, relative to LTE [3]. It is unlikely that 5G technology will be commercialized before year 2020. But when it does, such increase in speed will ultimately require higher speed in the backhaul and aggregation links. While fiber has almost unlimited capacity (10 Tbit/s per fiber pair is commercially available now), more can be achieved by lighting another fiber pair and, therefore, ensures almost unlimited future proofing, it is unclear whether wireless solutions will meet 5G backhaul requirements with desired service availability.

References:

[1] Macrocell Mobile Backhaul Equipment and Services, Infonetics report, 2014

[2] Recommendation, ITU-R PN.837-1

[3] 5G Radio Network Architecture, Radio Access and Spectrum, FP7 – Future Networks Cluster, White Paper

Q4. The pricing of Domestic Leased Circuits (DLC) have been reviewed in July 2014. Apart from pricing are there any other issues that can improve availability of DLC?

Investment will flow where telecom operators can make money. Lack of availability of DLC's is directly linked to the fact that due to all the RoW and regulatory hurdles, telecom companies are not investing in access networks, and therefore availability of a robust infrastructure that only optical fiber can provide, is constrained.

Q5. What are the specific reasons that ISPs are proactively not connecting with NIXI? What measures are required so that all ISPs are connected to the NIXI?

Corning is not in a position to comment.

Q6. Would the hosting of content within the country help in reduction of the cost of broadband to a subscriber? If yes, what measures are required to encourage content in data centers situated within India?

It depends on the individual circumstances, and how much of the network the broadband provider owns.

It could go up if the cost of broadband connection includes the cost of building and maintaining a communication link from an individual subscriber to the point of presence (POP) of the broadband provider in the area where the subscriber is located, and not the cost of delivering the information from its origin to the provider.

However, it can go down as well, if this cost is defined as the cost of delivering the information all the way from the source to the consumer.

Additionally, quality of the customer experience is another factor to consider when determining whether to host within the country.

Q7. Are PSUs ideal choices for implementing the National Optical Fiber Network (NOFN) project?

There is a role for the Public Sector in implementing national fiber optic networks. At a minimum consistent products, deployment techniques, regulatory requirements (and certainty), national vision, clear objectives, aggregation of demand and elimination of bureaucracy are all actions any government can take to incent new network deployment. For case studies, lessons learned and other tools please see the FTTH Council Community ToolKit **http://toolkit.ftthcouncil.org/**

Specific to India, PSU's should not be in the business of providing broadband access (or for that matter any telecom services) across the board. Their role is much more valuable to the nation where the "business case" for privately owned telecom operators doesn't exist. Examples of this are:

a. Connecting remote locations with optical fiber (NOFN concept).

b. Providing subsidized broadband access to the poor (the network used may or may not be owned by the PSU directly).

Q8. Should awarding of EPC turnkey contracts to private sector parties through International Competitive Bidding (ICB) be considered for NOFN project?

Any actions taken that would increase the speed of deployment of this network, and the accountability of the contractors to meet committed timelines, should be considered.

a. Awarding of EPC turnkey contracts would facilitate and increase the speed of rolling out a NOFN network. Specifically, experienced operators would have the opportunity to focus on building to an executable plan while leveraging experience, capabilities and an existing trained workforce to validate, test and commission part of the projects in conjunction with the EPC turnkey contractors. International Competitive Bidding would allow a faster start and subsequent rollout as a new entity could take up to several years to build the necessary capability i.e. the National Broadband Network build by start-up NBN Co. in Australia. A uniform pan-India policy on major issues with rolling a new NOFN such as Right-of-Way, service offering, network architecture, build practices and building access would help simplify and replicate roll out methodologies in a more effective manner.

b. Additional actions to consider are involvement of non-government companies even if Indian, as EPC/EPCM contractors, with a more realistic deployment plan, but also with stiff non-performance penalty clauses in the contracts.

Q9. Are there ways in which infrastructure development costs can be reduced? Is it possible to piggyback on the existing private sector access networks so as to minimize costs in reaching remote rural locations?

The areas where access networks don't exist for PSU's also don't exist for private telcos, due to the reasons explained in answers 1 and 2. The government is best served in making it as easy as possible for private telecom operators to invest in building their access networks, so that PSU's could then piggy back on those networks.

Q10. What can the private sector do to reduce delivery costs? Please provide specific examples.

New implementation rules and product technologies can help reduce the cost of rolling out a NOFN. The private sector has experience in large infrastructure builds that could easily be leveraged to increase roll out speed and allow for a faster adoption rate of these new technologies. Examples of lower cost implementation technologies include shallow/narrow micro-trenching, micro-cable, higher percentage of aerial deployment, non-redundant network architecture, and simple plug and play products all can contribute to lower costs. Additionally, some operators have found that sharing the cost of network construction and competing on services is a sustainable model in areas of strong service adoption. Examples can be found in Scandinavia, Spain, France and other regions.

Q11. What are the major issues in obtaining right of way for laying optical fiber? What are the applicable charges/constraints imposed by various bodies who grant permission of right of way? In your opinion, what is a feasible solution?

The key issues are:

a. Multiple stakeholders. Each location, each "mohalla" in India has people staking claim to being competent authority from whom permission is required.

b. Extortion. Telecom operators often talk about even non-government bodies demanding payment to allow infrastructure work to continue.

c. No nationwide standard or awarding body. Even within states, there is no one government body that a company can approach, pay and get right of way for infrastructure deployment. There is no standard "policy" that operators can follow. There is no single municipal body that can guarantee access to the right of way, even if awarded.

d. High cost. All these complexities drive cost of RoW up, and make telecom operators resist investing the time and money in developing high quality high bandwidth access networks.

Creating a nationwide standard, policy and approval methodology for companies to apply for *and exert their right to* RoW will be a significant enabler towards driving investment in access networks.

Q12. Should the Government consider framing guidelines to mandate compulsory deployment of duct space for fiber/telecommunications cables and space for telecommunication towers in all major physical infrastructure construction projects such as building or upgrading highways, inner city metros, railways or sewer networks?

It is always a sound decision to deploy ducts whenever trenches, roadways, and utilities are open. The incremental cost of the duct can substantially reduce deployment costs and increase deployment speed while providing the duct owner a future revenue source. There are numerous examples of governments requiring the publication of open RoWs to allow other entities to place infrastructure (duct/fiber cable) to avoid future civils access.

Q13. What are the impediments to the provision of broadband by cable operators? Please suggest measures (including policy changes) to be taken for promoting broadband thru the cable network.

The MSO industry in India plagued by one critical issue: Lack of scale. Unlike telecom operators, even the largest MSO's don't have the scale to cover a full city in India. Therefore, making big capital investments are difficult for them.

The kind of network builds and upgrades that India needs will likely be best implemented by telecom operators due to their scale, and therefore we don't believe any policy changes aimed at MSO's will make much impact in this regard.

Q14. What measures are required to reduce the cost and create a proper eco system for deployment of FTTH in the Access network?

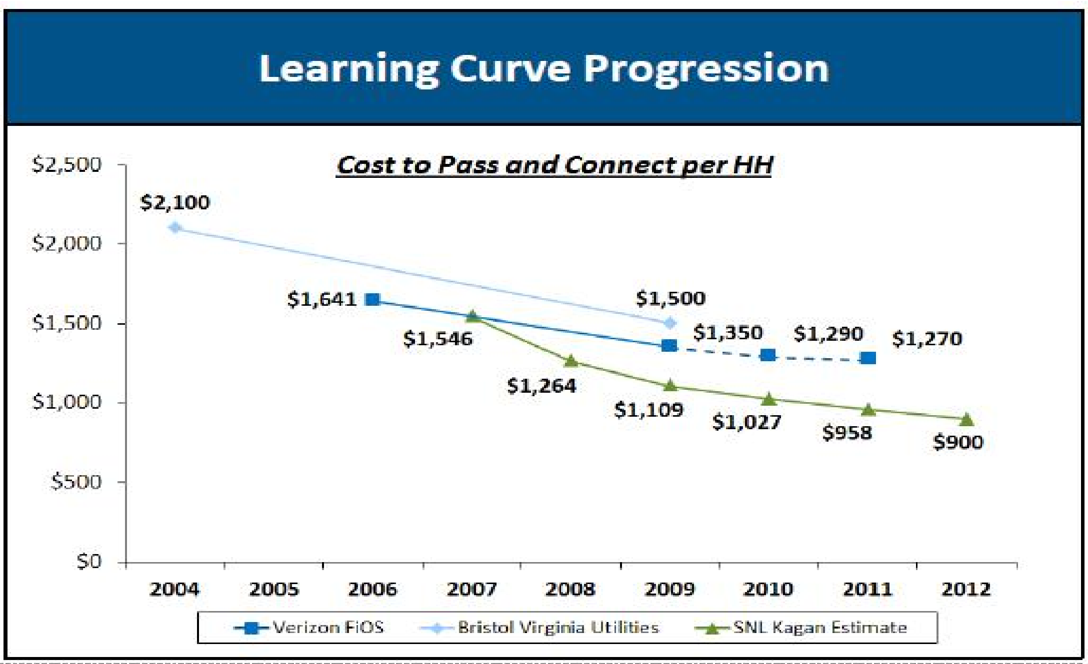
There are four universal areas that could help reduce costs when deploying FTTH in the access network. The lessons learned from previous FTTH deployments can be applied to most other regions and deployment scenarios. The successful application of these four areas when planning for a FTTH roll out could result in relative savings similar to those observed in figure 1 and documented in the attachment.

a. Improve field efficiency: There is a learning curve applicable to any major deployment or implementation of new technology. Accelerate the learning curve through training and consistency in design, deployment methodology and the application of lessons learned across all constituents and regions.

b. Use solutions that help decrease cost of labor and increase deployment speed: Solutions that facilitate the access to a larger pool of installers independently of their skill will help reduce cost by applying to common rules of supply and demand. This insulates the NFON from the likelihood that other growing industries will decrease access to the applicable labor force. Solutions that allow for simple and fast training of the workforce will help increase speed and independence of operators during the rollout as they are not limited by availably of properly trained personnel.

c. Leverage experience of suppliers and other global carriers: The lessons learned from large scale deployments can allow India to avoid repeating errors made by others. Leveraging experienced suppliers that have already worked through scale up/scale down on global projects can improve network reliability, avoid costly mistakes and improve repeatability. Many global carriers are open to sharing their experiences and should be utilized prior to starting construction. Corning can assist with lessons learned from a supplier perspective as well as provide access to other carriers that have experienced large FTTH builds.

d. Interoperability and quality: Ensuring that equipment is able to operate with next generation specifications such as the G.984 ITU standard (or similar) will be key to avoid future cost of rework. Utilize a small number of large manufactures that have products that can interoperate or substitute to avoid risks of lack of supply due to inability to scale or production errors.



Q15. Are there any regulatory issues in providing internet facility through Wi-Fi Hotspots? What are the reasons that installation of Wi FI hotspots has not picked up in the country? What type of business model needs to be adopted to create more Wi FI hotspots?

We believe these deployments are around the corner in India. Wi-Fi hotspots can only be as effective as the networks that they are connected to. So without a robust, fiber-based access network, the business case for mass Wi-Fi deployment is weak.

Q16. What are the other spectrum bands which can be unlicensed for usage of Wi FI technology or any other technology for provision of broadband?

Not applicable to Corning.

Q17. How much spectrum will be required in the immediate future and in the long term to meet the target of broadband penetration? What initiatives are required to make available the required spectrum?

Every country's spectrum needs are different but there is a direct relation between mobile data traffic and available radio spectrum. The total spectrum licensed to wireless operators in the US is approximately 478 MHz and the Federal Communications Commission (FCC) has predicted that the wireless operators will have a 275 MHz spectrum deficit by 2014 if no new spectrum is allocated. Operators are going to need this new spectrum to build out their LTE networks and support critical applications such as Voice over LTE (VoLTE) and eventually move to LTE-Advanced. The FCC has set a goal of allocating 300 MHz of spectrum over the next five years with the eventual goal of 500 MHz by 2020. Some of this spectrum will be available by reallocating spectrum currently used by television broadcasters, mobile satellite providers and additional blocks from the current (AWS, WCS) bands.

But, even with more spectrum, effective management is one of the most critical requirements – certainly this will be true to meet a target of 512 Kbps per POP. Allocating new spectrum is probably the easiest method of improving your wireless broadband network but it is also expensive and fairly complex. Even though spectrum needs of each country are different, some of the following principles may help in improving your wireless broadband penetration:

- **Smarter allocation of spectrum**
  All radio spectrum is not necessarily equal – spectrum should be allocated or assigned depending on the use case. For instance, the lower frequency bands such as 700 MHz have significantly better propagation outdoors and are much better suited for outdoor environments while higher frequencies such as 2.6 GHz and 3.5GHz are very good for in-building applications because of decreased interference, improved sectorization and frequency reuse.

- **Flexible allocation of spectrum for new technologies, services and future market needs**
  In addition to improving spectral efficiency of 3G frequency bands (HSDPA, HSPA+, etc.), allocating new spectrum for LTE/LTE Advanced technology will significantly improve spectral efficiency because of some of the advanced features that are built into the LTE/LTE Advanced specification. For instance – Coordinated Multipoint (CoMP) on LTE Advanced is a technique that improved the utilization of the network and the overall quality for the end user.

- **Fair, efficient and transparent process of awarding licenses**
  There are several methods of awarding spectrum licenses such as comparative hearings, lotteries, auctions, etc. Going forward, market based licensing policies will play a critical role in ensuring that the benefits of telecommunications technologies and services are made available to the widest range of people in the most timely and efficient manner. Competitive bidding or auctions have proven to be effective at spectrum management because market forces and not government regulators are better able to decide what technologies and services are required by the consumer.

Q18. Are there any other spectrum bands apart from the ones mentioned in Chapter 2 to be identified for provision of wireless broadband services?

Need additional time to craft a response.

Q19. What are the measures required to encourage Government agencies to surrender spectrum occupied by them in IMT bands?

Treating spectrum as a national asset is likely the best method. Which would imply that any organization or company-whether government or privately owned, is borrowing its use in line with the guidelines established by the government. In this environment, the value of the spectrum is unlocked, and individual agencies cannot resist or block return of such asset to the government if required, based on the guidelines.

Q20. What should be the time frame for auctioning the spectrum in 700MHz band?

N/A

Q21. Do you agree with the demand side issues discussed in Chapter 5 and 6? How can these issues be addressed? Please also indicate any other issues on the demand side which are not covered in the CP.

This question requires separate answers: one for urban areas and one for rural areas:

In urban centers

It is our belief that if the infrastructure exists, the value it creates for individuals is so great, that all other perceived impediments will be removed. Much like building roads creates demand for vehicles and that there is no need to educate consumers on the benefits of cars before building such roads.

Please consider that all major telecom operators in India are already struggling with oversubscribed networks, not lack of consumers. And broadband use in India has only just begun. Imagine what would happen to the networks when the next 50M Indians get on line.

The issue is purely a supply-side issue. The industry and its economics will ensure that demand side issues are addressed.

In rural India

Here is where all the demand side topics discussed in your document are true and very important to consider. Since rural India deals with 2 issues-access and poverty, demand side issues in these areas are most likely solved by a combination of PSU builds (as mentioned in our comments earlier) and government subsidy-either provided directly to consumers, or to telecom operators for building networks.

Q22. Please give your comments on any related matter, not covered above.

The Costs of Deploying High-Speed FTTP Broadband in Australia

An External Perspective

Prepared for: CORNING

Prepared by: CSMG

November 2013

Table of Contents

1. Executive Summary

Summary of Cost Model Findings

- ☐ We estimate that the cost to provide high-speed FTTP broadband to 93% of Australian premises by 2021 in accordance with existing NBN Co plans would be $36.9. This is $0.5B less than the estimate included in the NBN Co 2012 Corporate Plan.
- ☐ Changes to existing NBN Co plans could reduce the cost of deploying FTTP relative to our base FTTP cost estimate by 24%, resulting in a lower estimated cost of $27.9B. Specifically, the NBN Co plan includes certain provisions that drive significant costs, and on-going developments in fibre broadband delivery technologies combined with cost-sensitive deployment approaches could be applied to further reduce deployment costs.
- ☐ A cost-efficient deployment of FTTP would cost only $3.0B more than an alternate deployment that is predominantly FTTN over a 10-year time horizon; however, after considering the eventual cost of upgrading FTTN infrastructure to FTTP, a one-time comprehensive FTTP deployment would be $6.5B less expensive than long-run FTTN costs of $34.4B.
- ☐ There are additional cost reduction methods that could be pursued, such as building Fibre to the Basement for all multi-dwelling units – one approach would drive $1.2B in additional savings relative to a cost-efficient deployment of FTTP, reducing overall costs to $26.7B.

1.1 Introduction

There is broad agreement that it is important for Australia to modernise its telecommunications infrastructure. Universal access to high-speed broadband has the potential to be a critical enabler of innovation and productivity. The task of identifying the optimal approach to meeting Australia's broadband needs is a complex one. In September 2013, the Government initiated a 60-day review process to examine alternatives in detail.

In support of this objective, Corning commissioned CSMG to develop a rigorous, bottom-up cost model to evaluate the trade-offs of various deployment approaches. This report lays out our methodology, analytical approach, the results of our analysis, and the implications.

1.2 Cost Model Overview

Our cost model was designed to achieve three objectives: We (I) estimate the baseline nominal Capex requirements for deploying FTTP in accordance with NBN Co Corporate plan specifications, (II) consider an alternate scenario under which an FTTP deployment is optimized to reduce costs, and (III) compare these costs to the long-run cost of deploying FTTN to the majority of Australians:

I. **Baseline FTTP:** To enable the bottom-up modelling of a nation-wide FTTP deployment, we first established the necessary FTTP architecture. Network requirements were based on those included in the NBN Co Corporate Plan, and where necessary assumptions were made based on technological capabilities, industry best practices, primary research, and third party benchmarks. We then used Australia-wide geospatial data sets with exchange, end user premise, and road locations to estimate aggregation nodes and plant requirements. Network elements and labour to deploy the required architecture were then costed.

II. **Optimized FTTP:** To estimate cost reductions that could be achieved by varying network specifications, benchmarks from other FTTP deployments were obtained and evaluated to identify reasonable cost savings techniques. Input assumptions in the baseline FTTP model were then adjusted to reflect the implementation of these cost reduction practices, and the FTTP cost estimates were revised accordingly.

III. **Long-Run FTTN:** To estimate the costs of an FTTN deployment, a similar bottom-up model was developed based on network requirements included in the April 2013 Coalition Plan using the same principles as the FTTP model. In addition to Capex estimates, operating expenses beyond those required for a FTTP deployment were considered over a 10-year time horizon, and the long-run costs of eventually upgrading FTTN premises to FTTP in a second deployment stage were estimated.

1.3 Summary of Results

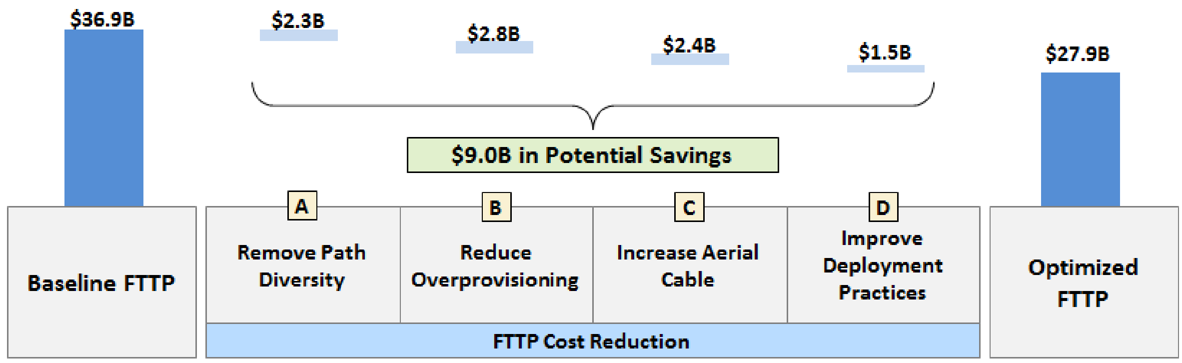
We estimate that the cost to provide FTTP broadband to 93% of Australian premises by 2021 is $36.9B. This estimate is based on network specifications and deployment practices that are described in the 2012 NBN Co Corporate Plan, and is $0.5B less than the $37.4B estimate included in that plan. Accordingly, our results are largely consistent with estimates released by NBN Co.

However, we find that by implementing changes to the network specifications and deployment practices included in the NBN Co plan, estimated costs could be further reduced by 24% to $27.9B. These cost-saving adjustments are based on on-going developments in fibre broadband delivery technologies as well as the implementation of cost-sensitive deployment approaches. Specifically:

Cost Optimization	Description
A. Remove Network Path Diversity	• Deploying a common hub and spoke architecture instead of rings decreases redundancy in the network, but also streamlines deployment • The change leads to reduced deployment costs, including duct construction and distribution joints
B. Reduce Fibre Over-provisioning	• Reducing fibre over-provisioning per premises leads to a reduction in labor costs (e.g., fibre splicing and hauling) and materials costs (e.g., smaller cable sizes, reduced need for certain equipment)
C. Increase Aerial Cable Use	• Increasing the use of aerial plant deployment reduces the need to use existing Telstra ducts or to build new underground plant • This reduces many costs including labour, conduit, duct, and trenching
D. Improve Deployment Practices	• Customer connect costs can be reduced by constructing the drop to the premises on a demand basis, which reduces all associated drop costs by the percentage of premises that do not take up service • Improved installation/testing of fibre hubs, in-premises installation practices, and improved design practices further reduce costs

This Optimized FTTP model (i.e., "Optimized FTTP") represents a cost effective alternative to the specifications included in the current deployment plan.

Figure 1.1: FTTP Cost Reduction (Nominal Dollars)



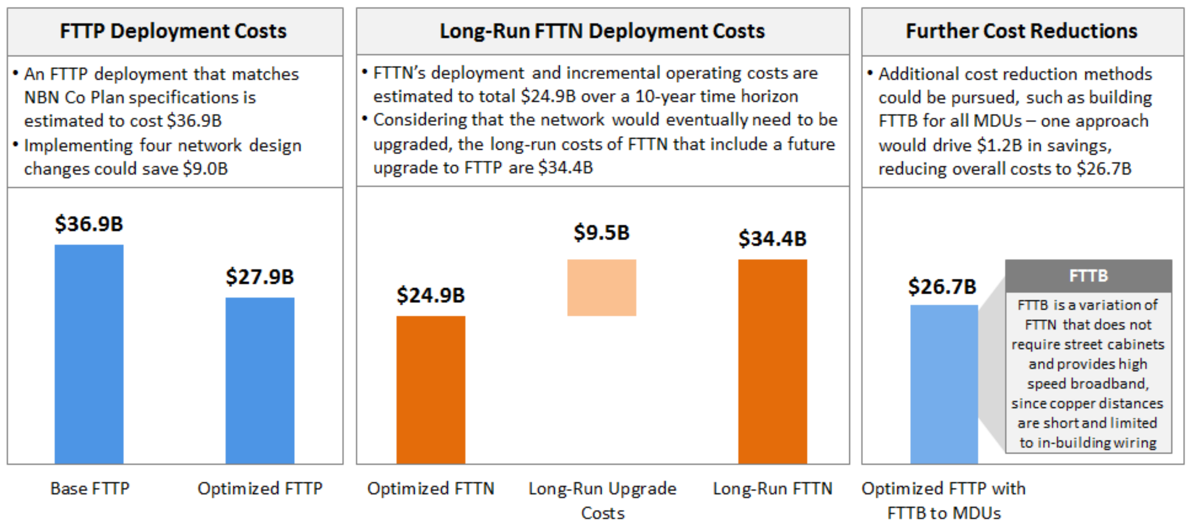
When comparing the costs of the Optimized FTTP model to those of an alternative FTTN deployment over a 10-year planning horizon through 2024, the cost trade-off is modest (refer to Figure 1.2). Specifically, FTTN deployment costs and incremental operating costs over this period would be $24.9B, only $3.0B (10%) less than deploying the Optimized FTTP network. While we did not model network revenue, this $3.0B difference between FTTN and Optimized FTTP could be made up with less than $2 in additional monthly revenue from each premises connected over a 20-year period.

In addition, an FTTN network would be inferior to an FTTP network in many ways. Current technologies would limit download and upload speeds relative to FTTP capabilities, and the future generations of FTTN technologies such as G.fast have high levels of uncertainty relating to speeds, cost, and additional network requirements.

After considering the eventual need to upgrade FTTN locations to FTTP, the cost of a two stage deployment increases to $34.4B. A one-time FTTP deployment costing $27.9B would be 19% less expensive. This $6.5B difference is in part due to the inefficiency of first upgrading the copper network before building an FTTP network, as certain network investments would be stranded, and the project would incur additional planning and management expenses.

Finally, there are additional methods that could be pursued to reduce costs below the $27.9B Optimized FTTP estimate. One example would be to deploy Fibre to the Basement (FTTB) for MDU premises, which is a variation of FTTN. This adjustment could drive $1.2B in additional savings relative a cost-efficient deployment of FTTP, reducing overall costs to $26.7B.

Figure 1.2: Summary Deployment Costs (Nominal Dollars)



Deploying the Optimized FTTP model to 93% of premises offers a number of benefits. It is considerably less expensive than existing NBN Co plans, and is only marginally more expensive than deploying FTTN. Once the long-run costs of upgrading an FTTN network are considered, the FTTP deployment has lower costs, and the majority of Australians would receive future proof FTTP connectivity quickly without the need for subsequent deployments. This type of FTTP deployment approach balances short and long-term costs and benefits for Australia.

The remainder of this paper is organised as follows. In Section 2 we describe our modelling methodology, in Section 3 we explain our cost estimates, and in Section 4 we summarize our conclusions.

2. METHODOLOGY

Our models were designed to meet a number of criteria so that our Capex estimates are comparable to that of the existing NBN Co Corporate Plan. Specifically, the models:

- Cover the same time period (i.e., 2011-2021)
- Use the same premises count assumptions (the number of homes/businesses connected)
- Hold common costs constant (e.g., transit, fixed wireless and satellite)

To model FTTP Capex requirements, we took a bottom-up approach to estimate all costs of deploying the network based on Australia's existing exchange locations, Australia's unique geography, and specific architecture requirements.

This process was completed by first mapping actual exchange locations and their service area boundaries and then overlaying Australian dwelling and business location data to identify areas that would require service. We then modelled the service areas according to NBN Co network deployment architecture as follows: We identified Fibre Aggregation Node (FAN) sites, which are serving areas larger than exchange offices, and usually established where an exchange office is located; each FAN Site serves several Fibre Distribution Hubs (FDHs) through its distribution network; FDHs were organized into Fibre Service Area Modules (FSAMs), each of which are collections of up to 16 FDHs; each FDH provides FTTP connections to premises within a Fibre Distribution Area (FDA).

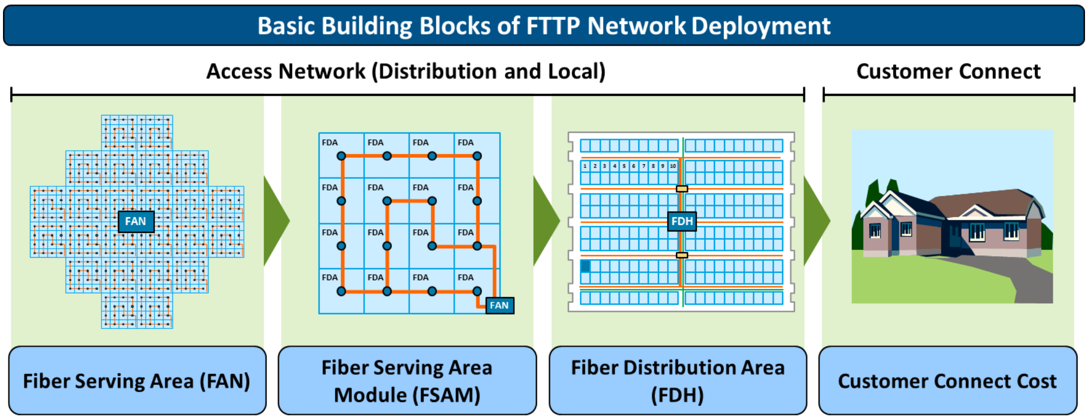


Figure 2.1: FTTP Network Structure

To estimate plant requirements, we used a spanning tree algorithm that calculates efficient paths to connect FSAMs to FANs along actual road segments in each service area. We then estimated the necessary plant to connect FDHs within the FSAMs and the connectivity required between FSAMs. Costs for each FAN service area were then estimated based on network access and customer-connect equipment and labour that would be required to deploy the modelled architecture.

The FTTN model uses the same structure as the FTTP model, with a revised architecture that:

- Accounts for the need to utilize a larger number of exchange sites
- Includes fibre deployment to street-based VDSL cabinets
- Utilizes existing copper networks to connect street-cabinets to FTTN premises

- Provides fibre connections to Greenfield premises, premises without suitable copper to support minimum VDSLs speeds, and the basements of MDUs
- Can be upgraded to FTTP in the future

Additionally, the FTTN model includes other network requirements and constraints included in FTTN plan released by the then Coalition Government in April 2013 (e.g., speed requirements).

2.1 Macro Assumptions

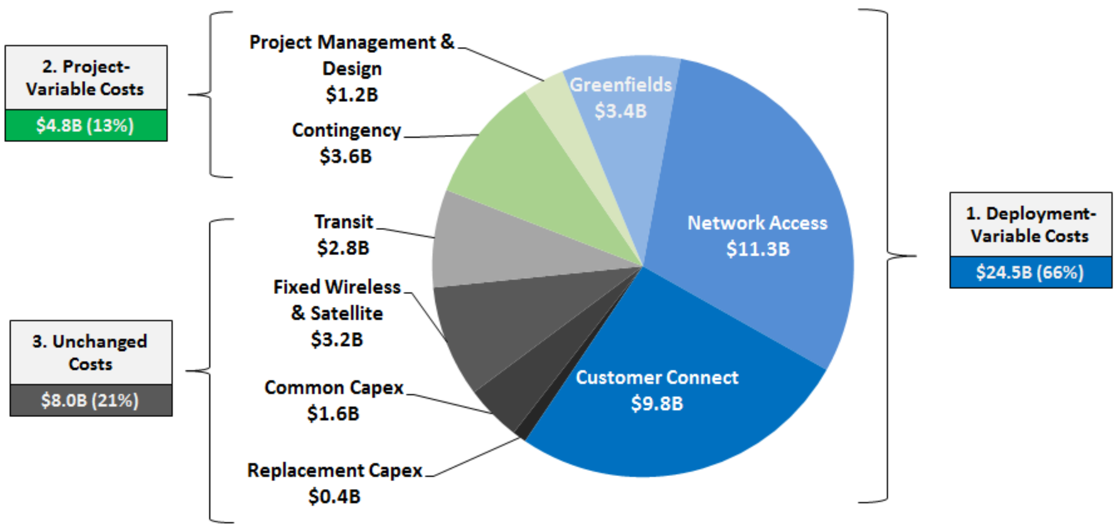
Our assumptions regarding total premises and costs other than deployment Capex were based on data included in the NBN Co Corporate Plan. The NBN Co Corporate Plan includes the following breakdown of premises at the end of 2021, and we assume these premises counts at the end of 2021 to ensure estimates are comparable:[1]

Figure 2.2: NBN Co Corporate Plan Premises by Type (2021)

Location Type	Premises
Brownfield	10,091,000
Greenfield	2,111,000
Total Wireline Premises	**12,202,000**
Fixed Wireless & Satellite	974,000
Total Premises	**13,176,000**

NBN Co also released a breakdown of the Plan's $37.4B Capex by cost type:

Figure 2.3: NBN Co Corporate Plan Capex by Type - $37.4B Total (Nominal Dollars, 2011-2021)



We have grouped these cost types into three categories, each of which was treated differently in our FTTP cost model:

[1] NBN Co 2012-2015 Plan, p. 37. Note: Brownfield premises represent existing housing units. Greenfield premises represent new housing units and are assumed to be 50% new developments (i.e., new housing communities) and 50% infills (i.e., new housing units within existing communities).

1. **Deployment-Variable Costs:** Network Access, Customer-Connect, and Greenfield costs, representing $24.5B or 66% of the NBN Co Capex estimate, were independently estimated.

2. **Project-Variable Costs:** The following costs, representing $4.8B or 13% of the NBN Co Capex estimate are not directly tied to per premises deployment:

   - **Project Management & Design:** These costs were assumed not to vary in the FTTP deployment, but were assumed to be 50% greater in a FTTN deployment that included FTTP for certain premises (e.g., Greenfield premises) to account for the added complexity of deigning and managing the deployment of two architectures.

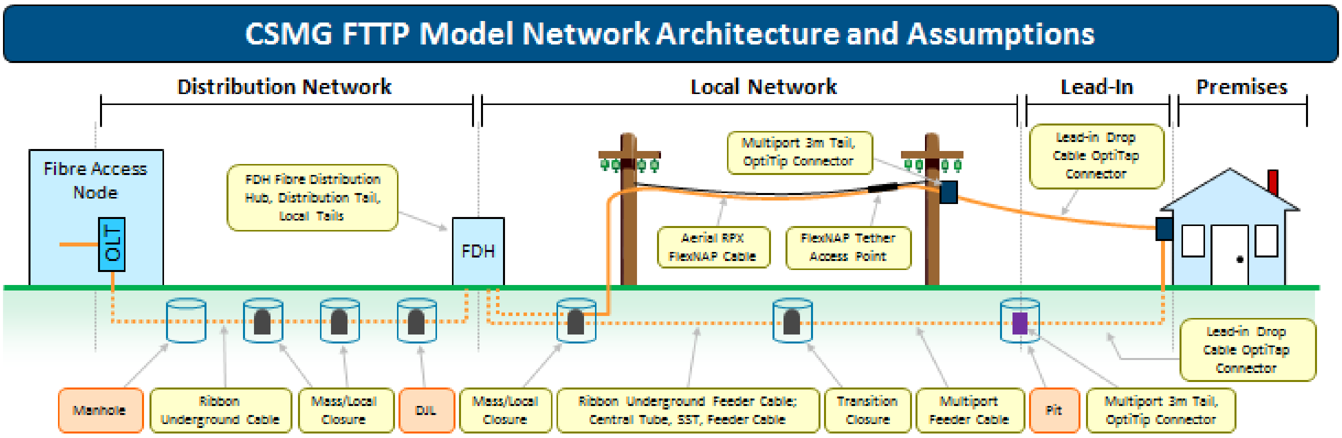
   - **Contingency:** Contingency costs of 10.7% of overall Capex are assumed by NBN Co. We assume they maintain the same proportion of the estimated Capex.[2]

3. **Unchanged Costs:** The remaining costs, representing $8.0B or 21% of the NBN Co Corporate Plan Capex estimate, were not independently estimated. Accordingly, we flow these costs into all of our Capex estimates without changes.

2.2 FTTP Network Architecture

FTTP deployment Capex requirements are based on a network architecture that is consistent with both NBN Co Corporate Plan specifications and best practice FTTP approaches. Based on these requirements, we modelled the FTTP architecture as follows:

Figure 2.4: FTTP Architecture



Architecture segments fall into the following categories:

- **FANs:** Fibre Access Nodes (FANs) are the main building blocks of the FTTP network architecture, providing the connection between the transit network and the access network. Each FAN site serves a Fibre Serving Area (FSA) through its distribution network connecting to several Fibre Distribution Hubs (FDHs). FDHs are organized into Fibre Service Area Modules, logical groupings containing up to 16 FDHs. Every FDH cabinet has a capacity of 576 fibres and can serve up to 200 premises with 2.9x overprovisioning.

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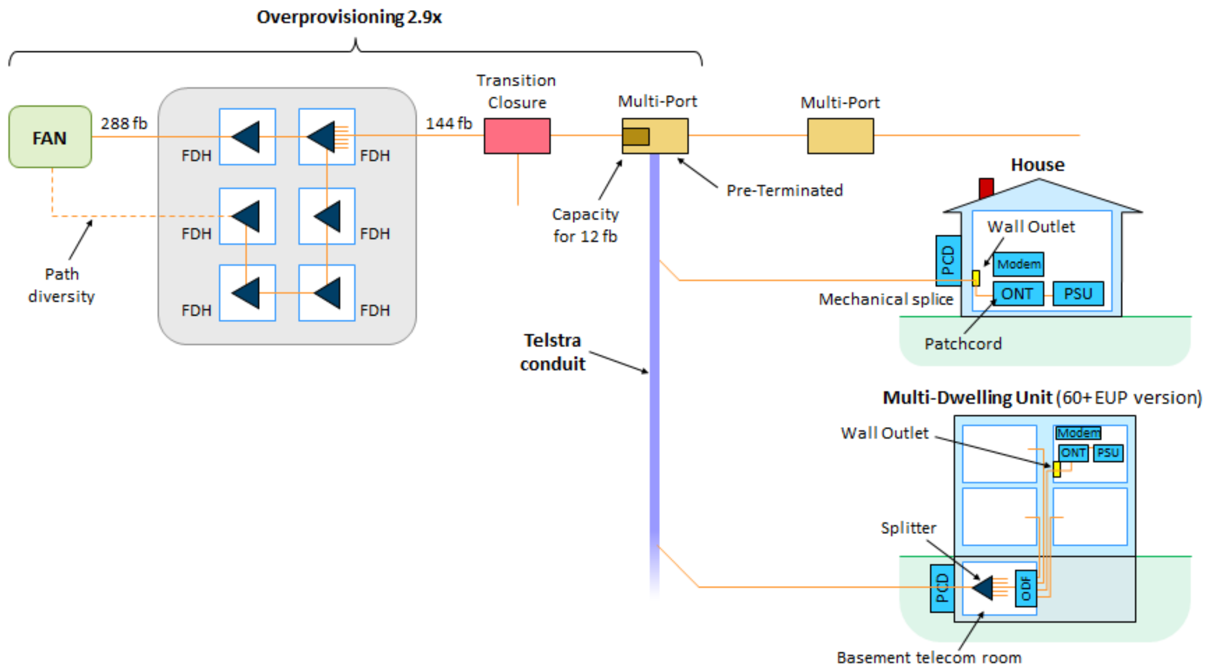
[2] NBN Co, Report to Parliamentary Joint Committee on the National Broadband Network, 19 April 2013, p. 4. Note that the reports states that it includes "a contingency of 10%," but the costs calculate to 10.7%.

- **Distribution Network:** The Distribution Network connects all of the FSAMs (groups of FDH cabinets) back to the FAN Site through two diverse paths. A large portion of the distribution network conduit is already available and a small portion needs to be constructed in cases where the ducts are full or there is need to build path diversity.
- **Local Network:** The Local Network connects the premises to the splitters inside the FDH cabinets. The Local Network can be aerial or underground while the distribution network is always underground. For underground plant, there are transition closures and network access points (i.e., multi-ports) between the FDH cabinets and the premises. Each multi-port serves 4 premises and every 10 multi-ports connect to a transition closure which in turn connects to the local closure next to the FDH cabinet. For aerial plant, instead of the transition closures, there are FlexNAPs next to each Multiport that feed each multiport with 12 fibres. The network is overprovisioned by 2.9, i.e. for each 1 premises there are 2.9 strands of fibre reserved between the multi-port and the FAN Site.[3]
- **Lead-In:** The lead-in network to each premises can also be underground or aerial. Underground deployments will either use Telstra ducts or require new conduit construction. Aerial deployments are typically combined with aerial local network since cross-overs from underground local network to aerial lead-ins are not common.
- **Premises:** The construction of the lead-in is followed by installation of the lead-in cable which terminates on the outside wall of the premises with a mechanical splice inside a Premises Connection Device (PCD). The PCD is connected to a wall outlet inside the premises which in turn connects to the Optical Network Terminal (ONT). For Multi-Dwelling units with over 60 units the splitter is installed inside the basement telecom room instead of the location of the cabinet.

Figure 2.5: FTTP Premises Connect Architecture



[3] Estimates based on interviews with industry experts and NBN CO network planning documents

- **Other Considerations:** For Greenfield Infills and Greenfield New Developments, the lead-in construction is assumed to be provided by the property developer. In Greenfield New Developments, the construction of the local network up to the FDH unit is also assumed to be provided by the developer. In the case of MDU Units, the in-premises installation includes inside wiring to in-unit ONTs and the Consumer Premises Equipment ("CPE") installation.

2.3 FTTP Geospatial Modelling

Geospatial modelling formed the foundation of our bottom-up Capex estimate by providing Australia-specific geographic information that was then leveraged to estimate required network infrastructure requirements and Capex costs.

2.3.1 Modelling Approach

The geospatial modelling process was completed in 7 steps:

1. **Map Telstra Exchange Locations:** All Telstra exchange boundaries and exchange locations were mapped using a telecom exchange infrastructure database and comprehensive Australian map and road data.[4] Together these elements provide a detailed view of service area sizes and geospatial boundaries throughout Australia.

Figure 2.6: Example Exchange Map[5]

2. **Overlay Dwelling and Business Premises:** We then overlaid Australian dwelling and business location data onto the map to estimate the number and location of premises in each service area, as well as the relative premises density of different regions within service areas. This was completed using 2011 Australian Census data and census area geospatial boundaries available from the Australian Bureau of Statistics.[6]

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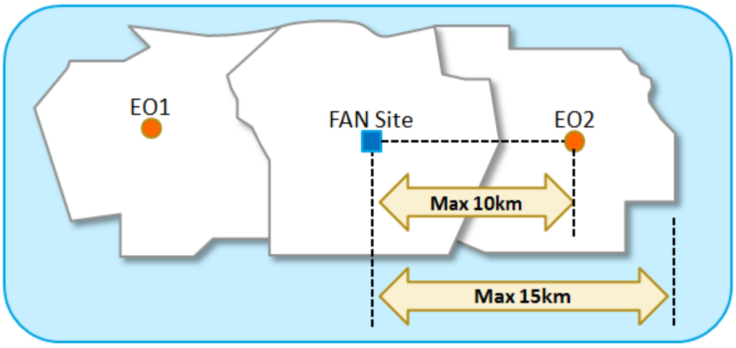
[4] Pitney Bowes, Experian
[5] Exchange boundaries in green, and exchange locations depicted by the diamonds
[6] Dwelling data was used at Statistical Area Level 1 (SA1), including dwelling counts and statistical area boundaries, which include 54,805 distinct areas with populations ranging from 200-800. Business data was

3. **Distribute Premises Along Road Segments:** Premises were then evenly distributed along road segments. Limiting distribution to road segments eliminates regions within census areas that would not require FTTP service because they are not accessible by road.[7]

4. **Remove Premises Covered by Fixed Wireless and Satellite:** Communities representing the least dense 7% of premises that would receive Fixed Wireless or Satellite were then identified and removed from the set of premises to receive wireline service.

5. **Group Exchanges into FAN Sites:** Exchange areas were then grouped into FAN sites using knowledge of NBN Co planned FAN sites where available, and a clustering algorithm that adheres to FTTP GPON constraints (e.g., maximum 15km distance) to group remaining exchange areas.

Figure 2.7: Illustrative FAN Site Grouping



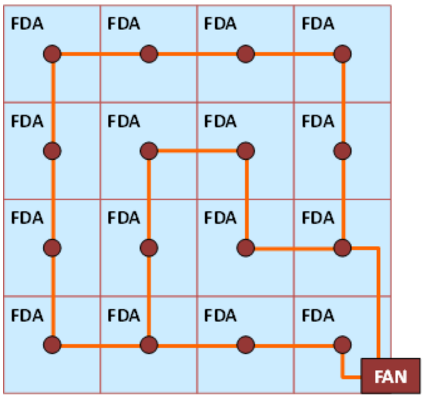
6. **Estimate FSAM Distribution Areas:** The remaining populated territory along road segments was then divided into FSAM distribution areas. Once completed, each FAN service area contained a set of FSAMs that would require up to 16 FDHs.[8]

used at Statistical Area Level 2 (SA2), the most granular level of business data provided by the Australian Bureau of Statistics.

[7] In rare cases in which significant concentrations of premises are located away from public roads (e.g., along private driveways) this method underestimates required street cabinet distribution areas.

[8] Each distribution area could have one or more FSAMs depending on premises density and equipment capacity. Premises within each distribution area were assumed to grow from 2011-2021 such that the total nationwide premises count matches the 2021 premises estimate, while excluding Greenfield New Developments since they would likely require new service areas.

Figure 2.8: Example FSAM Areas



7. **Estimate Required Plant Distribution:** The total length of fibre required to connect the central point of each distribution area to the FAN was estimated using a spanning tree algorithm that calculates distances along actual roads.[9]

2.3.2 Estimates of Required Network Elements

The geospatial model provided key outputs including which exchanges would be included in the deployment, the number of FDHs that would be required in each distribution area to support FTTP, and the length of fibre backhaul required to connect nodes in each service area.

The following table summarises these key output metrics:

Figure 2.9: Summary Geospatial Modelling Estimates by Geotype[10]

Metric	Dense Urban	Urban	Suburban	Rural	Total/Average
Total FANs	4	222	206	508	**940**
Percent of Total Premises	3%	76%	13%	7%	**100%**
Total FDHs	2K	47K	8K	5K	**62K**
Percent of Total FHDs	3%	75%	13%	8%	**100%**
Premises/FDH	200	199	193	169	**195**
FDHs/FAN	444	192	37	9	**60**
Distribution Network (Km)	0.5K	34K	19K	34K	**87K**
Distribution Network / FDH (Km)	0.25	0.7	2	6	**1.3**
Local Network (Km)	3K	85K	18K	12K	**118K**
Premises/Local Network (Prems/km)	146	109	88	73	**103**

[9] The road-based distance calculation begins at the nearest intersection to the starting and ending points, which systematically underestimates the required distance. This bias is likely somewhat offset by the fact that FDHs would not necessarily need to be located in the centre of each distribution area.

[10] FANs were categorised into geotypes using the following criteria: Dense Urban – 3,000 premises/km, Urban – 150-3,000 premises/km, Suburban – 40-150 premises/km, and Rural < 40 premises/km

2.4 Cost Modelling

Using data outputs from geospatial modelling, bottom-up cost estimates were developed for each segment of the network. The following types of premises were treated differently within each FAN:

- Brownfield Single Dwelling Units ("SDUs") and Multi-Dwelling Units ("MDUs")
- Greenfield New Developments SDUs and MDUs

Cost modelling for Brownfield and Greenfield premises was completed using the same approach, with specific adjustments at certain parts of the network, as described in section 2.4.5.

2.4.1 FAN Sites

There are several cost components at the FAN Site. Each FAN Site holds Optical Line Terminals (OLTs) based on the number of premises served within the FAN area at the take-up rate, and Optical Distribution Frames (ODFs) which are also dependent on number of premises served at the take-up rate. Each FAN site has a labour cost, which includes pit preparation outside the Exchange offices, fibre runners, installation of racks and ODFs, cooling, and power. The cost of splicing at the FAN site depends on cable size, and is calculated on a per-splice basis that includes cable preparation requirements.

2.4.2 Distribution Network

FSAMs were categorised into dense urban, urban, suburban, or rural geotypes.[11] Distribution network costs (i.e., costs from the FAN to the FDHs) were estimated based on plant requirements and the estimated Australia-specific costs of distributing plant from the FANs to each FSAM area. Cost components include:

- Construction cost of the network based on the percentage of existing Telstra duct versus new construction, and variation in trenching and pits/bores based on geotype
- Hauling costs for fibre throughout the distribution network were estimated per km
- Splicing costs were assumed to be one splice per kilometer to account for road turns, obstacles, etc.
- Fibre cable materials cost, which depends on the size of the fibre cable
- Distribution local joints (DJLs) costs, which includes cost per closure and splicing cost

2.4.3 Local Network

The Local Network represents the connectivity between the FDH and the multiport. Major cost components include construction of the network, hauling and fibre material costs, as well as the cost of transition closures, FDHs, and multiport with the associated installation and splicing costs.

- **Fibre:** Local Network construction could be completed in one of three ways: via existing Telstra duct, aerial construction, or underground construction. The breakdown of type of construction varies by geotype:
  - In cases where Telstra ducts were used, a leasing cost was applied per building; for underground build, costs for trenching and pits/bores were applied; for aerial build, a cost was applied per km for make ready and poles, in addition to a cost per FlexNAP

[11] Refer to Figure 2.9

- Hauling costs throughout the local network were estimated per km

- **Equipment and installation:** FDH Cabinet costs included equipment cost for the cabinet and splitter, as well as installation and OTDR testing; Multiport costs included multiport, connector cable, as well as pit remediation where needed, installation and OTDR testing; Transition Closure and Mass Local Closure costs included the equipment, installation, and splicing cost (cost per splice and cable preparation).

2.4.4 Lead-In and Premises

Lead-in and premises customer-connect costs (i.e., lead-in and premises costs) were estimated for MDUs and SDUs. With regard to lead-in, all costs were estimated per SDU or per MDU building, with the following assumptions:

- **Fibre**: Lead-in network construction could be done in three ways: via existing Telstra duct, aerial construction, or underground construction.
  - In cases where Telstra ducts were used, a cost to purchase the conduit from Telstra was applied per building; for underground build, costs for trenching and pits/bores were applied; for the distance between the premises and the multiport, an average of 12m for lead-in construction, varying by geotype.
  - Material cost of fibre along the lead-in network includes connector cables.
- **Equipment and Installation:** Lead-in Installation cost includes the installation of the drop, and differed by SDU and MDU. MDU lead-in installation costs include additional costs of internal cabling and other materials. Each premises also has a Premises Connection Device (OCD) outside the building.

Premises customer-connect costs include all the equipment inside the premises and the associated installation costs. All costs were estimated per MDU end user premises (EUPs) and SDUs with the following assumptions:

- Equipment costs include: Wall outlets, Premises pigtails to connect PCD to wall outlets, Indoor Optical Network Terminals (ONT), Broadband Modems, Power Supply Units (PSU), and Indoor Drop Cables (patch cord).
- Premises installation costs include modem installation.

2.4.5 Greenfield Locations:

For Greenfield New Developments and Greenfield Infills, we modelled costs using the same network architecture and assumptions, with the following exceptions:

- **FAN:** For Greenfield New Developments, we removed all FAN site costs and replaced them with a fixed price for a Temporary Fibre Access Node (TFAN). These are temporary nodes deployed via a road-side cabinet to enable each new development to be connected to the transit network. We also added additional fibre distance per TFAN to account for additional transit network, with the associated construction, hauling, splicing, and fibre material costs at Distribution Network rates.

- **Local Network:** In Greenfield New Developments, there are no costs for the construction of the local network up to the FDH unit, as this is assumed to be provided by the developer.

- **Lead-in Network:** For both Greenfield New Developments and Greenfield Infills, all lead-in construction costs were removed, as lead-in construction is assumed to be provided by the property developer. This does not include the cost of lead-in installation and fibre material.

2.4.6 Cost Aggregation

FTTP costs were calculated and aggregated at two levels. First, for each FSAM area, the cost of the Customer Connect, Local Network, and Distribution Network are aggregated into a total per-FSAM cost. FSAM costs were then aggregated at the FAN Site level depending on their associated FAN area, with the addition of the FAN Site equipment and labour costs.

The calculated costs for FAN service areas were then aggregated with project variable costs and unchanged costs, described in Section 2.1, to estimate the total nominal Capex costs through 2021.

2.4.7 Optimized FTTP Costs

There are certain steps that can be taken to reduce the projected cost of an FTTP network relative to specifications included in existing NBN Co plans. These changes preserve all or most of the benefits of bringing fibre to premises, but eliminate certain avoidable costs of building the network.

Cost Optimization Change	Description	Network Impact
A. Remove Path Diversity	A hub-and-spoke topology instead of ring architecture drives reduced duct construction within FSAMs and from the FSAMs to the FAN Sites. This approach also reduces the number of distribution joints, and their associated splicing and installation costs.	Moving from a ring to a tree architecture marginally decreases network availability.
B. Reduce Overprovisioning	Reducing over-provisioning of fibre from 2.9x to 1.2x per premises effectively means a reduced number of fibres between FDH & Multi-port. This approach reduces splicing cost at the Mass/Local Closure and both sides of the Transition Closure	Reducing overprovisioning has no effect on quality of service to subscribers or the ability to meet demand assuming forecast growth level.
C. Increase Aerial Cable	Greater use of aerial drops (30% vs. 15%) reduces payments for Telstra lead-in conduit (to the premises), and also drives greater use of Aerial Local Network instead of Telstra's existing ducts[12]	Shift to aerial cable has no effect on quality of service to subscribers.

[12] Note that savings from reduced purchase of Telstra lead-in conduit take into account the NBN Co commitment to purchase 2.7M conduits. Increasing aerial drops to 30% leaves more than sufficient premises to meet the take or pay commitments in the Telstra Agreement. Similarly, for the associated increase in use of Aerial Local Network, we assumed no reduction in long-term lease costs for the use of 130K km of existing Telstra ducts under the Telstra Agreement as these payments are also subject to "take or pay" conditions.

D. Improve Deployment Practices	Change to Demand Drop rather than homes passed reduces lead-in costs for those premises that do not take up service (with an assumed 70% take-up rate) Improvements to the following network components can also help to reduce costs: FDH installation/ OTDR testing, In-premises installation, and Design Process (centralized designs w/ automation)	Change to demand drop and more efficient network testing do not impact network quality

2.4.8 FTTN Costs

FTTN costs were modelled using the same approach described above to model FTTP costs with a number of adjustments to reflect the different architecture, and a number of different assumptions. Network requirements and assumptions included in the April 2013 Coalition Plan were taken into account. Specifically:

- 565,000 premises deployed with FTTP by the end of 2014[13]
- 637,000 premises with poor copper quality to receive FTTP[14]
- Greenfield premises to receive FTTP
- MDUs to receive FTTB with no in-building wiring
- The same premises will receive Fixed Wireless and Satellite
- All remaining premises receive VDSL via FTTN cabinets

Based on these requirements and assumptions, the network was modelled using two separate architectures. For the 565,000 premises that receive FTTP by the end of 2014, as well as for Greenfield New Development premises, an FTTP network was modelled. This is based on the fact that existing deployments are, and new Greenfield communities will be, located in distribution areas that are exclusively FTTP (i.e., FTTN street cabinets will not be necessary).

For all remaining premises, modelled a hybrid network architecture that can support both FTTN and FTTP was modelled, for the following reasons:

- While the majority of premises would receive broadband via an FTTN VDSL network, each distribution area would need to potentially support a subset of Greenfield Infill premises or premises with poor copper quality with FTTP broadband.
- MDU premises, which would be spread among service areas, would receive FTTB, thus requiring a direct fibre connection to the building.
- FTTP connections could be requested on-demand, requiring architecture capable of supporting this technology in each service area (i.e., capacity, splitters, and FTTP-capable hardware).

For copper access within the hybrid service areas, vectored VDSL2 is assumed to be installed within cabinets. Up to a sub-loop length of 915m, this architecture allows downstream speeds of 25 Mbps

[13] Coalition Plan Background Papers, p. 31
[14] Estimated by subtracting the 565K completed FTTP premises and 1.6M Greenfield premises from the Coalition's FTTP premises estimate. See: Coalition Plan Background Papers, pp. 30-31

using VDSL2, and 50 Mbps using vectored VDSL2.[15] It is further assumed that the equipment purchased is vectoring-ready and will therefore only require a firmware upgrade in the future to fully enable vectoring.[16]

The geospatial modelling and cost aggregation approaches were similar to those of the FTTP deployment; however, exchanges were not grouped into FAN sites, and distribution areas represent cabinet service areas.

Figure 2.10: Example Distribution Areas

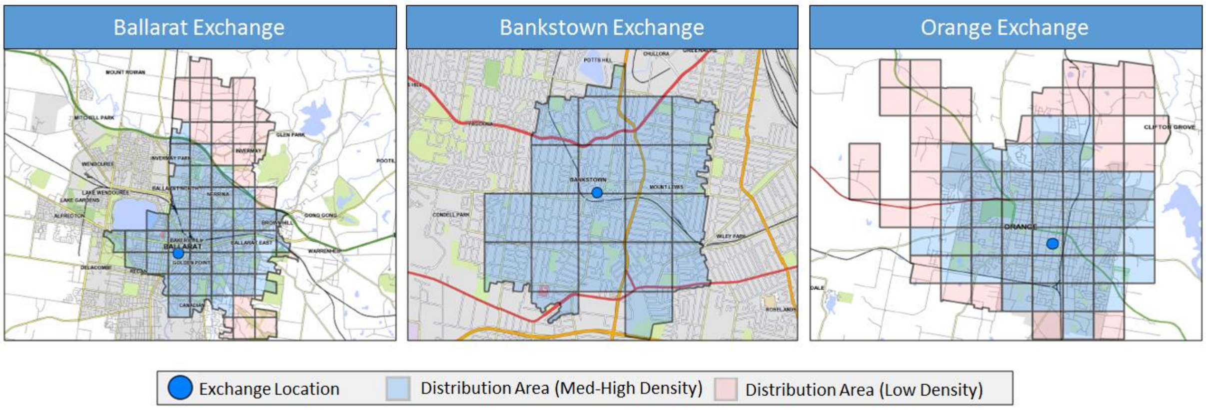
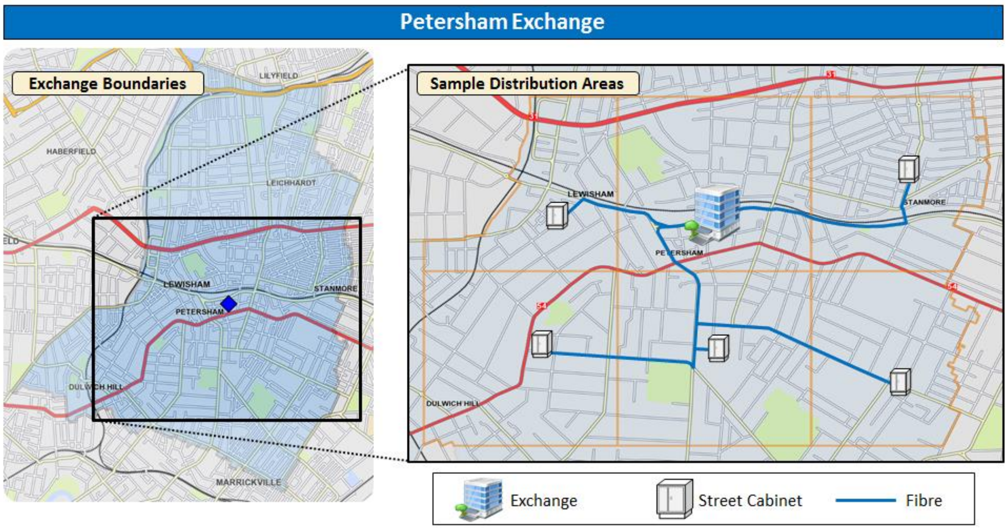


Figure 2.11: Illustrative Example of Modelled Cabinet Placement within an Exchange



Finally, to determine the cost of later upgrading FTTN premises to FTTP, the incremental access costs per upgraded location are estimated using the FTTP specifications based on existing infrastructure that had been previously deployed.

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[15] "Dynamic Spectrum Management for Mixtures of Vectored and Non-vectored DSL Systems", CISS 2010. Note: The network-side DSL equipment has been modelled to be vectoring–ready. This is based on recent market trends, as vectored-ready VDSL DSLAMs are currently offered by a variety of OEM vendors.
[16] Bonding has not explicitly been assumed in the base case due to uncertainty regarding copper quality and available copper pairs.

3. Cost Estimates

Two versions of an FTTP deployment to 93% of Australian premises were modelled: a Base FTTP deployment that is consistent with NBN Co network specifications, and an Optimized FTTP deployment that includes changes to network specifications that reduce costs. A single FTTN deployment was modelled that is consistent with the deployment described in the April 2013 Coalition Plan.

3.1 Base FTTP Costs

The cost to provide FTTP broadband to 93% of Australian premises is estimated to be $36.9B. This estimate is based on network specifications and deployment practices that are described in the 2012 NBN Co Corporate Plan, and is $0.5B less than the $37.4B estimate included in that plan.

Our base estimate of $36.9B is largely consistent with the NBN Co estimate of $37.4B. The primary differences between the estimates are due to customer connect costs:

Figure 3.1: NBN Co Plan vs. Base CSMG Estimate of FTTP (Nominal Dollars, 2011-2021)

Cost Category	NBN Co Plan	Base CSMG Estimate of FTTP	Capex Difference	Percent Difference
General*	$9.6B	$9.6B	$0.0B	0%
Network Access	$12.0B	$12.1B	-$0.1B	0.8%
Customer-Connect	$12.5B	$12.0B	-$0.5B	-4%
Fixed Wireless & Satellite	$3.2B	$3.2B	$0.0B	0%
Total	**$37.4B**	**$36.9B**	**-$0.5B**	**-1.3%**

* Includes transit, replacement, common, and project design and management Capex

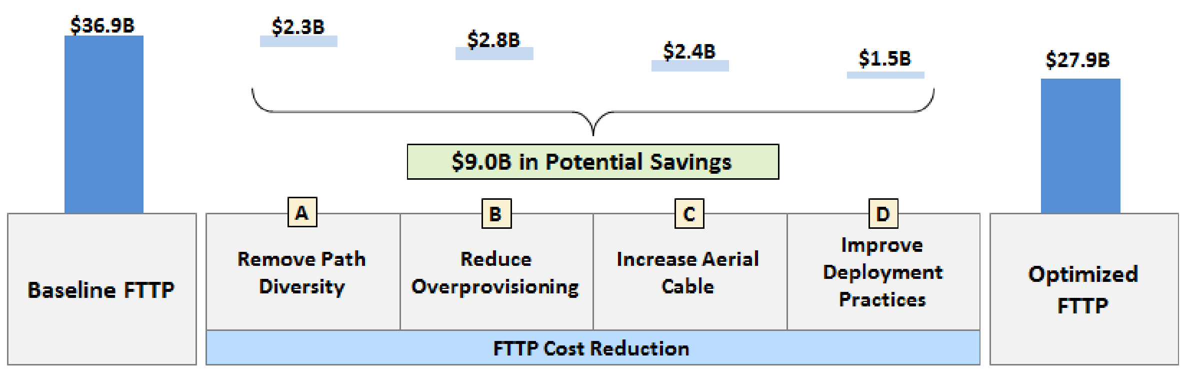
These differences are likely due to slightly differing materials and labour cost input assumptions, and different methodologies used to determine required fibre plant distances.

3.2 Optimized FTTP Costs

By implementing changes to the network specifications and deployment practices included in the NBN Co plan, costs could be further reduced by an estimated 24% to $27.9B. These network changes in the cost-optimized FTTP model are based on on-going developments in fibre broadband delivery technologies as well as the implementation of cost-sensitive deployment approaches.

The following specification changes drive these savings:

Figure 3.2: FTTP Cost Savings (Nominal Dollars, 2011-2021)



The changes in model assumptions for each of these specification changes were based on industry standards and carrier precedents.[17] The 24% reduction in cost was driven by decreases in both network access and customer-connect costs:

Figure 3.3: CSMG Base vs. Optimized FTTP (Nominal Dollars, 2011-2021)

Cost Category	CSMG FTTP	CSMG Optimized FTTP	Capex Difference	Percent Difference
General*	$9.6B	$9.6B	$0.0B	0%
Network Access	$12.1B	$6.5B	-$5.6B	-46%
Customer-Connect	$12.0B	$8.4B	-$3.6B	-30%
Fixed Wireless & Satellite	$3.2B	$3.2B	$0.0B	0%
Total	**$36.9B**	**$27.9B**	**-$9B**	**-24%**

* Includes transit, replacement, common, and project design and management Capex

These savings are considerable, and this Optimized FTTP model represents a cost effective alternative to the more expensive specifications included in the current deployment plan.

3.3 FTTN Costs

Bottom-up FTTN capex costs are estimated to be $22.1B, which accounts for 55% of premises to receive VDSL based FTTN, 38% of premises to receive FTTP or FTTB in the case of MDUs, and the remaining 7% of premises to receive fixed wireless or satellite. For premises that would receive FTTP or FTTB, the same cost-optimization specifications that were included in the Optimized FTTP estimates are assumed. In addition to the FTTN capex costs, $2.8B of additional nominal operating costs that would be incurred from 2015-2024 are included. The addition of these costs raises the total FTTN cost estimate to $24.9B.

3.4 FTTN Operational Cost Considerations

Publically available statements from operators that have transitioned to FTTP and numerous studies indicate that FTTP provides significant operational cost benefits.[18,19,20,21] FTTN networks have higher fault rates and greater maintenance because they distribute active optronics and VDSL equipment in

[17] GPON, VDSL, and HFC networks typically do not include path diversity (e.g., Verizon, BT). Reducing overprovisioning and increasing aerial cable usage are both network architecture approaches used in the US. A global standard is to complete the drop when the customer requests service, while improvements in efficiency via testing are available with new techniques and products.

[18] BIS Shrapnel, a research firm, estimates that a fully deployed FTTP Australian national broadband network would save $700M annually in maintenance costs. See ZDNet, "NBN to save up to AU$700m in copper maintenance costs", 20 August 2012.

[19] The FCC in *DA- 13-807 In the Matter of Connect America Fund, High-Cost Universal Service Support, 2013* states that "fiber networks result in significant savings in outside plant operating costs over time" and "a DSL network… has higher expected operating expenses and is more likely to require significant additional investment"

[19] KT Network Technology Laboratory, *Economics and Methods to Provide Optimal Access Network in Broadband Access Network* puts the FTTP fault rate at about half the VDSL fault rate, 2007

[20] In a study of Verizon, SBC, and Bell South, Bernstein Research found that FTTH would achieve a 100% reduction in central office expense, and a 30-70% reduction in customer service and network maintenance expenses. See Bernstein Research *Technology Transitions Workshop Transcript at 290-92*

[21] See also Analysys Mason: "The Cost of Deploying Fibre-based Next Generation Broadband Infrastructure"

street cabinets near customer premises. These cabinets must be powered and cooled and when there is a fault they are more likely to require a truck roll to the cabinet compared with FTTP networks that centralize active equipment in the exchange.

Furthermore, vectored VDSL, which would likely be required to meet Australia's broadband speed requirements, drives additional complexity and risk. It is less proven because it is just beginning to be implemented today. It is more complex and more subject to external, sometimes intermittent, point-sources of interference. This sort of interference can generate disproportionate trouble calls and truck rolls as it can be very difficult to isolate and correct.

Finally a hybrid deployment, such as proposed by the Coalition Government, would likely incur greater operating expenses than an end-to-end FTTP network because maintaining both fibre and copper networks will require either two parallel workforces, or a single, highly-trained (and larger) workforce that is able to service faults in both network technologies. Operating both copper and fibre networks will also increase the back-office and systems burdens associated with administering the parallel infrastructure.

Estimates of savings vary and different estimates will often include overlapping benefits. Given our need to rely on public data rather than proprietary operator data, we have conservatively selected just two clearly delineated areas of benefit which can be more rigorously quantified: reduced truck rolls for fault repair and reduced energy costs.

For each of these operational costs we calculated the difference between the cost per VDSL premises and per FTTP premises. We then added them together ($34 per premises for reduced truck rolls) + ($18 per premises for reduced power costs) = $52 Opex savings/premises/year. We then multiplied this by the difference between subs served by FTTN/year in NBN Co. plan compared to subs served by Coalition plan.[22] This resulted in total estimated Opex savings of $2.8B from 2015 through 2024. Steady-state per year savings are estimated to be $377M.

Other cost differences between the two plans (aside from truck rolls/fault repair and energy savings) exist, but we have not quantified them as we did not find reliable ways to estimate the amount of the benefit or because the benefit overlaps with a quantified benefit. We believe there would also be significant savings from:

- Fewer customer support calls due to reduced faults
- Reduced real estate costs from fewer exchange sites, reduced floor space, and smaller cabinets
- Fewer transit network lines due to fewer exchange sites
- Lower management costs due to simplified network management systems
- Elimination of costs for inefficient legacy equipment and for the inefficiency of running two networks

3.4.1 <u>Fault Repair Costs</u>

Copper networks have a higher fault rate and require greater maintenance spending than fibre networks. This is due to several factors, including copper's mid-span active components and higher susceptibility to water and other weather effects. In addition, the copper network is old, and media reports, union statements, and other sources have suggested that suboptimal maintenance has

[22] These costs were scaled by deployment schedules.

reduced the quality of the network[23]. In contrast, building over with fibre allows NBN Co to begin with a new network.

The higher fault rate of copper requires more frequent maintenance trips, a larger standing maintenance workforce, and ongoing replacement materials costs.

Based on third-party estimates that VDSL networks have twice the fault rate of FTTP networks[24] and taking into account the number of truck rolls per premises per year for FTTP[25] allowing for the somewhat higher cost of truck rolls to repair FTTP[26] vs. FTTN[27] we find that the savings from reduced truck rolls for fault repair per incremental FTTP premises per year is $34. We have left out customer support call savings for faults that do not result in a truck roll.[28] Based on the difference in fault repair costs and adjusting for relative network coverage throughout rollout, we estimate that incremental fault repair costs of approximately $1.8B over the period of 2015-2024.

3.4.2 <u>Electricity Costs</u>

FTTN networks have significantly higher power requirements than FTTP networks.[29] A study by Jayant Baliga[30] et al. established that FTTP PON requires 7 Watts of energy per premises, while FTTN requires ~14 Watts per premises. Based on these different power requirements, accounting for Australian electricity prices, and adjusting for the network distribution of architectures and scaled deployment, we estimate that incremental electricity costs of approximately $1.0B over the period of 2015-2024.[31]

[23] ABC, "NBN alternative: Is Australia's copper network fit for purpose?", 20 September 2013
[24] Alcatel Lucent as cited by Stephen Wilson in, "Research Viewpoint, NGA operational expenditure" (Analysis Mason, 2013), 15.
[25] Sofie Verbrugge et al. in, "FTTH deployment and its impact on network maintenance and repair costs," *Transparent Optical Networks, ICTON* (2008): 2-5. 10% truck roll/year/premises (FTTP) derived by dividing 0.52 FTTP repair hours/premises/year by a 5.23 hour average repair time/fibre truck roll
[26] EXFO "Go beyond OTDR, leave no faulty network behind" (2011). $534 cost/FTTP truck roll derived by multiplying $100 truck roll cost/hour by 5.23 hour average repair time/fibre truck roll
[27] Sofie Verbrugge et al. in, "FTTH deployment and its impact on network maintenance and repair costs," *Transparent Optical Networks, ICTON* (2008): 2-5. $438 cost/FTTN truck roll derived by multiplying $534 cost/FTTP truck roll by 63% of FTTN faults on fibre side and adding the product of $273 cost/copper truck roll and 37% of FTTN faults on copper side
$273 cost/copper truck roll derived by multiplying $100 truck roll cost/hour by 2.68 hour average repair time/fibre truck roll
[28] BIS Shrapnel, a research firm, estimates that a fully deployed FTTP Australian national broadband network would save $700M annually in maintenance costs. See ZDNet, "NBN to save up to AU$700m in copper maintenance costs", 20 August 2012. Applying that figure over the 2015-2024 period, weighted for rollout, suggests the FTTP plan may yield as much as $5B in maintenance savings. Adjusting for the number of premises that would be affected in a FTTN plan, and for the sub-loop portion that would need to be maintained, we estimate the FTTN plan could have additional Opex of $2.8B from 2015-2024. Additional Opex costs could potentially be greater if NBN Co maintained all copper sub-loops in "Hybrid FTTN/FTTP" areas.
[29] For example, the cabinets require significant power for DSLAMs, air conditioning, and other components, while fibre splitters work passively. Similarly, the copper network is actively energized, in contrast to fibre. There are also greater power requirements for CPE as VDSL modems require more power than fibre ONTs.
[30] Baliga, Jayant; Ayre, Robert; Hinton, Kerry; Tucker, Rodney. "Energy Consumption in Wired and Wireless Access Networks." IEEE Communications Magazine, Vol 49 Issue 6, June 2011, pp. 70-77.
[31] Based on constant power usage

3.5 Eventual FTTN Upgrade Costs

Our FTTN estimate includes the connection of 38% of premises with FTTP or FTTB, but does not include the cost to upgrade the 55% of premises served by FTTN to FTTP at some point in the future. These additional upgrade costs are estimated to total $9.5B, resulting in a long-run cost of an FTTN deployment of $34.4B. This estimate assumes that MDUs connected with FTTB are not upgraded (i.e., any cost to rewire buildings is not included).

There are three main cost inefficiencies of deploying an FTTP network in two stages, with an FTTN network serving as intermediate architecture:

- **Stranded Infrastructure, Hardware, and Labour:** The VDSL cabinets, DSLAMs, and other FTTN-specific hardware could not be reused in the FTTP network, and represent excess expenses that are not on the FTTP upgrade path. In addition, duplicative customer-connect technician time would be required for installation and troubleshooting to migrate customers to each of the network access technologies.
- **Project Management and Design:** There would be additional overhead associated with executing a subsequent upgrade to FTTP.
- **FTTN Network Constraints:** Our FTTP estimate is based on a streamlined fibre network with 940 Fibre Access Nodes and approximately 62,000 Fibre Distribution Hubs, compared with a need to maintain approximately 2,400 exchanges and nearly 70,000 street cabinets in a FTTN network.[32] Once the FTTN network is built, any comprehensive upgrade to FTTP would begin with the less optimal FTTN network structure.

3.6 FTTP and FTTN Comparison

A one-time FTTP deployment costing $27.9B would be 17% less expensive than the long-run FTTN costs of $34.4B. This $6.5B difference in costs are due to the inefficiency of first upgrading the copper network before building an FTTP network, as certain network investments would be stranded, and the project would incur additional planning and management expenses.

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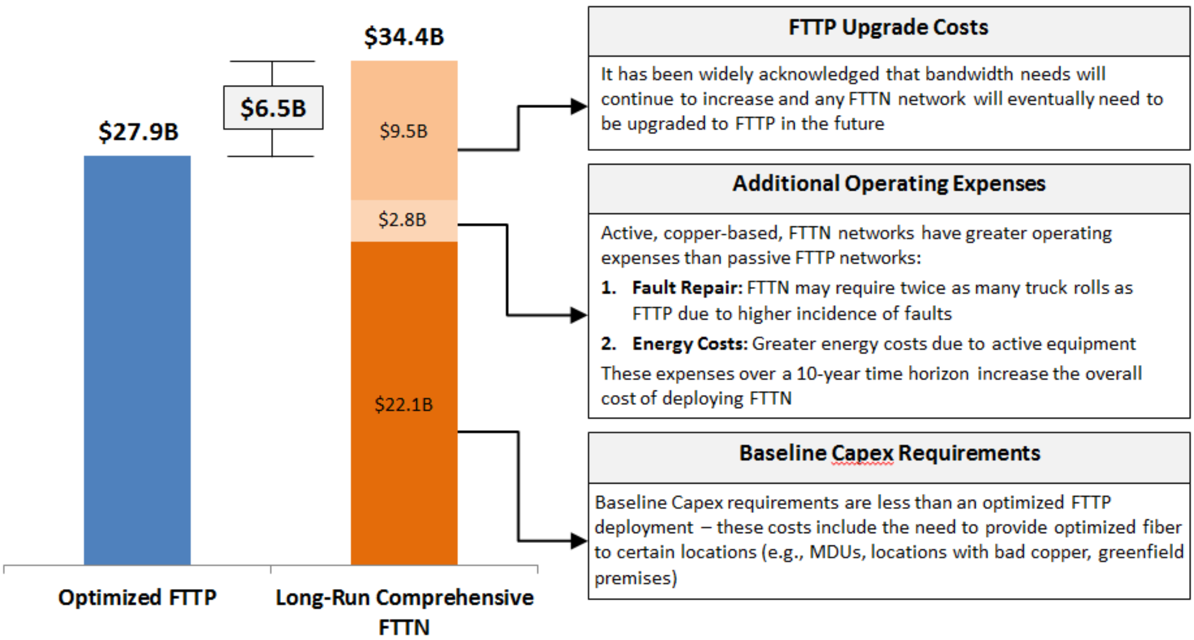
[32] NBN Co Corporate Plan 2013-2016.

Figure 3.4: Optimized FTTP vs. Long-Run Comprehensive FTTN (Nominal Dollars)



Once considering an eventual FTTP upgrade for all wireline premises, such that 93% of premises have FTTP or FTTB, FTTN becomes sub-optimal in the long-run:

- **General Costs:** Additional project design and management and contingency costs would be required to complete the second deployment.
- **Network Access Costs:** The difference in the cost per premises also reflects the stranded FTTN VDSL investments, i.e. active cabinets, VDSL modem equipment and installation.
- **Customer-Connect Costs:** Greater customer-connect costs due to stranded investments are partially offset by a reduction MDU customer-connect costs due to the elimination of in-building wiring when compared with the NBN Co Corporate Plan.

Figure 3.5: Per Premises Capex by Plan*

Metric/Capex	NBN Co FTTP	CSMG Optimized FTTP	CSMG FTTN	CSMG FTTN + Upgrade Costs***
Premises **Percent of Total**	12.20M 100%	12.20M 100%	12.20M 100%	12.20M 100%
General** **Deployment**	$720 $2,010	$710 $1,230	$920 $770	$1,090 $1,400
Total Cost/Premises	**$2,730**	**$1,940**	**$1,690**	**$2,490**

*Excludes Fixed Wireless and Satellite locations
**Includes transit, replacement, common, and project design and management Capex; includes marginal opex from 2015-2024 for CSMG FTTN and CSMG FTTN + upgrade costs
***7.2M premises would be upgraded

Further, when the costs of FTTP are viewed by various demarcation points, it becomes clear that FTTP to the Pit/Multiport is actually less expensive per premises than FTTN. Hypothetically, the network could be deployed to this point, and retail service providers could be responsible for the remaining construction; however, such an approach would have revenue and competitive implications that have not been fully evaluated or considered as part of this study.

Figure 3.6: FTTP Costs to Different Demarcation Points vs. FTTN*

FTTP Cost to Demarcation Point:	Cost per Premises ($/Prem)	Total Cost
Pit/Multiport	$1,250	$15.3 B
PCD	$1,670	$20.4 B
CPE (CSMG Optimized FTTP)	$1,940	$23.7 B
CSMG FTTN*	$1,690	$20.6 B

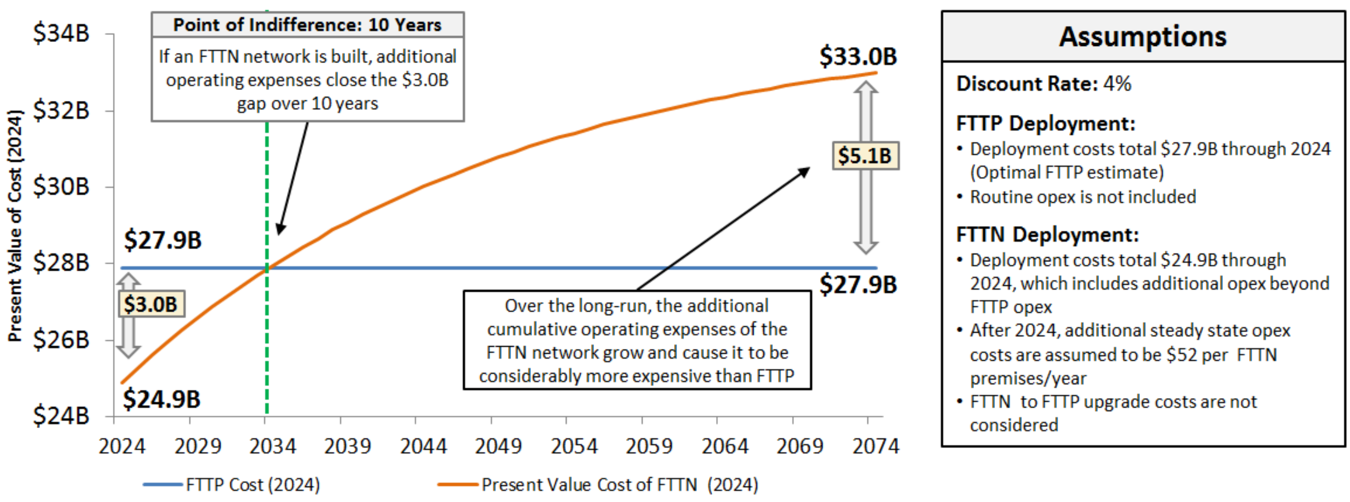
*Excludes Fixed Wireless and Satellite locations; includes transit, replacement, common, and project design and management Capex; includes marginal opex from 2015-2024 for CSMG FTTN

3.7 FTTP and FTTN Present Value Comparison

The Optimized FTTP deployment is more cost effective on a nominal basis than an FTTN deployment with a later FTTP upgrade. When considering the present value of deploying and running the two networks beyond the 10-year initial estimate time horizon, the Optimized FTTP deployment is still preferable over an FTTN network, even without a future FTTP upgrade.

Assuming no future FTTN to FTTP upgrade, the additional operating costs associated with FTTN drive greater costs over time on a present value basis. For example, after 2024, using a 4% discount rate and the steady state additional operating costs assumptions of $52 per FTTN premises previously described in Section 2, the point of indifference is 10 years. After that point, greater operating costs make the FTTN deployment more expensive than the optimized FTTP deployment.[33]

Figure 3.7: Point of Indifference - Optimized FTTP vs. FTTN (Present Value in 2024)



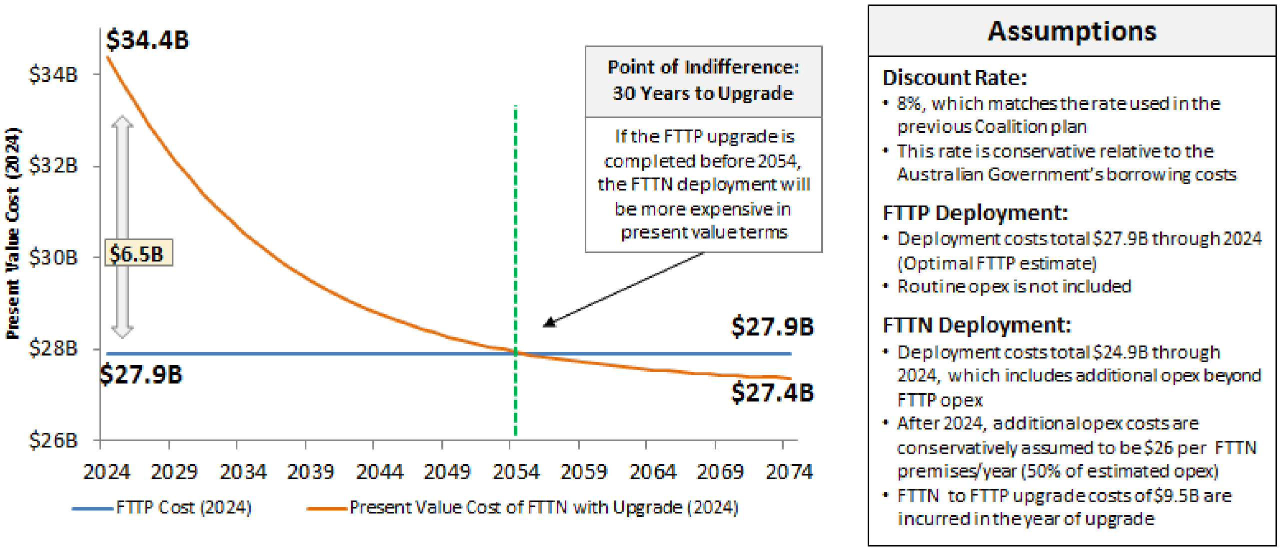
Once an eventual upgrade from FTTN to FTTP is considered, the optimized FTTP deployment is even more favourable. Using a 4% discount rate, and accounting for the incremental steady state

[33] Present value calculations assume nominal costs through an initial 10 year time horizon, during which network deployment would occur, ending in 2024

additional FTTN operating costs, the Optimized FTTP is always less expensive on a present value basis than the FTTN network with a later FTTP upgrade – regardless of the upgrade year.

Using even more conservative assumptions of an 8% discount rate, and assuming additional annual FTTN Opex costs are just $26 per premises, just 50% of our estimate of $52 per premises, the Optimized FTTP network still has a lower present value cost than the FTTN network with a later upgrade, as long as the upgrade occurs within 30 years of the completion of the initial deployment:

Figure 3.8: Point of Indifference - Optimized FTTP vs. FTTN with Upgrade (Present Value in 2024)



Thus the point of indifference, using very conservative assumptions, is that the Optimized FTTP deployment is more cost effective than the FTTN deployment with a later FTTP upgrade if the upgrade occurs any time before 2054.

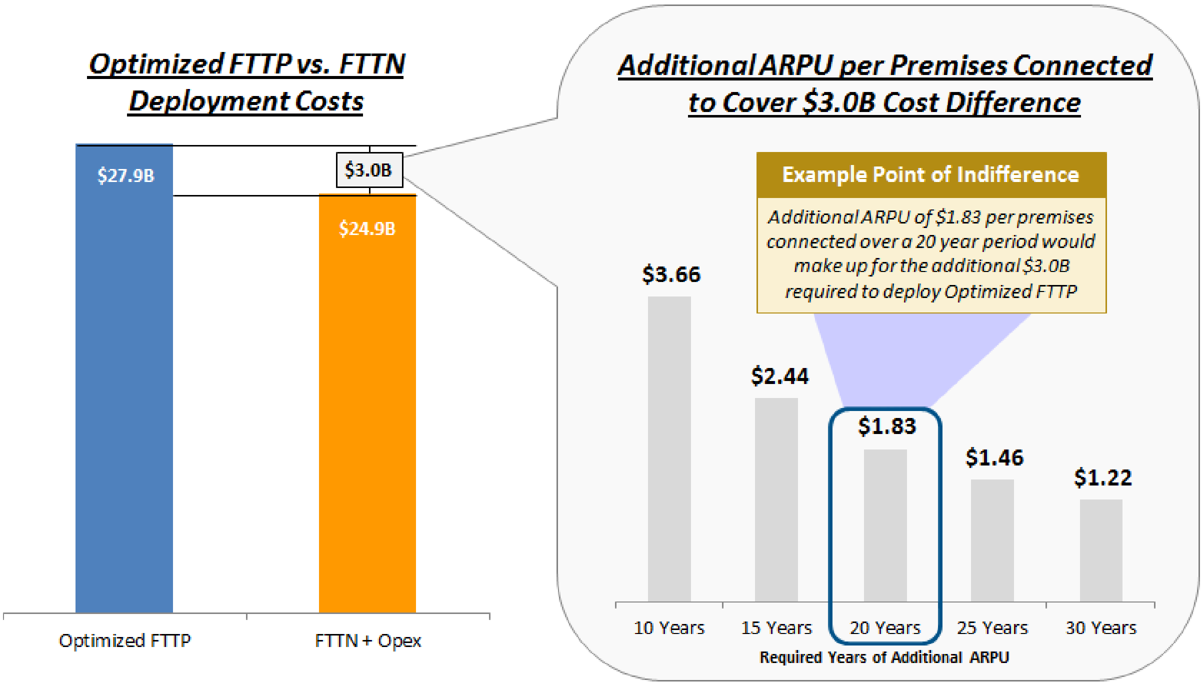
3.8 Revenue and Replacement Cost Considerations

Another consideration when evaluating the $3.0B difference between the Optimized FTTP deployment and the FTTN deployment is the amount of revenue that would make up the difference. Although the focus of this study was on the costs of deployment, revenue is an important factor in the comprehensive cost-benefit analysis.

There are many reasons why an FTTP network should drive greater ARPU across many customer segments. These reasons include the value to consumers of greater download and upload speeds, which could be realized through tiered pricing plans for different levels of service, as well as the potential for business customers to pay a premium for high speed products.

We found only a small increase in the monthly ARPU per premises connected over medium-term time horizons could cover the $3.0B cost difference. For example, for less than $2 per premises in additional ARPU over a 20 year period, the added FTTP deployment costs would be covered. This scenario and others are outlined in Figure 3.9.

Figure 3.9: Revenue Considerations[34]



A second important consideration is the long-run replacement costs of the network. Although an FTTN network has lower deployment costs over a 10-year period, these costs do not account for the eventual need to replace core components of the network, including the copper plant itself. These costs can be substantial, and the required capital should be considered, and potentially accrued for, as part of a long-run network investment planning exercise.

There is precedent for these long-run costs to be taken into account in government network costing. For example, in the U.S., the Federal Communications Commission (FCC) concluded in a recent broadband cost modelling proceeding for deployment subsidies that FTTP networks have lower deployment costs than certain DSL-based networks. In this finding, both the long-run capital and operating expenses of the network were considered.

Specifically, the FCC indicated that, a DSL network "has higher expected operating expenses and is more likely to require significant additional investment to make faster broadband offerings available" and that "Network construction costs are essentially the same whether a carrier is deploying copper or fibre, but fibre networks result in significant savings in outside plant operating costs over time." [35]

While we recognize that in the case of Australia, initial FTTN construction costs would be lower because existing plant could be leveraged, over a long-term horizon there would be substantial plant replacement costs that should be considered. It is for this reason that the FCC adopted a long-term cost model that accrues for eventual plant replacement capital expenditures, as well as the long-run

[34] ARPU analysis assumes 12.2M wireline homes passed, the 70% take rate, and an 80% margin on additional revenue

[35] Refer to *FCC DA- 13-807 In the Matter of Connect America Fund, High-Cost Universal Service Support, 2013*

network operating costs, to compare the costs of FTTP and copper-based deployments. Australia should evaluate the cost-benefit trade-off using a similar long-term framework.

3.9 Considering FTTB Deployment for MDUs

Another option that could be considered is a hybrid deployment of FTTP to all SDUs and FTTB for MDUs, which represent 18% of the 93% of premises covered by FTTP. This change in architecture would reduce fibre wiring and ONT costs. Additionally, fibre deployment and the associated labour costs would be lower in the Local Network since each MDU building could now be served by one fibre, whereas each FTTP premises would have an individual fibre connection. While the abovementioned costs would be reduced, new costs would include installation of a mini DSLAM in MDU buildings and the installation of VDSL modems inside each premises.

FTTN deployed over the last portion of the copper loop as in the case of FTTB can offer broadband speeds close to the theoretical maximum of VDSL (100Mbps[36]), and this adjustment could drive $1.2B in additional savings relative a cost-efficient deployment of FTTP, reducing overall costs to $26.7B. However, despite the Capex savings associated with FTTB, there are a number of challenges. For example, there may be additional operating expenses relative to FTTP for troubleshooting and maintaining the distributed mini DSLAMs, and for maintaining and monitoring two wireline architectures.

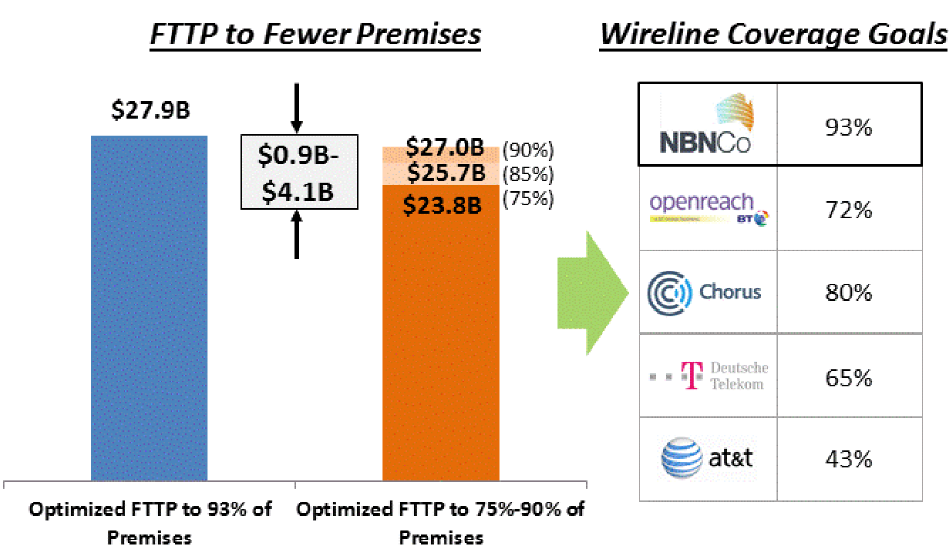
3.10 Revising FTTP Coverage Requirements

Wireline telecom deployment costs are significantly greater in low density, rural areas. FTTP, like all wireline access architectures, can be a costly way to serve premises in low density, rural areas. Wireline coverage of 93% of premises is a high coverage objective compared to many operators' announcements and studies. Operator's plans for wireline coverage have rarely exceeded 80%, due to commercial and density considerations.[37,38,39] Studies have recommended lower wireline coverage levels to prevent cost inflation in rural areas.[40]

We estimate that reducing FTTP coverage to 75% of premises – in line with international coverage benchmarks – could reduce the cost of deploying an optimized FTTP architecture to $23.8B. This figure does not include any additional costs to make up the coverage difference (costs for increased wireless coverage/connectivity were not modeled). However, we believe that increasing the percentage of wireless coverage to serve rural areas can offer a lower cost per premises and significant savings.

[36] Using profile 17a.
[37] Chorus figures refer to commercial FTTN rollout, not pending FTTH upgrade under governmental mandate
[38] Deutsche Telekom has 65% planned for 2016. Possible 80% long-term goal, but no solid plans
[39] 43% refers to VDSL-capable percentage of AT&T footprint
[40] McKinsey, NBN Co. 2011-2013 Plan

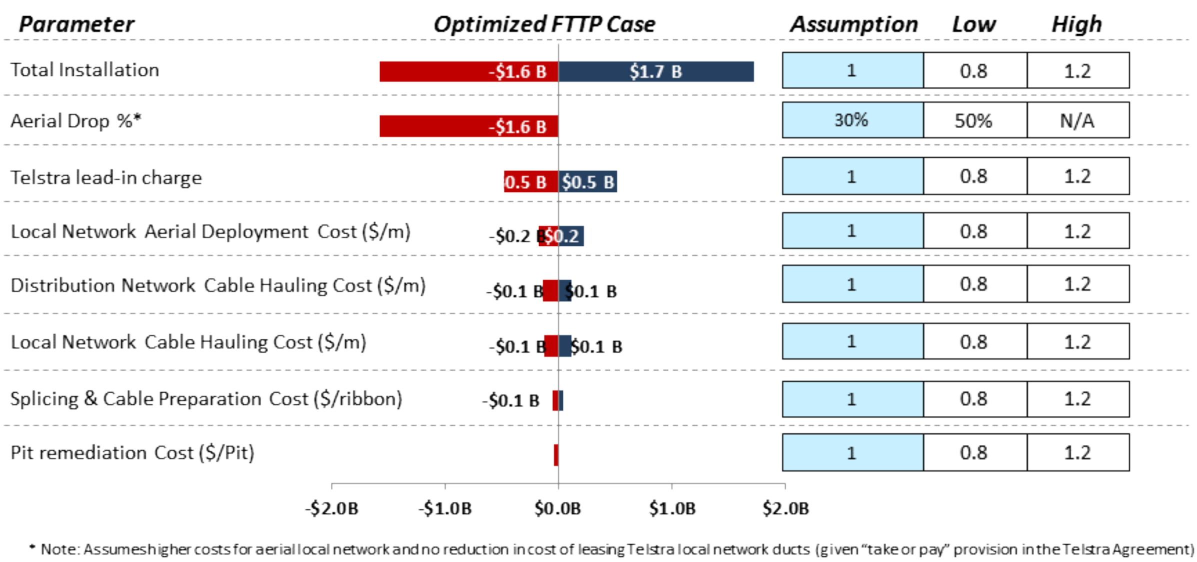
Figure 3.10: Cost Impact of Reduced FTTP Coverage[41]



3.11 Estimate Sensitivities

In our modelled Optimized FTTP case, several labour cost inputs are based on past negotiations between contractors and NBN Co. Some of these labour cost inputs have been conservatively reduced or assumed to remain the same during the network optimization process. In applying sensitivities to these costs, we find that our model is highly sensitive to these labour costs, to a higher percentage of aerial drops, and also to reduced Telstra lead-in charges. Other costs such as hauling or pit remediation that might also benefit more from the smaller cables in our optimized FTTP model do not have a significant material impact on the modelled costs.

Figure 3.11: Sensitivity of Optimized FTTP Case to Key Parameters



[41] Costs do not include expenses to increase wireless coverage or for wireless customer premises equipment

4. CONCLUSIONS

Deploying the Optimized FTTP model to 93% of premises offers a number of benefits. It is considerably less expensive than existing NBN Co plans, and is only marginally more expensive than deploying FTTN. Once the long-run costs of upgrading an FTTN network are considered, the FTTP deployment has lower costs, and the majority of Australians would receive future proof FTTP connectivity quickly without the need for subsequent deployments. This type of FTTP deployment approach balances short and long-term costs and benefits for Australia.

We believe that this report can help inform the Australian government's evaluation of the alternatives. We welcome further opportunities to contribute to the government's decision making process in the hopes of helping Australia select the optimal path to meeting its broadband needs.

5. Appendix

5.1 Detailed Cost Modelling Methodology

The following are cost assumptions across the different network parts and premises types:

Network Area	Service Elements/Costs by Location Type
FAN	• Site preparation for converting an existing Exchange Office into a Fibre Aggregation Node (FAN) • ODFs, fibre splicing and installation • GPON OLT equipment, racks and installation • Each OLT chassis can host up to 16 line cards, each offering 8 GPON ports
FAN to FSAM	• Distribution fibre network has been considered with path diversity connecting the FSAMs to the FAN Site • FDH cabinets are connected to form FSAMs; up to 16 FDHs included in an FSAM • Cable sizes in the distribution network determined based on the number of FDHs inside the FSAM • Distribution network construction cost takes into account availability of Telstra duct • New construction of distribution network is required in cases of path diversity or non-available Telstra duct capacity • No aerial network has been assumed in the distribution network • Fibre costs include material cost of fibre, splicing and hauling costs
FDH	• FDH cabinets, installation costs and splitters • FDH cabinets have a capacity of 576 fibres • Number of FDH cabinet determined based on the required overprovisioned fibre capacity • Each FDH cabinet has a distribution closure where the cabinet's fibre tail cables are spliced on both the east and west side of the distribution fibre cable • Each FDH cabinet has a local closure where the 576 tail fibre cable is spliced into the 144F fibre cables that feed the transition closures • Fibre testing (OTDR) is included from the FDH cabinet to the Multiports and also to the FAN Site
Local Distribution	• Each transition closure feeds 10 Multiports, each with a 12 fibre feeder cable • Each transition closure is connected back to the local closure with a 144 fibre cable • 12 fibre feeder cables are spliced into the transition closure and are pre-terminated on the other end that connects into the OptiTip cable • The OptiTip cable is part of the 4-port Multiport (aka Network Access Point) which is installed inside a pit location • The Multiport itself is not overprovisioned and serves 4 premises • Pit remediation is required in locations where Telstra duct is not available • 15% of the local network has been assumed to be aerial • In aerial local network, transition closures are substituted by FlexNAP access points that accompany each installed Multiport. • An average make-ready and installation cost has been calculated per pole • Greenfield new development locations have available underground local network constructed by the developer
Lead-In	• Lead in construction cost can both be aerial or underground • Underground lead-in can be through Telstra ducts (additional Telstra fee for using lead-in) or new underground construction • The lead-in cost includes plugging the Lead-in OptiTap cable into the multiport and mechanically splicing its other end into a Premises Connection Device (PCD) installed on the outer wall of the premises • In Greenfield locations, lead-in construction is performed by the property developer
Premises	• Premises installation includes a pigtail from the PCD to a wall outlet installed inside the premises • From the wall outlet, an Optical Network Terminal (ONT) device is connected through a patch cord • A Power Supply Unit (PSU) is also included, offering uninterrupted service to the ONT • A broadband CPE device is connected to the ONT • For MDUs, additional inside wiring costs are included • For MDUs over 60 units, splitters are installed inside the telecom room

5.2 Glossary

Access Network	In FTTP, the portion of the network between the Fibre Access Node and the drop. In FTTN, the portion of the network between the exchange and the drop.
Asymmetric Digital Subscriber Line (ADSL)	A technology for delivering high-speed data transmission over a copper phone line. Uses copper phone lines from the exchange to the customer premises.
Brownfields	Pre-existing premises that will be upgraded. Pre-existing premises to be covered by fixed wireless or satellite are not referred to as Brownfields in this analysis.
Cabinet	In FTTN, the equipment enclosures that are the demarcation point between fibre and copper.
Capital Expenditure (Capex)	The cost of purchasing tangible and intangible assets, including labour and other costs related to the capital investments.
Customer-Connect	The portion of the network comprising the drop to customer premises, as well as equipment on customer premises.
Distribution Area	In FTTN, the area served by one cabinet. In FTTP, the area served by one Fibre Distribution Hub.
Distribution Network	In FTTN, the part of the network that connects the exchange to the cabinet. In FTTP, the part of the network that connects the Fibre Access Node to the Fibre Distribution Hub. The fibre used in this portion of the network is referred to as Distribution Fibre.
End User Premises (EUP)	A single dwelling or premises within the MDU.
Fibre Access Node (FAN)	A facility that houses the active equipment providing services to a Fibre Serving Area (FSA).
Fibre Distribution Hub (FDH)	In FTTP, the equipment located in a Distribution Area where Distribution Fibre is split to provide Local Fibre that runs down each street. The geographic area served via a single Fibre Distribution Hub (FDH) connects addresses to the serving FAN site(s) via Local Fibre. Typically serving up to 200 premises.
Fibre Serving Area Module (FSAM)	A logical collection of up to 16 FDAs. Typically, a single fibre sheath will connect the FSAM and its (up to 16) FDHs back to a Fibre Access Node (FAN). The number of premises contained in an FSAM is typically between 2,000 – 3,000, depending on location and network planning / topology.
Fibre-To-The-Basement	The network design in which the Fibre network is deployed to the basement of MDUs.
Fibre-To-The-Node (FTTN)	The network design in which the Fibre network is deployed to nodes, or cabinets, within several hundred meters of customer premises.
Fibre-To-The-Premises (FTTP)	The network design in which the Fibre network is deployed to each premises.
FTTx	Fibre to the x (FTTx) is a generic term for any broadband network architecture using optical fibre to replace all or part of the usual metal local loop used to connect subscribers to telecommunications services. The generic term was initially a generalisation for several configurations of fibre deployment (FTTN, FT1C, FTTB, FTTH...), all starting with 'FTT' but differentiated by the last letter, which is substituted by an x in the generalisation.
Greenfield Premises	New premises that can be either New Development or Infill Premises. Greenfield premises developments represent the growth of the premises market.

Greenfield Infills	A type of Greenfield development where new premises or a redevelopment (i.e. demolition and rebuild) are planned to be built on currently developed land that is surrounded by established areas, where Telstra copper services are currently available.
Lead-In Network	The portion of the network where the connection from the street to the premises is carried out. Also known as the drop, and considered part of the Customer Connect.
Local Network	In FTTP, the part of the network from the Fibre Distribution Hub down each street. In FTTN, the copper access network which extends from cabinets down each street.
Megabits Per Second (Mbps)	A unit of measurement of transmission speeds. One Megabit Per Second is equal to 1,000 kbps. X/Y Mbps means a maximum downstream speed of X Mbps and a maximum upstream speed of Y Mbps.
Multiple Dwelling Unit (MDU)	Residence buildings that contains more than one dwelling unit, which can range from duplexes to 200+ unit apartment blocks. Each dwelling unit is counted as one premise.
Network Access Points (NAP)	The point at which Drop Fibre is connected to Local Fibre. Also known as the Multi-port.
New Development	A type of Greenfield development where new premises are planned to be built on undeveloped land, where Telstra copper services are not currently available. Also referred to in NBN Co documents as broadacre.
Operating Expenditure (Opex)	The ongoing cost of running a business, system or product.
Premises	Premises are defined as addressable locations which NBN Co is required to connect. More details on addressability can be found in NBN Co Corporate Plan documents.
Single Dwelling Unit (SDU)	Premises that contain only one dwelling unit.
Transit Network	In FTTP, the part of the network which connects Fibre Access Nodes with each other and with Points of Interconnect. In FTTN, the part of the network that connects exchanges with each other and with Points of Interconnect.
Very-high-bit-rate Digital Subscriber Line (VDSL)	A technology for delivering high-speed data transmission over a copper phone line. Enabled by FTTN. Uses copper phone lines from the cabinet to the customer premises.

5.3 About CSMG

CSMG is a boutique strategy consulting firm serving the telecom, technology, and digital media industries. We combine our deep understanding of the global market with rigorous, analytic techniques to provide strategic management consulting services to organisations around the world. CSMG has extensive experience developing economic models for fixed and mobile networks in developed and developing countries. Examples of our work include bottom-up LRIC models, top-down financial analysis, WACC determination and margin assessment.