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Wholesale Fiber is the Key to Broad US FTTP Coverage

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Executive Summary

The US is lagging behind when it comes to gigabit speed broadband, both in terms of coverage and adoption. Prices for high-speed broadband are considerably higher there than in most other developed markets, and while cable and incumbent operators have invested in (respectively) node-splitting upgrades and fiber to the premises deployment, these investments are limited to dense urban areas.

As the Federal government examines infrastructure investment with an emphasis on broadband infrastructure, it is time to examine why previous rounds of public intervention have failed to produce better results when it comes to coverage and adoption and propose alternative models.

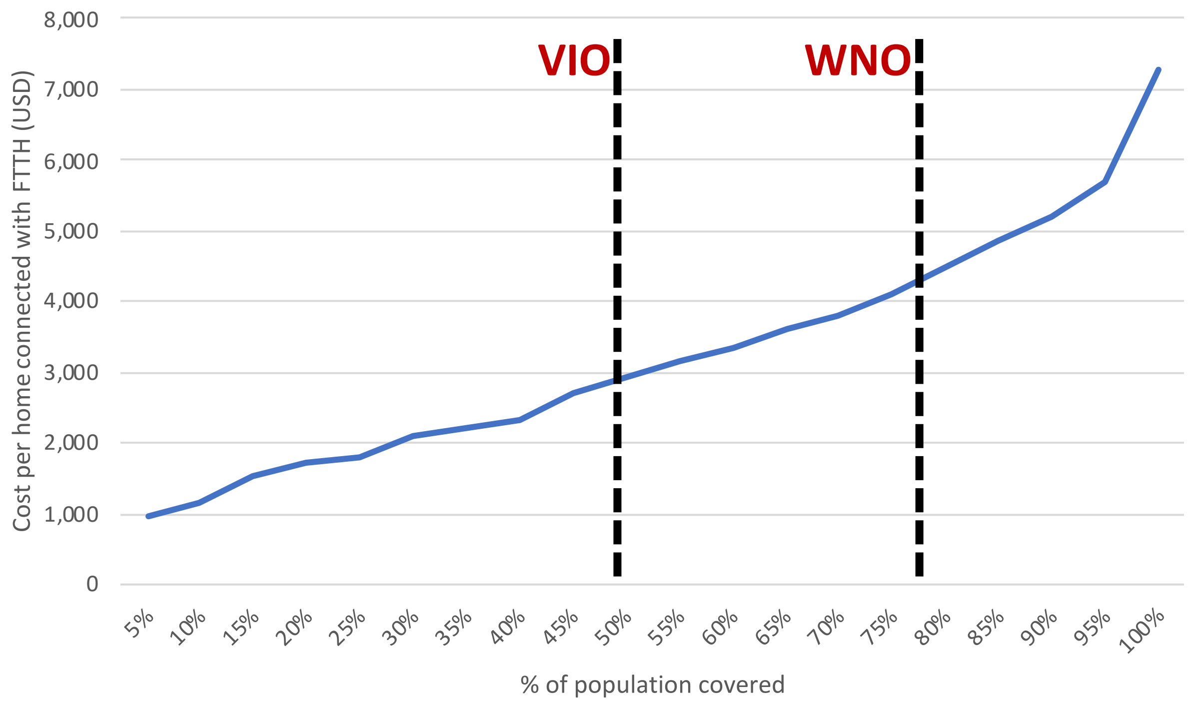
In particular, as the rest of the western world gradually embraces wholesale fiber networks as a more efficient way to provide fiber broadband to unserved households, it is worth measuring the differential impact of a deployment undertaken by wholesale network operators (WNO) as opposed to the vertically integrated operators (VIO) who have until recently been expected to invest in this market.

Wholesale fiber networks do not serve consumers directly, they lease capacity to service providers who market to consumers. This model has a number of virtues:

- It doesn't disrupt competition: all players leasing capacity do so on equal terms;
- it provides end-consumers with a choice of service providers;
- it is seen by investors as infrastructure: a longer-term perspective and a lower cost of capital lead to a more efficient business model.

Our analysis shows that a WNO based model could cover close to 80% of US households with fiber to the premises whereas a VIO model could only reach 50% profitably.

Exhibit 1: Profitable FTTP coverage based on wholesale vs. vertically integrated model



Source: Diffraction Analysis

It may be argued that while current US fiber deployment only covers somewhere between 35 and 40% of the population depending on sources, announcements have been made that could extend that reach over our calculated 50%. Announcements, however, are not deployments, and have been shown in the recent past to often be more PR exercises than actual intentions[1].

The disaffection of incumbent operators and cable for more aggressive deployment of gigabit capacity broadband is explained by a combination of duopoly dynamics (where neither player has a clear interest in rocking a profitable market), other investment opportunities seen as more lucrative (in mobile, content, etc.) and a light touch regulation that imposes few constraints.

Since wholesale fiber networks could cover a large part of the population and still be profitable, they seem like a better model for a necessary nation building exercise. Their development has been hampered in the US by a lack of transparency in coverage and pricing. These and other policy initiatives could even the odds for these open initiatives, even in the absence of public funding.

In underserved markets (or markets served at such high prices that they leave entire population segments unable to afford gigabit broadband) public intervention may be necessary. If it is, and whether that happens through public private partnerships or directly, a WNO type model is more likely to deliver positive outcomes than funding established VIO players.

While the US-wide focus for a WNO style deployment would be primarily in the less dense 50% of households, the WNO may also make sense in denser urban areas. We have modeled the county of Los Angeles, showing that while WNO no longer outperforms VIO in terms of coverage (both could reach 85% of households profitably), WNO is viable. Since fiber coverage in LA is far from 85% today (estimated at 33%), that leaves plenty of space for the emergence of a wholesale fiber network there.

A wholesale network operator model is not only viable in many different scenarios, it seems like sensible approach in an age where superfluous use of resources is no longer deemed indispensable. While some investors are already eyeing WNO type projects in the US, a faster and more efficient adoption of this model will require some policy recognition of some of the issues plaguing the US market until now in order to favour the emergence of the most effective and least costly (from a public investment standpoint) model to offer the option of future-proof broadband to as many Americans as possible.

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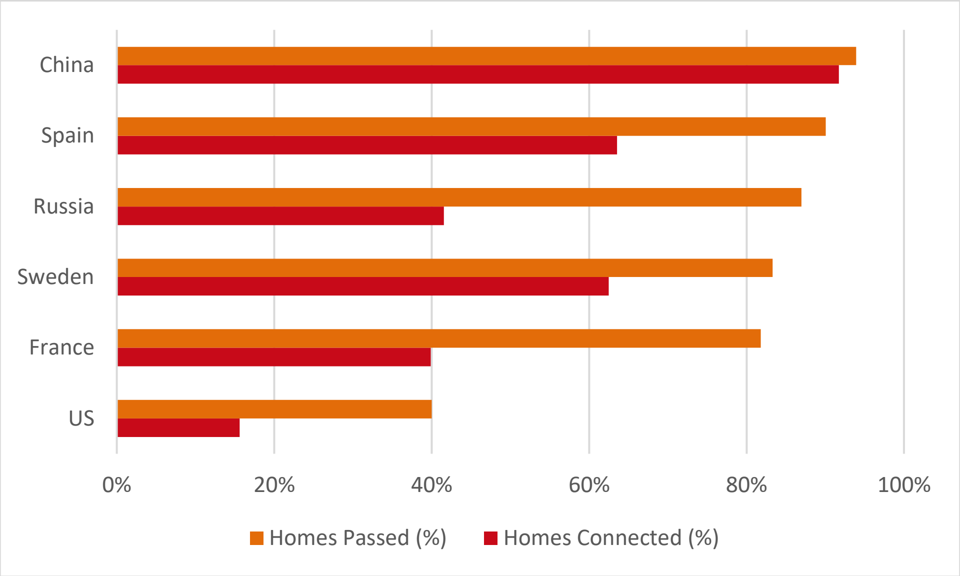
[1] https://www.techdirt.com/articles/20140307/04485626475/weve-entered-age-fiber-to-press-release.shtml

I. Introduction

While key aspects of the internet, and later broadband technologies were designed and first implemented in the US, the country is no longer at the forefront of broadband whether we look at coverage or average speeds. When it comes to fiber to the premises (FTTP), it's clear that the US is lagging behind many developed (and a few developing) nations[2].

Exhibit 2: FTTP Coverage and adoption (% of households)



Source: Diffraction Analysis, RVA, FBA, Idate, 2020

There are many reasons for the US lagging behind when it comes to high-speed broadband. Some are explained by market structure, some by policy choices and some by investment environment. But it looks like the current US government is finally serious about tackling these issues, at least those that it has control over. A massive investment plan for infrastructure is being discussed, and that includes fiber broadband. Simultaneously, some states are moving forward with their own infrastructure programs as exemplified by the California[3] open access plan initiated by Governor Newsom.

Paradoxically, the current situation may – at least in part – be explained by the fact that fiber to the premises has not been considered infrastructure in the same way that roads, bridges and airports have. The prevailing view in the US until now has always been that broadband is a retail business, requiring limited investment if it is to pay back fast. Fiber to the Premises isn't inherently "expensive" as is often argued by incumbent operators as an explanation for their lack of appetite in this field. It's a long-term payback infrastructure investment, well suited for infrastructure investors and patient capital like pension funds. The issue, then, is not so much that the investment is too high but rather that the wrong market players have been expected to invest.

In sharp contrast, many European countries now have significant wholesale FTTP capacity. The largest player in Italy, Openfiber, is a wholesale only player, the incumbent in Britain, Openreach, is wholesale by design, and in France, most of the local deployments in low density areas are wholesale as well.

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[2] It should be noted that while the Chinese numbers need to be examined with caution (state owned companies in China have less compulsion to be truthful about their reported numbers), coverage there is massive nonetheless. Even if we cautiously take out 15% coverage, it's still 80% of the population.

[3] https://arstechnica.com/tech-policy/2021/07/california-passes-historic-plan-for-statewide-open-access-fiber-network/

The key reason why this shift to wholesale is happening is that wholesale fiber models are inherently more effective when it comes to getting the broadest possible coverage of the population. There are a number of reasons for this which will be explained later in this paper, but suffice it to say at this stage that a wholesale model has inherently lower cost of capital, which in turn leads to a massively improved business model.

As the US looks at investing significant amounts of public money into kickstarting FTTP coverage, it seems logical to examine how those funds might best be used in order to maximize their impact on individual broadband consumers, and more broadly, on the economy. Two years of pandemic constraints have shown how crucial high-quality broadband is not only for daily life, but for work, education, communications and more.

In this paper, we will run a number of parallel financial models to examine the coverage that could be achieved by vertically integrated operators (ie. players who sell broadband to consumers via infrastructure that build and use exclusively) and compare it to the coverage that could be achieved by pure wholesale players (who build infrastructure and resell it to ISPs who in turn serve the consumer market). We will examine the US market as a whole as well as one example of a dense urban county (LA county).

These models not only have different revenue and cost inputs, they are also differently impacted by policy and regulatory intervention. This comparison should tell us how much the market structure impacts the ability to deploy fiber broadband and the extent of that deployment into the hard-to-reach parts of a given geography.

Methodology

In order to make this comparison the authors – on the basis of extensive qualitative and quantitative research – have built a high-level business model whose output is "profitable coverage" i.e. the proportion of a theoretical territory that could be covered with FTTH while still generating positive returns for the entity deploying the fiber. The variable inputs are based on the revenues, operating expenses and capital costs (or expectations of risk) of a Vertically Integrated Operator (VIO) versus those of a Wholesale Network Operator (WNO).

Terminology

In telecom circles, a term that is often used to mean wholesale is "open access". However, there is ambiguity around that term as it applies equally to retail (vertically integrated) operators who resell some of their network assets to competitors and to pure wholesale networks. In order to avoid that confusion, we will use the term "wholesale network" throughout this piece to mean operators who do not play on the retail market but only operate as wholesale providers to ISPs who in turn serve the end-users.

There is a lot of discussion in the context of open access as to whether a wholesale network should resell at the passive layer (layer 1), ie. dark fiber or at the active layer (layer 2), ie. bitstream capacity. While important both to the corporate structure of the player deploying and selling and to the operational model implemented, we find that this distinction has little significant impact on the business model itself. Our model is conceived as being layer 2, but the results would not be significantly different were it layer 1.

More broadly, while we will used the term FTTP (Fiber to the Premises) to mean fiber broadband, we will also use the term NGA (next generation access) as a generic term for all transmission media that deliver broadband speeds above 100Mbs.

Finally, in order to avoid any confusion when it comes to discussing alternative broadband access solutions, we will not describe with the commonly used term “technology” which has confusing implications when talking about infrastructure but rather the more neutral “transmission medium” term used in EFF papers. Additionally, in order to avoid confusion between generations of mobile technologies (4G, 5G) and gigabit speeds (1G, 10G) we will write gigabit or gbps instead of G.

II. Understanding Broadband Coverage Policies

All around the world, broadband service providers are shifting to Fiber to the Premises as their primary access technology. FTTH has not become the dominant access transmission medium in many countries yet, but the writing is on the wall. Countries such as the Netherlands, Sweden, France or New Zealand already have more customers on fiber than on any other medium, and market evolution in most developed markets points in that direction.

There are three drivers for this growth, besides the obvious increase in demand for faster and more reliable broadband services:

- **Private market appetite:** established market players in most markets have now realized the benefits of Fiber to the Premises for their own business: on the revenue side, FTTH drives market share increase, higher ARPU, and allows for additional cross-selling opportunities. On the cost side, it's simpler to manage and operate, less prone to faults and future-proof. Even incumbent operators who were initially reluctant like BT (Openreach) in the UK or Deutsche Telekom in Germany have now embraced mass FTTH deployment. Additionally, alternative operators (altnets), mobile operators, emerging wholesalers and even cable operators such as Virgin (UK), and Ziggo (NL) are moving towards offering FTTH;
- **Favorable policies:** it took a while for many governments to understand the hurdles that hindered private FTTH deployment, but in the last few years many governments have implemented policies that facilitate deployment through easier rights of ways, access to underlying reusable infrastructure, wholesale frameworks and price transparency and regulation. This has accelerated deployment by multiple market players, creating a dynamic and fast-moving market.
- **Public investment:** through a variety of approaches (public private partnerships, subsidized projects, grants, etc.), public investment has also helped with the deployment of fiber to the premises, particularly in areas where private investment was considered excessively complicated or expensive. Various governments have, over the years, opened funds for rural broadband, or simply areas where the private market had no intention to deploy.

Why fiber should be favored in public policy and investment?

But why fiber? With existing cable and DSL solutions, but also mobile and satellite offering broadband solutions, it is a legitimate question.

Fiber has a number of virtues that are hard to match for other transmission solutions. Not only does it deliver the fastest speeds and lowest latencies of any technology in the market today, it does that from the further away. In other words, it can deliver these speeds with the lowest density of active equipment if any technology. This has a number of important consequences:

- **It's future proof to at least a couple of decades:** whereas cable and fixed wireless need very frequent upgrades to keep increasing capacity, FTTP is on much longer cycles, even in the active layer. Properly deployed fiber to the premises only requires upgrades in the active equipment to improve performance. The current generation of technology being deployed allows for the delivery of 10 gigabit symmetrical services, with 25 gigabit symmetrical and 50 gigabit symmetrical not far behind. In comparison, latest cable technologies can now reach 10 gigabit with only 1 gigabit upstream at the cost of frequent node splitting investments, and fixed wireless can deliver up to 200Mbs but will require antennas much closer to the home to break the Gbps barrier;

- **It's CAPEX intensive, but very low OPEX:** while fiber is undoubtedly a significant investment, the capital expenditure required happens only once at initial deployment. If deployed well and without cutting too many corners, it is then incredibly stable over time and therefore cheap to operate and maintain. In contrast, most other technologies are lower on CAPEX but much higher on OPEX, leading to lower margins over time.

- **It's the cheapest price per GB on the market:** while technologies such as satellite and fixed wireless may look promising to extend coverage in high fiber deployment cost areas, they are incredibly expensive on a per GB basis. Most satellite offers currently on the market deliver performance closer to 50-100Mbps at a cost significantly higher than FTTP broadband offers.

That's not to say that these alternative technologies don't have a role to play, if only as transitory solutions in remote areas before fiber can be deployed there. But it seems like sensible policy to focus public intervention and public funding on long term solutions that will solve broadband access issues for decades to come rather than just the next few years.

Why is the investment case for FTTP seen as challenging in the US?

In most of the western world, it is now accepted that FTTP while a significant investment is a sound one. Private investors no longer have to be convinced that this is the case. For example, Germany and the UK have experienced significant interest from infrastructure and private equity funds. Recent examples are Mubadala with a GBP 1.125bn investment in Cityfibre[4] and *Unsere Grüne Glasfaser* (UGG), a JV of Spanish Telefonica and Allianz Capital Partners for a roll-out in Germany[5] with an envisaged €5bn capex plan. Both operators operate with a dedicated wholesale model.

Looking in the US, we have observed a growing number of transactions or announcement of funding plans. This includes, for example, the acquisition of Lumen's network assets in 20 states by alternative

What about incumbents deploying FTTP?

Our VIO model may seem pale compared to the commitments of some of the incumbents deploying FTTP in the US. A few elements help to shed some light on this: because it is impossible to accurately compare the investment opportunity for an existing vertically integrated fixed broadband player versus a new wholesale infrastructure entrant, we had to examine both scenarios as new entrants. This is not directly comparable to how an incumbent would view the investment decision. An incumbent has three massive advantages in this game: first, they already "own" a sizeable portion of the broadband market, second, they can upgrade their copper/coax plant cheaper than it would cost to fully deploy, and third they have existing copper broadband revenues to finance their fiber investment with. Unfortunately, the latter advantage also plays against them as it makes the investment in fiber hard to justify from a financial standpoint in the first place ("we already have an infrastructure, it's written off and it generates a lot of cash…") This is why few incumbents invest in fiber without public incentives to do so. When they do, it's usually because they face stiff cable competition in fixed broadband. In summary, an incumbent who decides to invest in FTTP would fare better than our VIO scenario (but probably not quite as well as our WNO scenario), but most incumbents will be reluctant to invest in FTTP in the first place.

[4] https://www.cityfibre.com/news/cityfibre-completes-1-125bn-financing-largest-ever-capital-raise-uk-full-fibre-deployment/
[5] https://www.telefonica.com/en/web/press-office/-/telefonica-and-allianz-create-a-partnership-to-deploy-fibre-in-germany-through-an-open-wholesale-company

asset investor Apollo[6] but also smaller players such as Frontier Communications[7] or TDS[8]. Most interestingly, infrastructure investors now eye the wholesale investment proposition as well, as the investment of Dutch pension fund APG in SiFi Networks illustrates[9].

That said, near ubiquitous coverage of the US market with cable, while not unique (the Netherlands, Belgium and a few other countries have similar cable coverage), creates its own set of challenges. Cable can, in theory, be upgraded to gigabit speeds although with highly asymmetrical broadband. That said, the laws of physics themselves cannot be bent, and in order to deliver higher capacity, fiber needs to be brought closer and closer to the end consumer, which requires waves of significant outside plant investment for cable network providers (MSOs). Many have been reluctant to consent this investment, so while cable coverage could theoretically be considered as competing with existing or FTTH, in practice it rarely is. Furthermore, while cable protocols are trying to keep up with evolutions in FTTH technologies, it is always one or more steps behind: while Docsis 3.1, the current best standard for cable can theoretically deliver 10Gbps down and 1Gps up, isn't widely deployed yet, 10GPON, the FTTH standard currently being deployed all over the world will deliver 10Gbps symmetrical. 25G and 50G FTTH plants are already being discussed.

It remains that cable is a particular challenge in the US context because of its near ubiquitous nature. While it rarely does match FTTH capabilities, it can theoretically do so if the MSOs are willing to consent the necessary investment in node splitting and Docsis upgrades.

One additional challenge of extending coverage of future-proof fiber broadband (FTTH) is that the cost of deployment is not even across a given country or region. **Exhibit 3** shows the shape of a typical curve for cost per household connected ranked from the lowest to the highest cost nationally. The curve has an exponential slope because the outliers cost considerably more than the easiest to reach. In general, you will find on the left of the curve the urban areas where population density is high, especially those parts of urban areas where multi-dwelling units are the norm. Less dense urban areas cost more, then suburbs, then rural areas.

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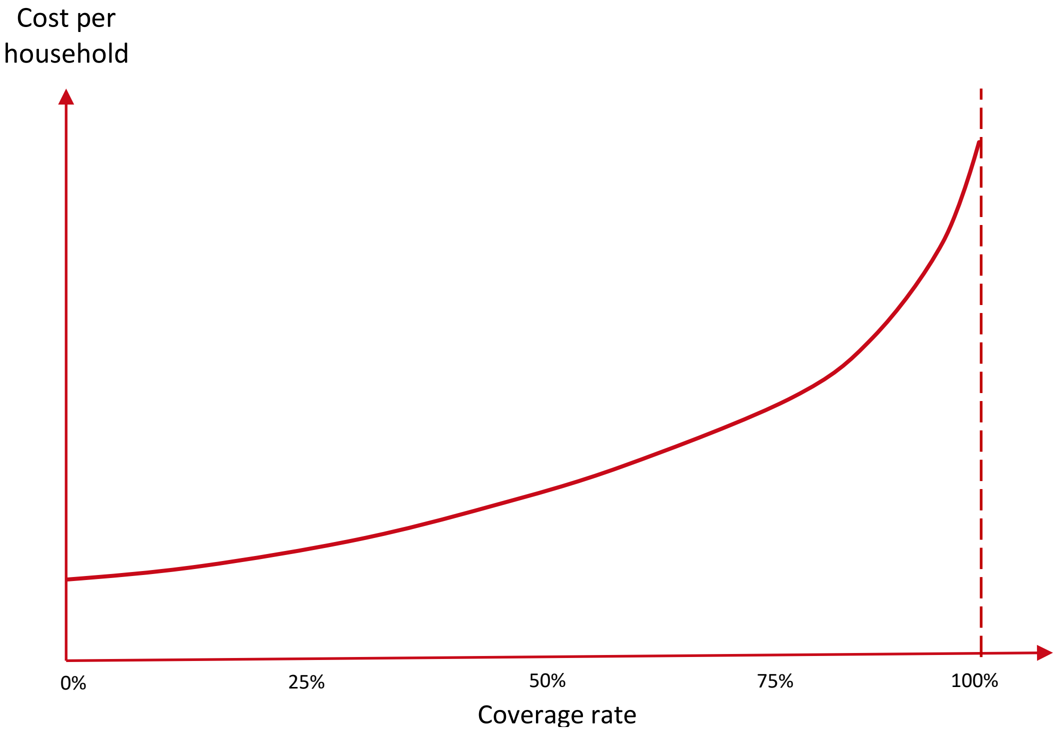
[6] https://www.apollo.com/media/press-releases/2021/08-03-2021a

[7] https://www.businesswire.com/news/home/20210805005317/en/Frontier-Communications-Accelerates-Fiber-Build-Out-to-Reach-10-Million-Locations-By-End-of-2025

[8] https://www.fiercetelecom.com/operators/tds-telecom-sees-urgent-need-to-increase-fiber-footprint-2021

[9] https://sifinetworks.com/corporate/apgs-stake-in-sifi-networks-will-help-bring-10gig-citywide-fiber-networks-to-more-than-a-million-homes/

Exhibit 3: Cost per household connected ranked from lowest to highest



Source: Diffraction Analysis

The slope illustrates the increasing difficulty for an economically attractive FTTH business model. A rational network company would increase its deployment effort as long as the incremental household connected contributes a positive net present value to the overall project. This threshold level for a typical incumbent operator is usually in the second tertile[10].

This has led a number of private operators in countries where FTTH is being deployed to announce their investment intentions and effectively carve out what can be considered the "profitable" part of the territory from their point of view. France is a good example because the government explicitly asked operators to express their coverage intentions with FTTH in order to focus public funding in areas where no next-generation access solutions would be available[11]. Other countries have had similar approaches or at least have enough coverage certainty that it is now possible to evaluate the degree of "profitable private coverage".

This highlights a number of important considerations:

- The proportion of the population that private operators are willing to connect without public funding is generally limited and rarely reaches above two-thirds of the population.
- Public funding is the primary tool for policy makers to push beyond this coverage threshold. It is a very expensive tool. (As an example, Germany has made available up to €12bn for fiber deployment [12]and will subsidize an overbuild of already subsidized VDSL infrastructure. On a European level, at

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[10] This is of course a simplification. In reality, in each given area, including in dense urban areas, there is a similarly shaped slope with outlying homes costing significantly more than average. This leads to non-contiguous, non-universal deployment even in areas deemed profitable overall. This is impossible to model however, so Exhibit 3 presents the average view for modelling purposes.

[11] And to comply with European State Aid rules.

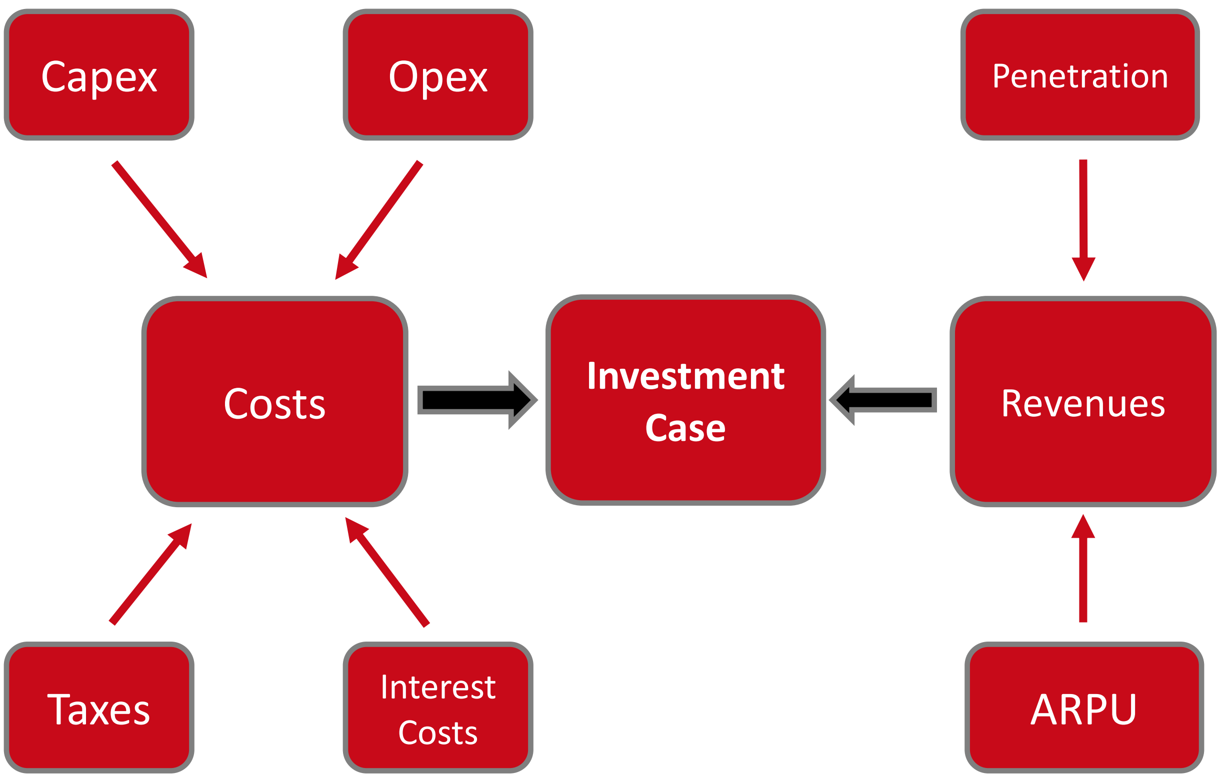
[12] https://www.bmvi.de/SharedDocs/EN/Articles/DG/relaunch-broadband-funding-programme.html

least 20% of the €724bn the Recovery and Resilience Facility[13] must be spend on so-called digital transitions projects which includes fiber access and data center infrastructure.

- Non fiber solutions that were put in place in the last decade to reach the more remote parts of the population (often ADSL/VDSL extensions) are already obsolete and need more public funding to be upgraded.

As NGA connectivity ranks high on the policy agenda, policymakers and regulators have discussed measures to stimulate investment in order to close the looming digital divide between rural and urban regions. The policy approach usually concentrates on measures to improve the investment case (see **Exhibit 4**) in a way that minimizes the subsidies that will be necessary.

Exhibit 1: Variables impacting the investment case – static approach



Source: Diffraction Analysis

- **Capex**: in Europe, historically, the key policy measures to reduce capital expenses (capex) for NGA focused on clearing regulatory hurdles for VDSL and Vectoring to be deployed (usually at the cost of undoing a lot of the regulatory successes of unbundling). These solutions already need to be revisited from an investment standpoint. Other longer-term approaches have targeted sharing of underlying passive infrastructure, particularly duct and poles. Note that the latter measures have positive as well as negative impacts on risk perception and therefore investment cases: they reduce costs of deployment, but increase the risk of infrastructure competition, thus increasing the risks

[13] https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en

associated with the revenue side of the equation, i.e. average revenue per user (ARPU) and penetration.

- **Opex**: There are not many examples of policies that address issues around operating expenses (opex). In fact, some of the policies (pushing Fixed Wireless Access, for example) tend to drive opex up through higher energy consumption, higher maintenance costs, and so on.
- **Taxes**: Tax incentives can come in many forms. A tax relief could benefit house owners that pay for a fiber connection to their home or modernization of in-building wiring, etc. In the USA, bonus depreciation plans or a general reduction in tax rates have been implemented[14]. However, there have been few – if any – NGA-specific tax incentive plans.
- **Interest costs**: Finally, to lower interest costs, government-backed development banks[15] offer low-interest loans with longer tenures or financial instruments that absorb some portion of the risk. Ideally, the latter should make funding more attractive for commercial banks or investors. This principle is usually referred to as "crowding in". In general, both private and public companies can apply. However, banks require collateral for their loans which an emerging company will usually not have. In contrast, public companies can weigh in their regulated revenues and assets from other activities as well as owner support in times of crisis. In these instances, it is generally not their broadband business itself that is valued.

On the revenue side, policy has a limited say except indirectly through price regulation (when there are wholesale obligations for NGA, which is not always the case). However, some of the cost reduction measures (as seen above) can have negative impacts on revenue profile and therefore increase risk, possibly cancelling on the revenue side the gains on the cost side. These regulatory arbitrations are examined in more detail in the next section under de-risking, also known as lowering the WACC.

It is clear from the above that reducing the risk of fiber infrastructure deployment is one of the most effective ways to increase the potential for private coverage and therefore decrease the need for public funding to bridge the "gap". However, there are few proven ways to radically decrease that risk in the current market structure. Initiatives to do so end up compromising either market competition, long-term infrastructure or both, and still cost significant amounts of public money.

But how much of that is tied to the current market structure?

What are the benefits of wholesale networks for the end users?

In this paper we hope to demonstrate that public funding would be applied more effectively to boost wholesale network deployment models than vertically integrated ones. Indeed, we will show that even in the absence of public funding altogether, wholesale networks can be profitable and emerge organically.

However, from the point of view of the end-user, wholesale networks also deliver benefits that are not to be discarded:

Competition: by deploying a single infrastructure on top of which multiple ISPs compete, wholesale networks promise choice to the end-users they connect. If a customer is unhappy with his or her

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[14] https://taxnews.ey.com/news/2018-0063-tax-cuts-and-jobs-act-will-affect-telecommunications-industry
[15] For example, up to €386bn of the EU´s Recovery and Resilience Facility will be made available via loans: https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en#the-recovery-and-resilience-facility

provider, they can switch (subject to contractual obligations) to another and not be locked in simply because there is no alternative.

Pricing: competition on the network will inevitably drive prices down. In European markets where wholesale delivery is dominant, broadband prices tend to be lower than vertically integrated retail prices. This is especially true of public or publicly funded wholesale networks where wholesale prices tend to be regulated.

Exhibit 5: Examples of retail prices on wholesale networks in Europe

(Average monthly price for first 24 months contract)

Country	ISP	Wholesale Network	Bandwidth (DL/UL)	Retail Price (US$, ex VAT)
Austria	Teletronic[16]	City of Vienna	1000/1000	79.41
Germany	1&1[17]	e.g. R-KOM (Regensburg)	1000/200	31.06
Italy	4ALL[18]	OpenFiber	1000/200	62.33
Netherlands	T-Mobile Thuis[19]	e.g. Open Fiber NL	1000/1000	48.34
UK	Brawband[20]	Cityfibre	900/900	46.00

*Exchange rates: US$/€: 1.17 and US$/GBp: 1.38

Interestingly, in Belgium, which so far has not seen the emergence of a lively wholesale market, broadband prices have stayed higher than in neighbouring countries.[21]

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16 https://teletronic.at/pri_cf.php (includes national fixed voice, CPE not included)
17 https://dsl.1und1.de/dsl-tarife (includes national fixed voice, CPE not included)
18 https://4all.it/privati/offerte/
19 https://www.t-mobile.nl/thuis/internet/glasvezel
20 https://www.brawband.co.uk/ (CPE included)

21 https://www.brusselstimes.com/news/belgium-all-news/175018/internet-surfing-calling-mobile-network-test-achats-belgium-phone/

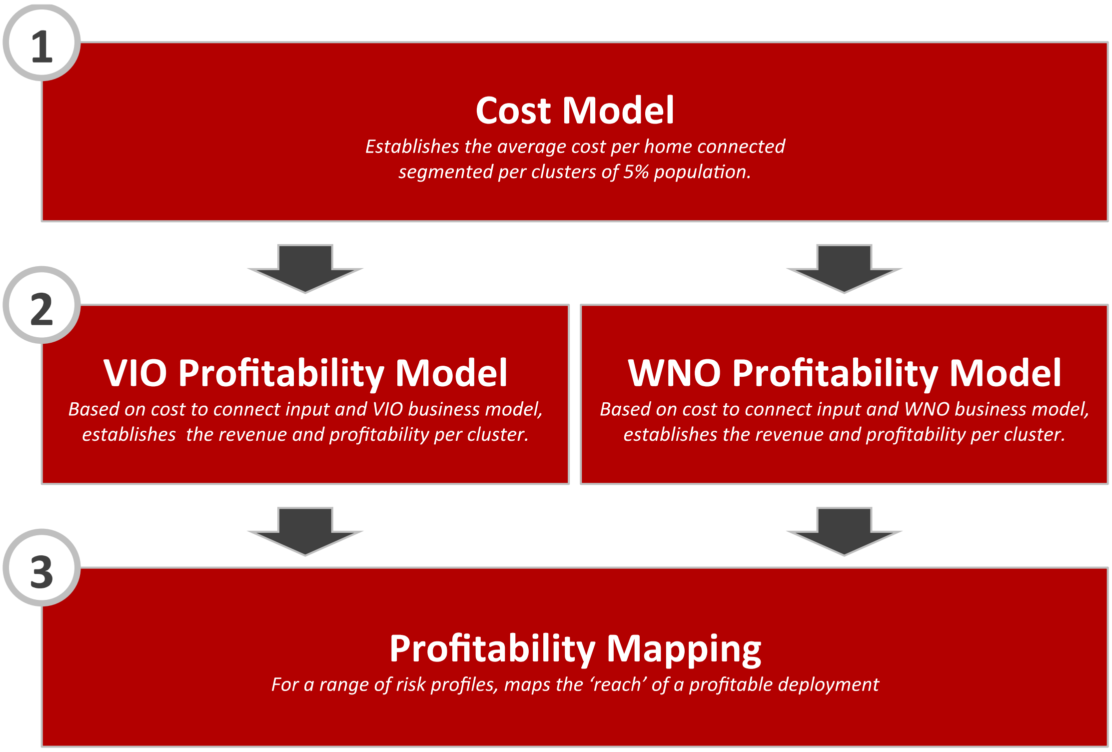
III. Comparative Profitability Models According to Telecom Market Structure

Our thesis is that the reason the policy measures designed to reduce risk in FTTH investment lack effectiveness is that they don't consider the element of risk tied to the telecom market structure. Infrastructure investment is not normally undertaken by retail businesses operating in a competitive environment, as illustrated by the emergence of tower companies in the mobile communications market structure. In telecom, it is envisaged simply because this is the market structure inherited from liberalization. The pre-liberalization wave of copper wireline infrastructure investment in telecoms was not undertaken on commercial terms but rather as part of the Kingsbury Commitment, a publicly mandated nation-building exercise. Expecting private telecom players operating on purely commercial terms in the retail market to invest in nation-building is at best misguided.

If we consider that gigabit speeds are becoming the norm in most of the western world, then by that standard, there is virtually no competition in the US market. FTTP can deliver that where it exists, Cable can deliver that in some areas where it has upgraded sufficiently, these rarely if ever compete with each other.

The output of our model is a coverage threshold that expresses how much of the population in a country could be reached by a market player based on said player's business model and financial risk profile. The methodological approach is summarized in **Exhibit 6** and detailed in the **Appendix**.

Exhibit 6: Methodological Approach to Comparative Profitability Model



Source: Diffraction Analysis

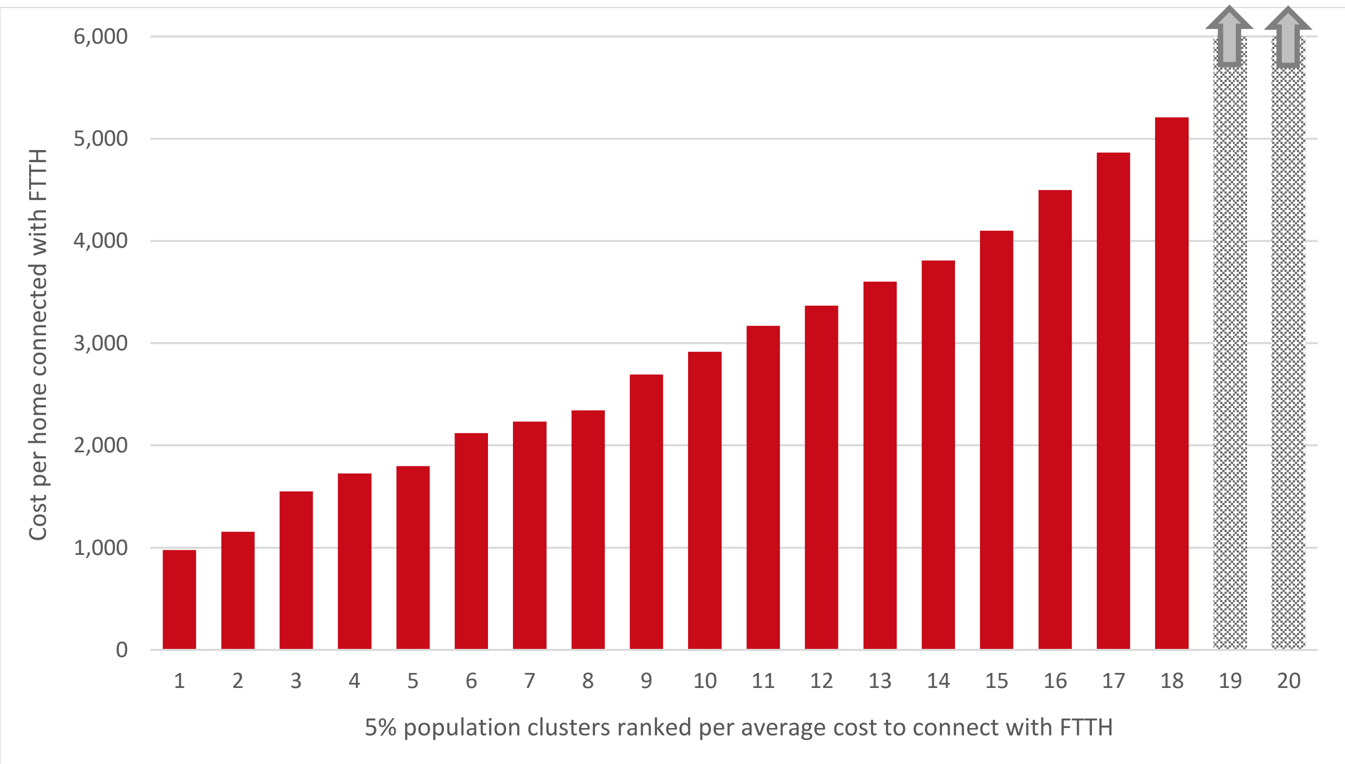
In order to reach the output:

- The baseline of the model exercise is a cost curve similar to the one in **Exhibit 2**. This represents cost inputs to the business model. The cost curve is segmented into 20 population clusters each representing 5% of the population, ranked by increasing average cost per home connected.
- Revenue models based on the nature of the market players are built: one is a Vertically Integrated Operator (VIO) model and the other is a Wholesale Network Operator (WNO) model.
- The cost and revenue models generate the output for a given risk profile. The output is then mapped for a range of risk profiles for both the VIO and the WNO approach.

Average cost to connect per cluster

The costs to connect per cluster of 5% population were built from a variety of public studies on costs to deploy FTTH[22]. **Exhibit 7** shows the curve derived from that cluster table. For the sake of our modelling, we assume that deployment costs are evaluated in absolute terms. They include the deployment from (and including) the central office all the way into the target home (whether the resident actually subscribes or not), and the truck roll necessary to activate the service in said home. They do not include middle-mile connectivity (backhaul), customer cost of acquisition (marketing, sales, investments that can improve customer experience, e.g. at the point of installation...) or customer premise equipment other than the equipment that terminates the fiber line: an optical network terminal (ONT) or Ethernet router depending on the active technology.

Exhibit 7: Cost per home connected with FTTH (US$) per population cluster



[22] See https://acaconnects.org/wp-content/uploads/2021/06/Addressing-Gaps-in-Broadband-Infrastructure-Availability-and-Service-Adoption-ACA-Connects-and-Cartesian-June2021.pdf, https://optics.fiberbroadband.org/Portals/0/Cartesian%202019%20FTTH%20Study%20Summary%20Findings%2020190604%20SENT.pdf , last accessed on September 27 2021

Source: Diffraction Analysis

We make the additional assumption for Clusters 19 and 20 have CAPEX requirements which are so high that they are left not suitable for unsubsidized FTTH considerations. In the least dense regions, alternative technologies such as mobile, FWA or satellite are intermediate solutions until either a subsidized model can emerge that is workable, or other utility networks are rolled out which would allow to share costs in deploying fiber alongside these networks (usually electricity upgrades).

This forms the baseline of the capex inputs into the business models for both VIO and WNO.

Business models and their return characteristics

Modelling businesses for fiber deployment that closely match reality isn't simple, especially if we want to compare two different models. Our approach is the following: we consider the model's inherent risk as expressed by its weighted average cost of capital (WACC) to be an external input, not an inherent property of the model itself. As we will demonstrate, pure infrastructure businesses do tend to have significantly lower WACC levels, but we postulate that it is not simply because they are pure infrastructure but because they have a higher degree of revenue predictability. Likewise, we do not discuss the potential difference in the capital structure of a VIO and WNO model. We assume that the WACC simply reflects the optimal capital structure in each model. (See **Appendix A** for further details).

In order to build a VIO and a WNO model that could be compared to each other we had to postulate a number of elements:

- Both models need to be deployed from scratch (i.e. not rely on pre-existing access infrastructure or pre-existing fixed broadband revenues)
- We assume that both models are undertaken by players who can quickly grab large numbers of new customers. For the VIO model, this implies an existing retail customer base and points to players such as mobile operators with no significant presence in fixed access, utilities with strong ties to residential customers or established fixed operators that want to expand their footprint. For the WNO model, it implies either an offshoot of a regional or local utility (electricity would be the most likely candidate) or a consortium of retail broadband operators and/or an investment fund (infrastructure or private equity) to be investors. Of course, a structurally separated incumbent would work as well, in principle.

Operating model

ARPU and EBITDA-margin estimates are key input parameters in our model. **Exhibit 8** details the key assumptions[23]. We have cross-checked our margin estimates by looking at reported EBITDA-margins from listed and unlisted companies. For example, Openreach (the network division of BT) reported an EBITDA-margin of 56.0% in FY 21, while NBN Netlink, the passive WNO in Singapore, reported 73.3% and Chorus (New Zealand) 68.5%. For the US market, we looked at EBITDA margins from integrated operators Comcast cable communications (2020, margin: 42.1%), AT&T Consumer Wireline (2020, margin: 34.8%), Charter (2020, margin: 38.5%) and Altice USA (2020, margin: 41.9%). We note that cablecos operate under a more diversified business model which is based on connectivity and content services. These businesses are apparently so interrelated that cablecos cannot (or do not want to)

[23] Assumption building is detailed in Appendix A.

report segment EBITDA. It is tempting to assume that the underlying connectivity (in other words broadband) profitability is per se much higher because the content business contributes a lower margin to the overall blended EBITDA margin. This possibly neglects positive effects on churn etc. In order to reflect such a possible understatement of the connectivity margin, we apply a 45% EBITDA margin assumption in our model.

Exhibit 8: Model assumptions

Model assumptions	WNO	VIO
Length of explicit forecast period (in years)	35	35
Revenue per month per subscriber (US$)	35	55
Inflation (years 1 to 35)	0%	0%
EBITDA-margin (assumed stable)	65%	45%
Terminal Value (EV/EBITDA multiple)	Implied: 7	Implied:7

Source: Diffraction Analysis

Some important considerations about the operations model:

- Deployment costs are expected to remain stable over time and are the same for the VIO and WNO models. ARPUs are also assumed stable during the explicit forecast period. In the real-world inflation would drive both labor costs and ARPUs up. In order to avoid having to make predictions about which way these would go, we assume extra revenues from ARPU inflation offset extra costs from labor inflation.

- In our models, while the ARPU levels and EBITDA levels are different, they counterbalance each other to a large extent. In other words, the high-ARPU VIO model has a comparatively lower EBITDA (as befits a retail business), which the lower-ARPU WNO model compensates with a higher EBITDA margin. Ultimately, while not identical, the EBITDA contributions of the two models are within the same ballpark.

Market model

Our assumptions for deployment costs assume a curve as shown in **Exhibit 7**. We segment the market in clusters of 5% population penetration points. Each cluster is characterized by an average deployment cost as shown. These deployment costs are hypothetical in the sense that we are not referring to an actual geography here, but they are within industry standards for developed markets taking into account cost of labor and urban density.

Our model assumes that the retail market share under the VIO model are the same as in the WNO model. This helps us to concentrate on the WACC differential effect only. However, this somehow is to the disadvantage of the WNO model if a neutral infrastructure is deployed nationally, not only will third-party service providers offer services over this network (as it allows them to no longer depend on the competing incumbent to serve customers) but the incumbent will as well[24] (as the investment case for the incumbent deploying his own FTTH will be severely degraded). Price and feature competition

[24] Examples: https://www.a1.net/oan-waldviertler-stadtland (Austria), https://glasfaser-nordwest.de/ (Germany, incumbent still has a 50% share in the network JV)

among service providers will lead to lower prices and/or better service. Overall, this leads to a higher market penetration.

In an ideal world (from a business model perspective), the WNO model would have 95% or greater market share nationwide, but we assume an ongoing competition from cable, legacy copper and possibly alternative infrastructure networks in the densest 50% of the population[25].

As it is, we assume that the WNO's market share in access will range from 50% in the first four clusters (urban areas where infrastructure competition will likely exist) to 80%[26] in clusters 14 to 18 (where fewer if any alternative options exist).

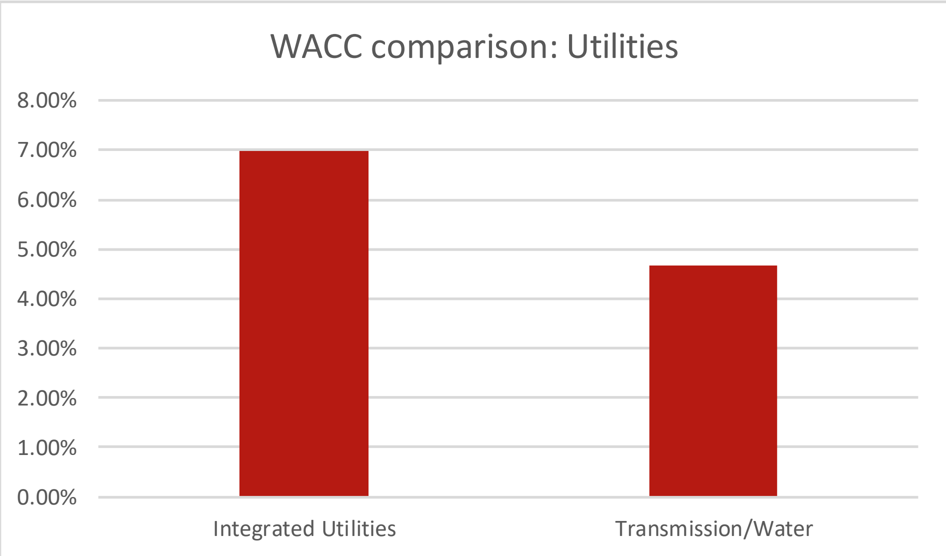
Note that this simplification is done on purpose. According to financial reports from larger players, their penetration rate is ~40%.

Evidence for the connection between WACC and business model

The different risk profiles of generation, retail and network businesses in the energy sector were analyzed by Schaeffler/Weber who write that "One may […] conclude that often liberalized generation and retail activities are characterized by higher systematic risks than the regulated network business"[27]. They cite three studies which on average show that the equity beta of an integrated utility is 0.74 compared to 0.63 for a network utility[28]. (See **Appendix B** for further details.)

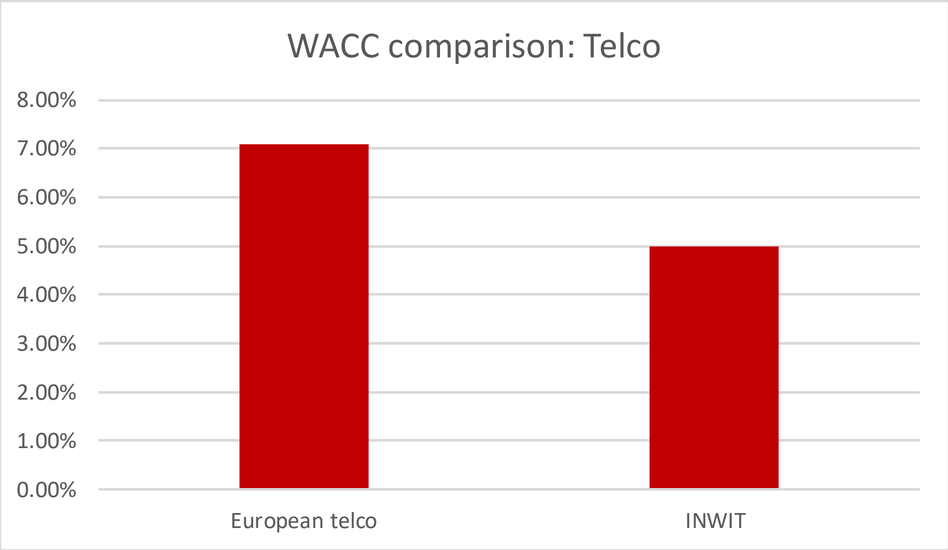
The result is confirmed by a research report from Crédit Suisse. The average WACC used for the valuation of integrated utilities is 7% compared to a WACC below 5% for transmission and water utilities as shown in **Exhibit 9**.

Exhibit 9: WACC comparisons in the utility and telecom sectors



Source: Credit Suisse Equity Research 02/2016: average of WACC applied to EDP, E.ON, Gas Natural, Iberdrola, RWE, SSE, Verbund (left) and National Grid, Severn Trust, Snam, Terna (right)

[25] This in turn means that a WNO structured around an alliance of existing broadband market players (incumbent included) or a fully-fledged structural separation would see our WNO model perform better than what we have modelled.
[26] This number would theoretically be higher but conservatively accounts for the large proportion of mobile dwellings in the US.
[27] See Schaeffler/Weber (2011), p8.
[28] The respective asset betas that correct financial leverage effects are 0.46 and 0.37.



Source: Citigroup, European telco: average of WACC applied to BT, Mobistar, Elisa, Proximus, Sunrise, TEF Germany, Drillisch, Freenet, NOS, Numericable SFR, Telenet

When looking into WACC estimates for telecom companies, we see the same pattern. Although there is only one pure-play telecom infrastructure company mentioned in **Exhibit 9** – INWIT[29] – it is striking that the difference in the WACC is approximately the same as in the utility sector.

Moreover, the fact that Telefonica´s decision[30] to spin-off certain infrastructure assets (mobile towers, undersea links, etc.) in a new company (Telxius) supports our thesis that there is value in running an infrastructure separate from a service business.

The interesting question now is if the WACC advantage of wholesale infrastructure can be replicated using 2021 data. To this end, we calculated WACC for US integrated operators and compared these with WACCs for wholesale infrastructure players. We derive a WACC advantage of 1.5% for the WNO model. The advantage would have been larger, had we excluded Verizon that is primarily a mobile operator.

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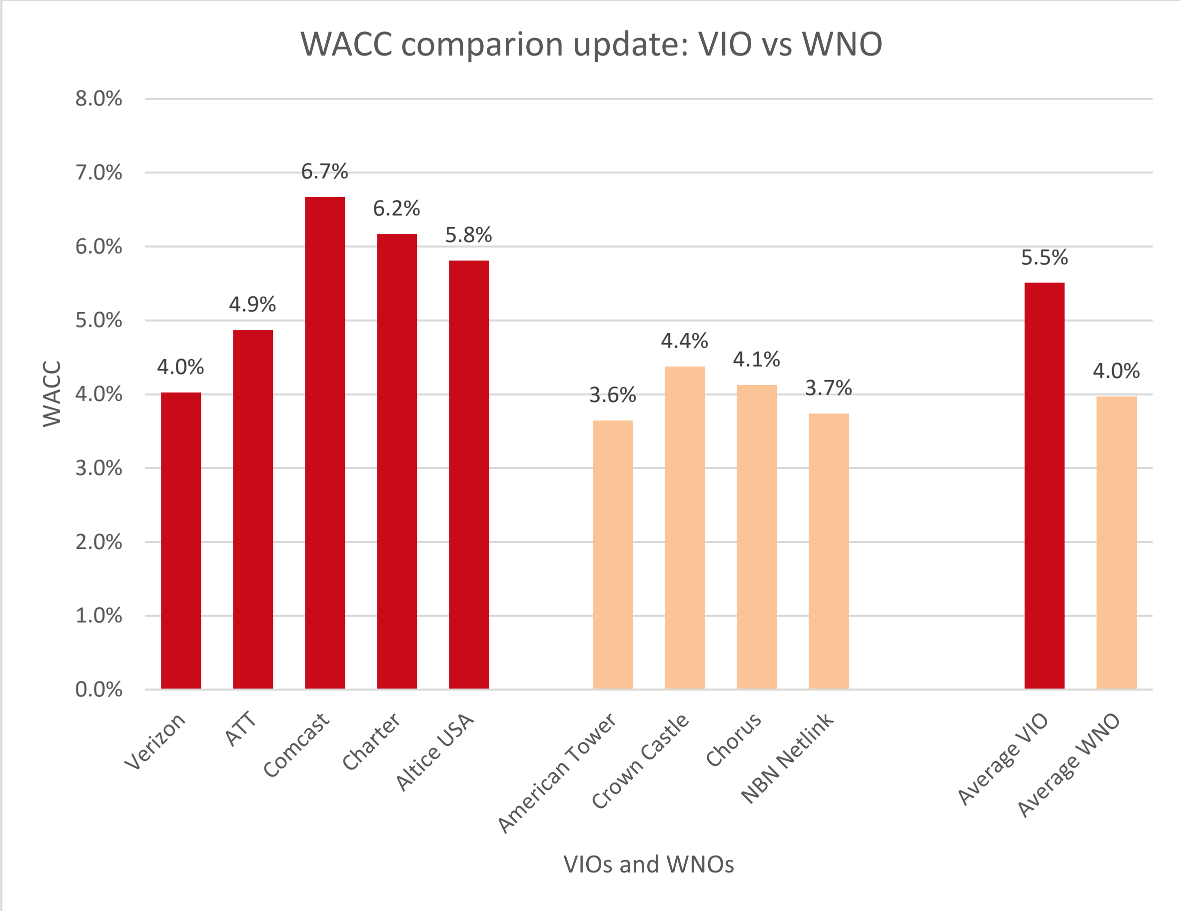
[29] INWIT (Infrastrutture Wireless Italiane S.p.A.) is the mobile tower business of Telecom Italia that was listed in June 2015)..

[30] Telefónica press release (10/02/2016) Telefónica creates Telxius, a global telecommunications infrastructure company (https://www.telefonica.com/en/web/press-office/-/telefonica-creates-telxius-a-global-telecommunications-infrastructure-company

Exhibit 10: WACC comparisons update for the telecom sector (US focus)



Source: own calculations based on Duff and Phelps estimates for the risk free rate and market risk premium, Refinitiv market data (via AskBrian)

Introducing the risk factor

A widely used metric when assessing financial models is the net present value (NPV) which is the sum of all discounted free cash flows (FCFs) to the present. The discount factor is the glue that makes FCF streams from different projects comparable. It represents the opportunity costs of investing in a similar model with the same risk-return characteristics. If the NPV is positive, the project is attractive and should be invested in. A project with a negative NPV should be avoided.

The discount factor (DF) is defined as $DF := \frac{1}{1+WACC}$

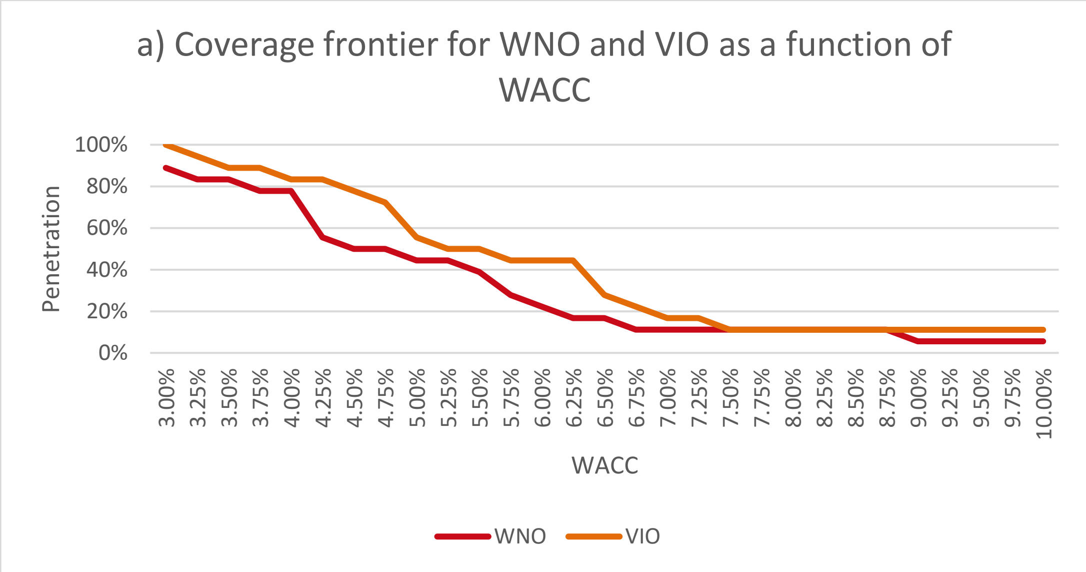
whereby WACC stands for the weighted average cost of capital. The WACC therefore represents what providers of capital expect from an investment with a given risk-return profile. (We defer a detailed discussion of the standard WACC formula to **Appendix B**).

In our model, investment profitability is directly dependent on the perceived WACC. We are looking at WACC only as an evaluation metric for investment viability. Therefore, we argue that outside of specific price regulation discussions, WACC should be as low as possible for the nation-building exercise of fiber for all to be achievable.

As we consider the WACC to be a parameter that public policy can affect in a significant way, we examine the results of our model at a range of WACC levels. **Exhibits 11a-c** show the ability of each model to cover a part of the territory depending on the WACC. The red area is the coverage potential of the VIO model, and the orange area is the additional coverage potential of the WNO model. Since we assume the WNO model has a 1.5%-pts lower WACC, the following exhibits detail the difference in coverage frontier.

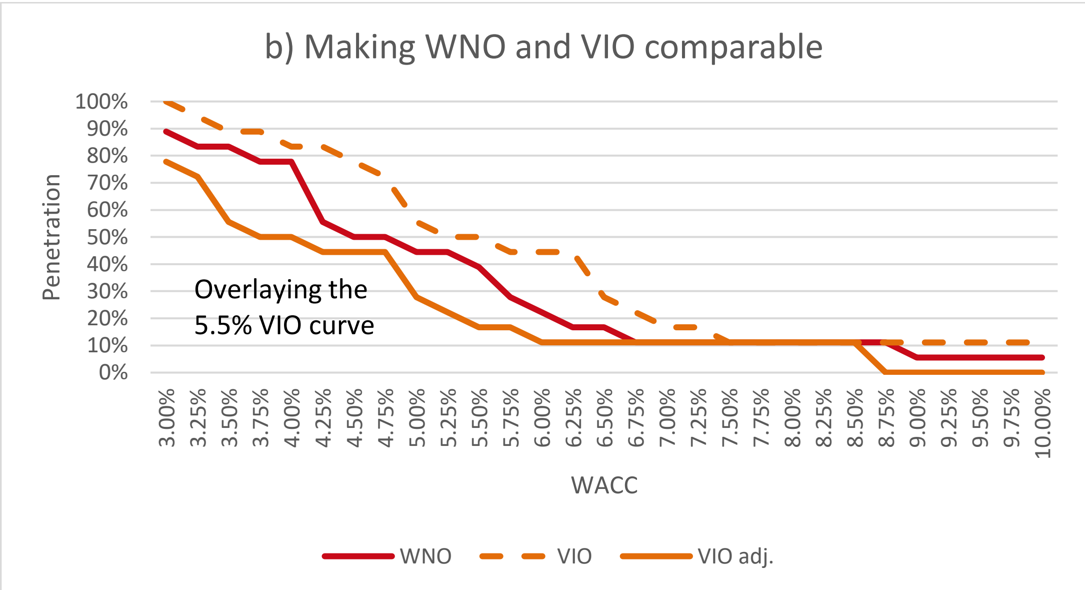
Exhibit 11a - c: Coverage 'frontier' of VIO and WNO models depending on WACC levels

As a starting point, we present coverage frontiers for both WNO and VIO business models. At any given WACC the VIO is superior to WNO. This result is driven by the fact that the EBITDA contribution per active customer is ~9% higher in the VIO model vs (45% x US$ 55 US$ = US$ 24.75 vs 65% x US$ 35.00 = US$ 22.75 on a monthly basis)



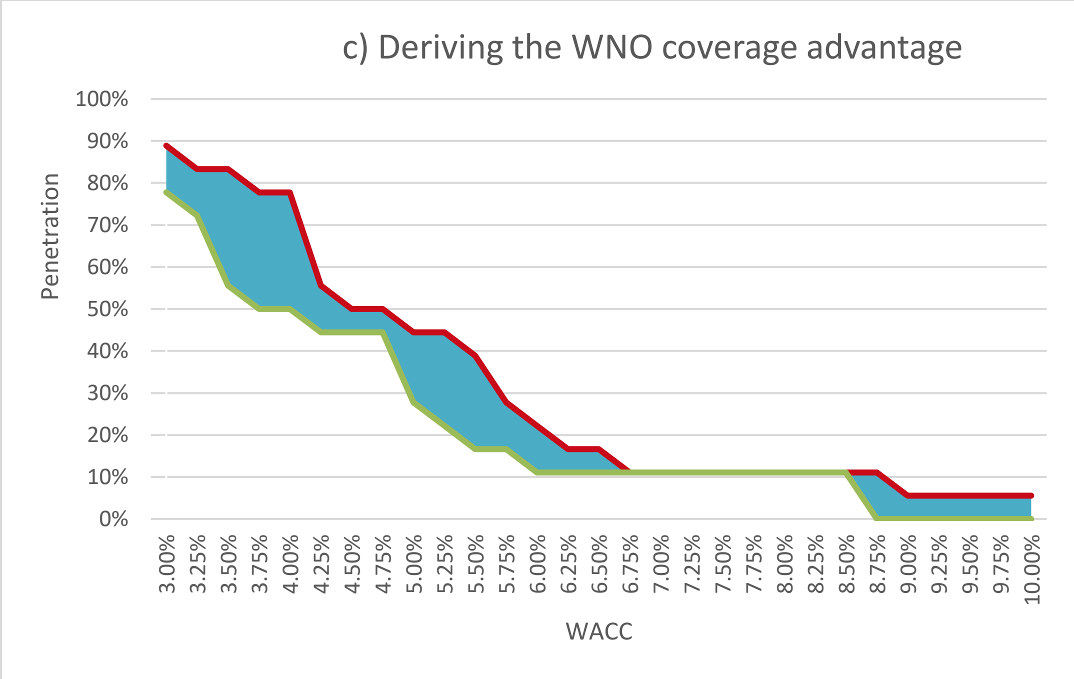
Source: Diffraction Analysis

However, the WNO business model is also inherently less risky. As a consequence, the curves need to be compared at different WACCs, not at the same WACC. To control for the 1.5%-pts advantage of the WNO business model, we shift the VIO curve by 1.5%-pts to the left.



Source: Diffraction Analysis

This shows that the WNO business model is the superior model when it comes to coverage, and we can quantify the coverage advantage. This advantage is meaningful in the relevant WACC interval between 4% to 7%. This is shown in the colored area between the two lines.



Source: Diffraction Analysis

From this initial result we can already draw a number of important conclusions:

- The ability of the WNO model to cover a larger portion of the territory is clearly superior. This is because of the lower cost of capital of the model.
- At a WACC of 5.5%, which is a "reasonable" assumption for a fixed telecoms business in the US (see also pp15-16), the VIO model would cover 50% of the population.
- At a WACC of 4% which is a "reasonable" assumption for a fixed infrastructure business in the US, the WNO model would cover 78% of the population.

Can public subsidies help the VIO curve look more like the WNO curve? To a certain extent they can, and this is effectively the model that was prevalent until recent years in Western Europe. In our model as it stands, the level of subsidy would have to be, on average, USD600 per additional active subscriber to "push" the VIO model towards the performance of the WNO model.

De-risking the project, *aka* lowering the WACC

As detailed above, the WACC is the result of the financial markets assessing a project, not a figure inherently tied to a specific market model. In other words, two WNO approaches in different countries would not be evaluated at the same WACC by the financial markets. The only exception, of course, is when the WACC is set by a regulatory authority, but then that is the WACC paradox in action: when it no longer serves as a relatively objective assessment of a project's viability, but rather as a tool to establish regulated prices.

Nevertheless, policy and regulation can impact the WACC even outside of price setting. Since the WACC reflects business risk, we call this de-risking. It is important to understand that the WACC in this approach cannot (simply) be set by a regulator. The regulator can only try to influence the perception of risk by investors who would then apply a different WACC. It may look rather strange, maybe even inappropriate, for policy makers to rely on capital markets to help fulfil their policy objectives. We argue rather that this approach is in line with other indirect instruments of broader economic policy to stimulate investments (central banks come to mind), and also that this approach should be operator-neutral and stimulate rather than stifle service competition.

There are a number of ways that a project can be de-risked, some desirable, some less so. **Exhibit 12** shows some examples of how European governments and/or policy makers tried to de-risk infrastructure projects.

Exhibit 12: European policy attempts to de-risk infrastructure deployment

De-Risking Measures	Consequences on VIO	Consequences on WNO
Lower deployment costs (lower rights of way, duct sharing...)	Increases infrastructure competition	Increases returns
Increasing regulated prices	Decreases overall competition	Decreases overall competition
Promote FTTC/VDSL	Not future proof (will require further investment down the line)	n/a
Anchor tenancy	Decreases competition	Increases take-up
Social tariffs	Increases take-up, decreases ARPU	Increases take-up, decreases ARPU
Encourage market consolidation	Decreases competition	n/a
Lengthen regulatory review cycles	Creates revenue stability, reinforces incumbent monopoly	Creates revenue stability

Source: Diffraction Analysis

It should be evident from the list above that while all the above measures de-risk parts of the business model, not all are equally applicable to both VIO and WNO models. In particular, many of the above when applied to a VIO model (i.e. one where infrastructure competition is assumed) either de-risk on the one hand while increasing risk on another (like opening duct infrastructure) or de-risk at the cost of competition. A structurally separate WNO model can be more easily de-risked because competition, while it may happen on the infrastructure layer, is not expected to do so. In other words, de-risking measures that only affect the infrastructure layer do not negatively impact service competition.

Model limitations

We note the following limitations of our model:

- We do not assume an infrastructure monopoly even in the case of the WNO model. We assume some cable or fiber alternative operator presence in the country.
- Only fixed-line communications revenues and EBITDA are considered. This excludes revenues from mobile services and content distribution.
- We restrict the model to the retail market. Potential other revenue sources such as business customers or mobile tower operator are not factored in. In our view, a more comprehensive

revenue model would lead to higher revenues, higher EBITDA but also a slight margin dilution due to higher complexity in network management and sales and marketing.

- We assume neither VIO nor WNO are regulated in the base case. Obviously de-risking and/or profit limitations to extend coverage would entail some regulatory oversight.
- Our model is built on incremental cluster NPV contributions. In other words, we assume that a cluster will only be commercially addressed if it contributes positive NPV to the overall project. This makes distinguishing direct and overhead costs complex. For simplicity's sake, we have allocated overhead proportionally to each cluster addressed.
- All projects with positive NPV can be financed.
- Our model captures FCFs from years one to infinity whereby the FCFs from year 26 onwards are reflected in a so-called terminal value. The terminal value is highly sensitive to changes in the WACC and can represent a significant portion of the overall NPV. So, for example, in the VIO case the contribution from the terminal value increases from 25% to 42% when the WACC decreases from 7% to 5%. We note that in concession models with a specified lifetime, the terminal value cannot contribute to the overall NPV[31] (unless parties have agreed on put or call options that define who will eventually own the network).

Key model conclusions

Before examining the implications and policy impacts of the findings, let us summarize the key points illustrated by this modelling exercise:

- In our model, a newly built Wholesale Network Operator at 4% WACC significantly outperforms a newly built Vertically Integrated Operator at 5.5% WACC when it comes to FTTH coverage.
- While policy and regulation struggle to de-risk VIO models without stifling competition, there are clear paths to de-risk WNO models while maintaining a healthy service-level competition.

[31] Ownership of the infrastructure remains with the public entity, so its terminal value is not part of the concessionary's business model.

IV. Conditions of an Efficient Wholesale Network Model

The above results demonstrate that an unsubsidized wholesale FTTH model could offer fiber broadband to a high proportion of the US population. But like all models, it needs to be tempered with reality. As wholesale network operators develop in Europe and (to a limited extent) in the US, we have more and more feedback on how they operate and what challenges they face. This in turn may determine some policy contexts that would favor the emergence of such models. Which will finally lead us to how public intervention or funding may enhance or magnify the deployment of wholesale fiber.

Challenges and issues of wholesale models

Wholesale FTTP models might be more effective at building coverage, but they face their own set of challenges when it comes to deployment and adoption. It's important to acknowledge those so that they can be addressed better:

Building scale

One of the issues that wholesale fiber models often face is not inherent to the wholesale model but rather a result of how it often comes to happen. With a few exceptions like New Zealand (Chorus) and Italy (Open Fiber), wholesale fiber deployment tends to be local and therefore, by definition, small scale. However, in order to operate efficiently and deliver to end users the promises built-into the model, a wholesale platform needs at least some degree of competition from ISPs serving the platform's customers. The small scale of many wholesale fiber projects has proven to be a hurdle as large national ISPs with brand recognition refuse to join the platform. Their key reason for doing so is that the investments in connectivity and systems is too high for a small number of customers. Assuming, as is likely, that in a US context wholesale fiber would also, at least at first, emerge locally, this scale issue needs to be addressed from the start.

The key solution to this challenge is for WNOs to adopt common practices and especially common systems so that ISPs need not build bespoke interfaces to provision and bill customers on each network. An even better solution would be to collectively fund and run a provisioning and billing that would act as a bridge across all the participating WNOs. This would help build scale very fast, changing the dynamics when talking to ISPs: it's a very different conversation convincing a large established ISPs that he has a potential of a few tens of thousands of customers and a few million. This could even bring over some of the incumbents when they realize the considerable market potential in territories they currently don't cover with fixed broadband and wouldn't have to invest infrastructure into to serve. In the context of public subsidies or municipal projects, policy driven constraint could be devised so that each WNO project doesn't go its own way when it comes to systems.

Middle mile access and affordability

In most western world contexts, when business modelling FTTP, the access costs far outweigh middle mile costs. And in most western countries, middle mile connectivity is abundant and affordable. That's not true everywhere in the US, and it may create some significant issues when examining deployment opportunities (wholesale or vertically integrated). Our model above assumes middle mile exists and is abundant, therefore does take middle mile into account only as reasonable OPEX. In the US context, the issue of availability is compounded by an issue around price transparency. In most western markets, middle mile costs are subject to price transparency (and therefore equivalency) regulations which means that a fiber deployment project not only knows which middle mile resources are available to backhaul their planned fiber access network, but they know that the prices are the same for all potential customers and won't vary widely over time. The availability of middle mile access and the conditions of its affordability are crucial to the emergence of any fiber alternatives to the incumbent's vertically integrated limited deployment. Failing an effective regulatory measure to address this issue, public authorities should be free to help the emergence of competing middle mile infrastructure or public networks to compensate for this market failure.

All out vs targeted deployment

In our modelling we assumed that the wholesale network operators would not only focus on areas where no fiber broadband was available but also deploy where incumbent operators have deployed fiber broadband. The main reason for this is that both from a network construction and a business model point of view it makes more sense. It's easier to build a contiguous fiber broadband access network, and higher margin revenues from low deployment cost areas can cross-subsidize higher deployment cost areas. Furthermore, specifically in the context of the US, existing take rates on fiber broadband are not very high[32], which means that even in areas covered by fiber there is still market share to be captured.

That said, if the key objective is to expand coverage, it may make sense to consider targeted deployment focused on uncovered areas. This approach would then work best in a concession model of sorts such as the one implemented by the French government for fiber deployment in areas where no VIO expressed deployment intentions. The absence of existing competition secures demand, allows for subsidized deployments without market distortion and reassures established market players (and may even convince them to participate in offering services on top of the wholesale infrastructure). Either model may work. The all-out models will likely be more financially viable, but may take longer to reach no-broadband areas. Targeted models work best in a context of public intervention.

Accelerating private investment through policy intervention

The policy and regulatory environment can be favorable or unfavorable not only to fiber deployment but to wholesale fiber deployment specifically. In particular, a privately funded wholesale model has investors looking for as much certainty as possible, wholesale being generally perceived as a more predictable model. Here are some elements that can be influenced by policy to make wholesale models more palatable to investors:

Accurate coverage mapping

Private investors are generally reluctant to overbuild existing fiber infrastructure. Because FTTP coverage is actually limited in the US, that leaves plenty of opportunity for deployment, but it requires accurate information about where fiber is commercially available and where it is not. In the US context this is an issue for multiple reasons. The first and most important one is that the way the FCC currently tracks fiber coverage (or rather available broadband speed, as a proxy) is by looking at the highest available speed subscribed in that census block. This means that if, for example, a business customer has a dedicated business line at 2Gbps, the entire census block could be considered to have 2Gbps service (ie. FTTP) available. The FCC aspires to only report residential class services but have created data collection processes to confound residential and business broadband connections; thus, if a

[32] RVA estimates that FTTH take-up is currently 44% (2020), which considering the first wave of US deployment is 15 years old, is a really low number compared to most European fiber experiences.

business customer has a dedicated business line at 2Gbps, the entire census block may be considered to have 2Gbps service (ie. FTTP) available[33].

At a state or county level, information about fiber availability isn't necessarily much more accurate: while many authorities track where fiber has been deployed, this doesn't account for the commercial availability of that fiber. In other words, if long distance fiber crosses a given county with no available ingress point to splice that fiber, it'll still be considered to have fiber. These issues could easily be addressed through the right policy tools and decisions, to ensure that national level fiber mapping is more accurate but also to enforce some traceability of access fiber, especially when underlying infrastructure (ducts or poles) is leased from public entities in the first place.

Passive infrastructure access

This is possibly the biggest issue in the US right now when it comes to broadband infrastructure deployment. There is a wealth of underlying passive infrastructure (ducts and poles, mostly) that – if reusable – would considerably lower the deployment cost of access fiber as well as speed deployment up. In many instances, this infrastructure is owned by private utilities or, most often incumbent telecom operators themselves. Sadly, infrastructure reuse often comes with considerable red tape, delays, and costs. Indeed, incumbents have been known to use pole attachment rules to slow down competitive fiber when they can[34]. It is telling that the largest wholesale fiber network in the US right now (Utopia in Utah) hardly if ever reuses existing infrastructure, even if deploying their own ducts is more costly: the impact on time to market of reusing infrastructure is such that the extra expense is worth it because the revenues come flowing much faster when deploying one's own infrastructure. This is absolutely an issue that policy can address. The UK regulator Ofcom has had a program in place for the last few years called "barrier busting" which aims at eliminating administrative hurdles to facilitate fiber deployment. This could and should be done in the US as well.

Price transparency and equivalency

This issue was alluded to before for middle mile availability, but it also has implications in fiber access. In order to build a predictable business model for wholesale FTTP, new entrants need to have an understanding of what they are competing against. In most western countries, whether price regulation exists or not for the incumbent operator, players need to have uniform pricing across the territories they serve. In other words, they cannot adjust pricing at a local level to either inflate their margins (when they have little to no competition) or stifle competition by pricing aggressively.

In the US, this is not the case, and cable operators in particular have been known to adjust pricing when they hear (or fear) that competition may be coming in a given area, so as to degrade the business model of their potential competitor before it has even entered the market. This is again an issue that can be easily solved by regulation, if not at federal level, then at least at state level. Market players should have to offer (at least) state-wide prices for equivalent services so that a healthy competitive environment can be built and that market entrants can accurately assess the economics of competing.

Interoperability

This may seem like a secondary point, but may turn out in the long run to be a crucial one. In most markets where private wholesale models have emerged, they have emerged locally. Even though each

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[33] https://arstechnica.com/tech-policy/2020/04/att-gave-fcc-false-broadband-coverage-data-in-parts-of-20-states/
[34] https://arstechnica.com/tech-policy/2013/12/why-att-says-it-can-deny-google-fiber-access-to-its-poles-in-austin/

may individually a viable business, the long-term perspective of many of those is consolidation. That's the exit that some of the investors are hoping for, and it's a logical trend in local infrastructure businesses as market matures. Consolidation however requires the perspective of economies of scale, and that can only happen if the networks being deployed are similar or identical in design.

The key challenge relates to the passive infrastructure itself (for example, the choice of fiber grade determines how compatible the deployed infrastructure is with future active upgrades) although active technology and various topology choices can also impact how easy it would be for a network to be merged with another network management system. While it seems difficult to enforce interoperability in a purely private market[35] (each player being free to deploy as it sees fit), policy can help raise awareness on that issue. It can also link public subsidies for local deployments to a set of binding choices[36] that would make interoperability easier down the line. Passive and active topology and technology choices have to be future proof for any attempt at consolidation to be viable.

The best use of public funding

As our analysis has shown, the most effective way to expand fiber broadband coverage with private investment is through a wholesale network operator model. But in the same way that actual coverage by vertically integrated operators is not at the level our model finds viable (because players choose to invest elsewhere), the fact that wholesale works on paper is not sufficient to make it thrive in reality. As we have seen above, many aspects of the general environment and policy context can hinder the deployment of wholesale operators if they're not addressed. But of course, one way to facilitate or even accelerate the deployment of wholesale fiber is through direct public intervention. In fact, that's where the use of public funds is likely to deliver the best bang for the buck.

Public investment vs. Public Private Partnerships

How to best inject public funds into wholesale fiber? It's not a simple question although there's enough experience with various models in Europe now that we can learn from what has worked. Obviously, as mentioned above, there can be public involvement in a wholesale fiber project without public funding, but let's focus now on the various forms of public funding and how they compare with pure private investment initiatives.

There are essentially two approaches to public funding. One is to establish public private partnerships where public funds are involved, but a private player builds and operates the network. One is for the public entity to fully fund its deployment and operations. Here we will briefly examine how these models work and the relative benefits of each.

[35] See the initiatives of SSNF in Sweden or the SwissFiberNet consortium in Switzerland.

Public Private Partnerships	Public Investment
Public Private Partnerships (often abbreviated as PPPs) regroup a variety of collaboration models between a public entity (state, county, municipality, etc.) and private players. While the models vary, the general philosophy is that public funding will either fully finance or (more often) cover the gap to a profitable model, but the actual business operations will be run by a private business. This is usually done as concessions, limited in time (15 to 25 years is customary for infrastructure) but renewable.	Public investment is direct, ie. the entity that finances is also the entity that will build and run the network being deployed. In some instances, this is done through a public utility that already exists and runs electricity or water (for example) for the public entity. In other instances, a publicly owned company is created from scratch to build and run the network.
BENEFITS PPPs allow public entities to focus on their core mission while still delivering the infrastructure they need. Because private partners are expected to make a profit, PPPs generally require less public investment as only the gap funding necessary to make an endeavor profitable need be invested.	BENEFITS Direct public investment gives governments (especially local governments) more flexibility when it comes to targeting deployment and addressing specific issues with broadband. Fiber business models become very profitable once the infrastructure has been paid off (usually 10-15 years). After this period a local government could conceivably lower prices dramatically since profit is not the goal.
DRAWBACKS If not private partner finds a given area attractive despite injection of public funds, then no PPP can happen. Public entities are subject to their choice of private partner. This is usually done through a competitive attribution process. If the private partner is ineffectual or defaults on the deal, public entities suffer and the fiber broadband network may not be deployed as well or far as initially intended. Also, because profit is expected from the private partner's point of view, PPPs are generally constrained by private market dynamics when it comes to products and pricing.	DRAWBACKS While FTTP might not look like rocket science, deploying and running it profitably still requires know-how. Though many US cities and towns have successfully built and operate FTTP networks, it is far removed from usual public service missions. It's not easy for a public authority to build and operate a network. As mentioned above, scale issues are compounded for local governments: while private businesses may aggregate customers across multiple networks they run, this is harder to do for local governments.

Further deployment, faster deployment and how to get both

The fact that we estimate close to 80% of the US population could be covered with private wholesale fiber profitably does not mean that it can happen overnight. From convincing investors to deploying and commercializing, it could take a decade or more to reach that threshold, even with all the right policy incentives in place. So how can an injection of public funding accelerate the trend? Essentially in two ways: by extending the coverage frontier further through public funding of networks where even a WNO model cannot find profitability (still a little over 20% of the population in our model) and/or by accelerating deployment.

- Extending the coverage frontier is a classic case of either gap funding of private players or fully public initiatives. In both cases this would normally apply to business models that aren't workable with purely private initiatives (ie. the 20% mentioned above). Gap funding is conceived as a subsidy that is handed to a private player to either deploy fiber in an area no one finds a commercial interest in or to deploy to 100% of a given territory (a municipality, typically) where only part of the territory can be profitably covered.
- Accelerating deployment is a means by which public money ensures a speedier implementation of a profitable business model. FTTP deployment is very capital intensive and quite often resources are tied in one area that cannot be allocated to another for parallel deployment. Public funding can allow a private player to allocate more means to the deployment process, thus speeding it up. Of course, this is also a good reason for a fully public endeavor if no private players want to deploy in a given area even though a viable business model is there.

In Europe, the State Aid rules were set up to allow this flexibility of public intervention to further deployment or speed it up provided that fiber (or other super-fast broadband solutions) were not already available or being deployed by private players in the area.

Addressing the demand issues, especially in low-income communities

While there is a clear and obvious correlation between broadband coverage and adoption, and while demand for faster broadband is no longer in question in the market as a whole, adoption can still lag in segments of the population or areas, particularly tied to low income. Broadband is a significant expense, and when balancing a budget, fixed broadband may not seem to be at the very top of vital expenses, especially for people who already pay for a mobile data subscription.

Subsidizing consumers with low income directly might seem like a seductive idea, but few countries do that, essentially because this is an expense over the lifetime of the end-users rather than that of the fiber project. Some alternatives have been used with some success however:

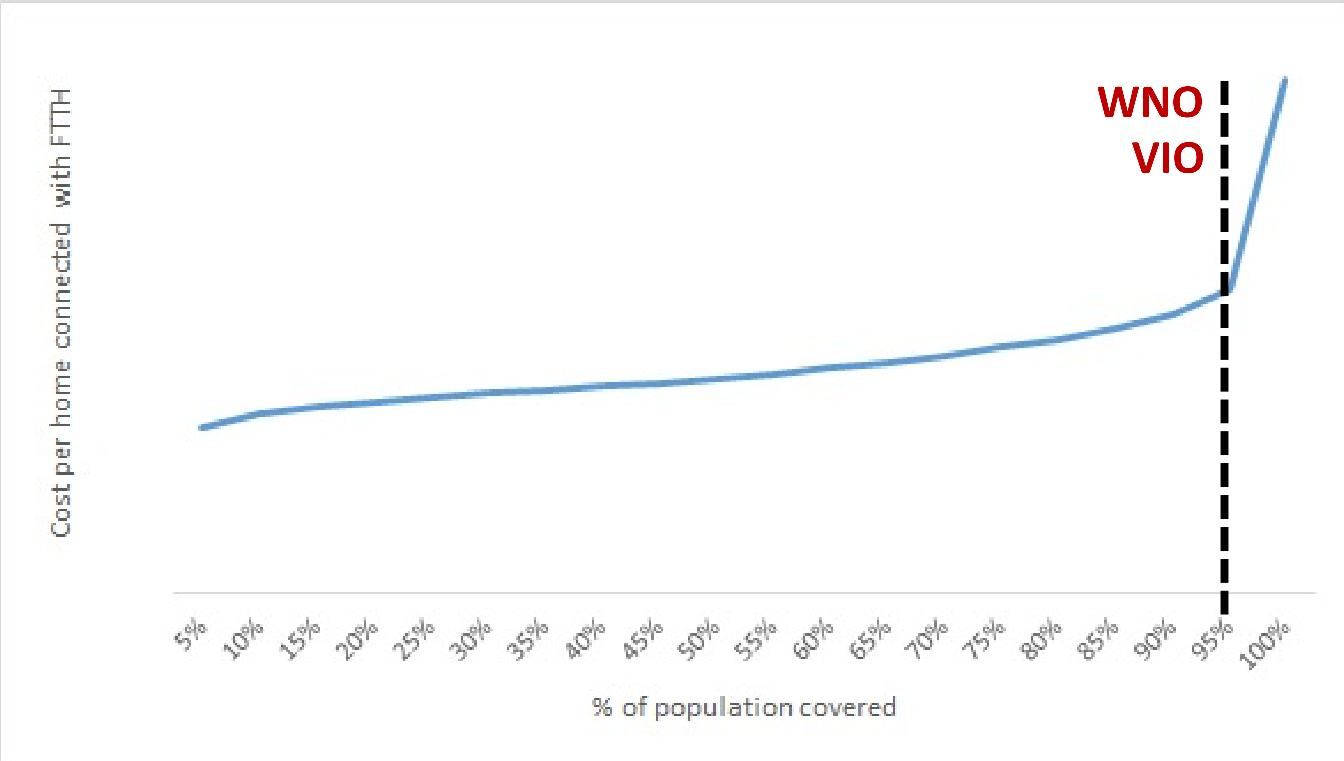
- Subsidizing home connection: usually through vouchers that pay for part or all of the initial home drop, thus allowing for a cheaper rate because part of the initial infrastructure investment is already paid for.
- Subsidizing devices: often end-users would like to subscribe to fixed broadband, but they can't afford devices that would make the most use of fixed broadband (computers, tablets, etc.) Subsidizing the purchase of such devices for low-income households is a way to overcome this hurdle without subsidizing the broadband access itself.
- Social tariffs: in the context of public private partnerships in Europe, funding conditions often include some form of social tariffs to ensure that low-income households don't have to pay as much as average customers. Ideally, these tariffs work on diminished margins for these customers, but it's important (at least in the context of a PPP) that low-income customers contribute even a little to the overall margin so that the social inclusion aspect of the project doesn't drag down the economics and slow down deployment.

In the context of European PPPs there have been past experiences of "free" offers at low speeds being enforced on the private partners of the PPP. Generally, these have not been very successful as business models often assume that the low bandwidth will eventually encourage users to upgrade. In practice, very little trumps "free", and quite often these provisions have been abandoned over time as they created a severe limitation on the take-up needed to get the business model profitable.

V. Applying the model to Los Angeles County

US FTTP coverage is low on the whole, but it is also very uneven. Somewhat ironically, even some of the densest urban areas in the country lack fiber coverage. Los Angeles county only has 33% fiber coverage, so less than the national average in one of the densest urban areas in the country. It seemed interesting therefore to examine how our models might apply to only LA County.

Exhibit 13: Coverage frontier for VIO and WNO in LA County



Source: Diffraction Analysis

As **exhibit 13** shows, the model demonstrates that in terms of coverage, there is no material difference between a vertically integrated and a wholesale model for FTTH in LA County. This is due to a significantly lower and flatter cost curve correlated to the building density in Los Angeles. In reality, the WNO model still performs a little better because it has a better NPV in the model output, but this isn't reflected in terms of coverage.

We assume that clusters with fiber coverage (33%, rounded up to 35% ie. clusters 1-7) largely overlap with clusters with gigabit cable coverage. For these clusters we model an equal market share for all gbps-capable infrastructures, ie. 33.3%. For the remaining 13 clusters, we model a market share of 45% for WNO. The rationale is as follows: 10% of the market rely on 4G/5G, DSL or FWA. The remaining 90% are again equally shared, in this case a cableco and the new WNO fiber entrant.

These results raise a very important question, and one that applies equally (though not quite so dramatically) to the national model: if it is profitable for Vertically Integrated Operators to deploy and sell FTTH to 95% of the LA population (50% in the case of the nationwide modelling) why is it not happening? There are essentially three answers to that question:

- the primary players from whom investment in FTTH is expected are incumbent operators (ILECs in US parlance). By definition, they own the copper network already, and while it is profitable to deploy fiber, it's less profitable (to them) than deploying nothing or squeezing more revenue out of their existing network. Of course, that approach is by definition short term: the minute a competitor starts deploying fiber, the copper network becomes near worthless. Since that competition hasn't been forthcoming, deployment is not high on the agenda;

- while fiber deployment (at least to the coverage threshold calculated) is profitable, it might still be less profitable (in the ILECs views) than other investments. This is why we have seen so much CAPEX pouring into mobile networks rather than fixed networks in the last decade.
- finally, even when investment is profitable, the CAPEX necessary to invest is still considerable. Existing market players with limited investment capability will not invest even knowing that the investment is profitable.

This leads us to a classic case of what in regulatory parlance is called a market failure: there is market potential, but no one in the market wants to address it. Which leads public authorities to a conundrum of sorts: while the decision to intervene when private players cannot find a business case (as in deep rural communities for example) is conceptually easy, doing so in areas where a clear business case exists might be seen as unfair, a waste of public funds, or both. Can wholesale be a solution to that conundrum?

The question is especially relevant in this particular case because while FTTH only covers 33% of LA County, cable covers 92%. And while most of that cable plant likely cannot compete in terms of speed and reliability with a state-of-the-art fiber network, any investor looking at LA County would likely be a little concerned of such high coverage. Wholesale network investors are particularly sensitive to a steady and predictable demand, one of the promises of the WNO model.

In our analysis, we calculated that we could significantly degrade our market share assumptions for WNO by 10%-pts to 35% in clusters 8 to 20 without degrading coverage although NPV is impacted (if market share degrades to 30% in all clusters, then 85% of the market can still be covered). Considering fiber only covers 33% currently, this seems like a workable assumption[37]. In other words, there is a realistic WNO business case to be built for LA County. The question then becomes: how to attract one or more private investors to deploy this wholesale network in the face of an existing competition that could scare them off?

One fine line that could be walked by public authorities could facilitate this investment without disrupting the market could be as follows:

- The county finances "public building" fiber network connecting schools, hospitals, public administration buildings, police sites, etc. The project is structured as a PPP with public funding allocated to the provider who, from this core network deployment, will reach out extensively to access the underserved areas of the county. In other words, the opportunity is not awarded to the cheapest deployment, but to the most ambitious.

[37] To illustrate that multiple fiber build is actually happening see (1) https://www.ispreview.co.uk/index.php/2021/09/connexin-pledge-to-end-kcoms-broadband-monopoly-in-hull-uk.html or (2) Berlin where a JV of utiliy Vattenfall and Eurofiber want to take on Deutsche Telekom in the German capital: https://www.golem.de/news/vattenfall-eurofiber-glasfaser-in-fernwaermekanaelen-fuer-das-land-berlin-kommt-2109-159931.html. Moreover, Berlin-based cableco Telecolumbus found a new investor (Morgan Stanley Infrastructure Partners) and has since then opened the network for other ISPs: https://www.telecolumbus.com/finanznachrichten/tele-columbus-ag-tele-columbus-setzt-mit-morgan-stanley-infrastructure-partners-und-united-internet-auf-die-umsetzung-des-ge-planten-glasfaserausbaus/

- In addition, that network acts as a county wide backhaul solution, at transparent and affordable prices so that other network initiatives aren't hindered by the middle mile market failure that might otherwise stifle network deployment initiatives.

Of course, even if it's unlikely that a county as dense as LA would not find a private partner to invest in, the county would be forced to invest directly. There are many successful examples of that in Europe and the US, and while it would take the county a little further away from its core mission, it would be addressing a market failure. Sometimes, these approaches are unavoidable.

VI. Conclusion

As the US federal government and various states consider boosting broadband infrastructure investment, our analysis demonstrates that the best approach would likely be to promote the emergence of wholesale fiber networks, whether locally or regionally. Because these networks are considered infrastructure by investors, they benefit from lower costs of capital which makes them inherently better suited for fiber investment. Furthermore, their emergence doesn't distort competition on the retail market as established players and newcomers alike can operate on equal terms on the these wholesale fiber platforms.

There is a lot, from a policy perspective, that can be done to facilitate the emergence of these wholesale FTTP networks, but probably the most important points to address concern the accurate mapping of existing fiber infrastructure, and the imposition of light regulatory solutions to ensure equivalent pricing so that customers across a given state pay the same for the same services. This will stop incumbent operators and cable from cross-subsidizing low competition areas to undermine emerging competitors in other areas.

The wholesale network model that we are advocating can be viable even if it overbuilds existing fiber networks where they have been deployed. The take-rates for FTTP in the US is low, especially considering the bulk of the fiber deployment happened over 15 years ago. The premium price positioning that the oligopolistic market allowed kept this take-up at lower rates. A wholesale player, by enabling competition on its fiber platform, would allow for more aggressive pricing and therefore a viable market share.

But it doesn't necessarily have to be this way. WNOs can also be deployed specifically in areas where gigabit broadband isn't available at affordable prices (though in order for that decision to be made, accurate mapping and pricing must be assessed). The beauty of it is that in this scenario, it would actually enable the participation of all market players including incumbent and cable operators. In other words, WNOs can be a great vector for existing market players to expand their territories without any CAPEX investment on their part. In many European markets such as Germany, the UK, France or Italy, established market players and even incumbents have been eager to embrace wholesale networks as a fast and low capital path to market expansion.

Public investment can of course accelerate or expand the reach of such wholesale networks and is a sounder model for public intervention in that it does not distort retail competition. Local, state or federal governments can encourage public private partnerships where private players would build and operate open networks partially funded by public entities to ensure their profitability. Failing that, they can also decide to invest directly through existing utilities or by creating new fiber utility entities from scratch. There are pros and cons to all of these models, but there are also successful examples for all of them.

As infrastructure in general, and fiber infrastructure in particular becomes a focus on public policy in the coming months and years, it's important to think outside the box: this isn't the first time that public funds will be funneled towards broadband in the US, but the results to far have been lacklustre at best. Focusing policy and funding efforts on wholesale fiber is a key solution to avoid the repetition of past failures and finally get the US citizens the affordable high-speed broadband they deserve and that most of the rest of the developed world already has access to.

Appendix A: Model Assumptions

The model approach is centered on the net present value (NPV) contribution of the marginal subscriber. We segment the entire market (the total number of households) into 20 clusters, each containing the same number of households.

The clusters are ordered by their estimated specific costs of deployment, as follows:

Capex per FTTH (US$	977	1,155	1,549	1,724	1,798	2,120	2,234	2,342	2,694	2,917	3,171	3,367	3,602	3,810	4,099	4,497	4,866	5,210
Cluster	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

The estimates by cluster are based on the capex formula derived by Cartesian (**C_{pass}= $7,549 -$2,161 * $\log_{10}$(Density)** plus a extra amount for a home connection (between US$ 277 and US$ 645 (calculated by the authors of this study and derived from an average value of US$ 550 by Cartesian)

The revenue assumptions per household for the two models, VIO and WNO, are US$55 and US$35, respectively (per month excl. taxes). We model stable prices over the explicit forecast period of 35 years.

The revenue assumption for the VIO (US$ 55) is oriented towards the lower end of the price indices range to increase affordability across consumer segments.

Operator	ARPU (US$ p.m.)
Index data	
BPI Consumer Choice Index	48.42
BPI Speed Index	74.80
Operator data	
Comcast	60.60
AT&T (IP Broadband)	53.52
Charter	62.35
Verizon	68.72
Altice USA (Broadband)	71.94
Average Operator	**63.43**

Sources: 2021 USTelecom Broadband Pricing Index (Arthur Menko Business Planning, Inc.), https://www.cmcsa.com/news-releases/news-release-details/comcast-reports-1st-quarter-2021-results, https://investors.att.com/~/media/Files/A/ATT-IR-V2/financial-reports/quarterly-earnings/2021/q121/1Q21_Trending%20_Schedules.pdf, 2020-Q4-FOI-v031021%20(1).pdf, https://investors.alticeusa.com/investors/alticeusa/results-and-presentations/event-details/2021/Altice-USA-Q4-2020-and-Historical-Pro-Forma-Financial-Information/default.aspx, https://ir.charter.com/static-files/853175db-33dd-4782-b20e-38df51bb1de8

The revenue assumption for the WNO (US$ 35) covers line rental and operations, including backhaul/backbone and IX fees. The difference of US$ 20 is the gross margin for an ISP for one active line.

Generally, we stress that our model approach only takes into consideration the retail market and ignores higher margin products sold to small businesses, enterprises, the public sector or mobile tower operators. Thus, we consider the WNO revenue model is conservative.

The margin model in both cases assumes a stable EBITDA-margin per incremental active customer of 45% (VIO model) and 65% WNO model.

US incumbent operators have an EBITDA-margin of around 40%., with Verizon at an estimated 16% being the exception. We apply the higher incremental margin of 45% for two reasons: (i) to stress the superiority thesis of the WNO model and (ii) to account for fixed costs elements in reported margins. We see the very low fixed broadband margin of Verizon as a strong sign that the mobile business is considered of far greater importance

Sample for VIO	EBITDA margin
Comcast Cable Communications	42.1%
AT&T (Consumer Wireline)	34.8%
Charter (all segments)	38.5%
Verizon Communications	*16.0%*
Altice USA (all segments)	41.9%

Source: 2020 Financial Results, except for Verizon: Citi Equity Research, dated April 22, 2021

The WNO margin range is derived from the reported EBITDA figures of wholesale and infrastructure-centric operator companies. In our view, the deployment of one common, modern infrastructure offers opex efficiencies.

Sample for WNO	EBITDA margin
BT Openreach (UK)	56.0%
Chorus (New Zealand)	68.5%
NBN Netlink (Singapore)	73.3%
American Tower	64.1%
Crown Castle	64.3%

Source: Company reports (last reported full year figures, unless otherwise noted)

As to capex in passive infrastructure and active equipment, we assume that the latter amounts to €100 per household with a depreciation period of six years (35 years for passive infrastructure). In addition, we model 1% of sales to be maintenance capex.

For simplicity, we assume that there is no shortage of capital or resources so that the network can be rolled out in all clusters with a positive NPV. In a similar vein, we do not make any explicit assumption about the capital structure. It is however implied in the WACC.

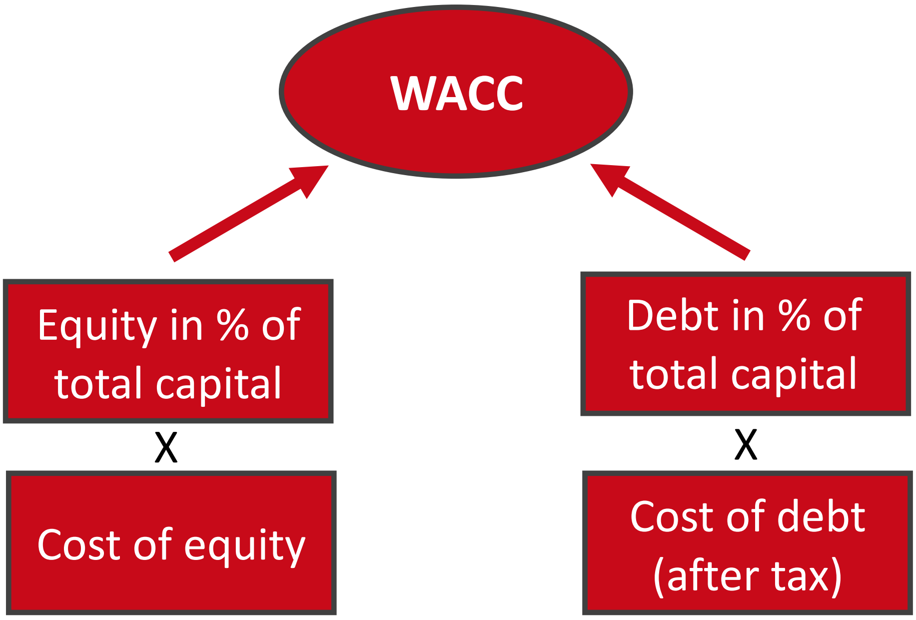
Appendix B: WACC Discussion

Company	r_f	r_M-r_f	β	t	r_E	r_D	E%	D%	WACC
Verizon	2.50%	5.50%	0.46	25%	5.03%	2.43%	61%	39%	4.03%
ATT	2.50%	5.50%	0.76	25%	6.66%	2.66%	55%	45%	4.87%
Comcast	2.50%	5.50%	1.04	25%	8.22%	2.33%	74%	26%	6.67%
Charter	2.50%	5.50%	0.99	25%	7.94%	3.08%	64%	36%	6.17%
Altice USA	2.50%	5.50%	1.12	25%	8.68%	4.13%	37%	63%	5.81%
Average									**5.51%**
American Tower	2.50%	5.50%	0.23	5%	3.74%	3.20%	82%	18%	3.64%
Crown Castle	2.50%	5.50%	0.38	5%	4.59%	3.46%	81%	19%	4.38%
Average									**4.01%**
Chorus	2.50%	5.50%	0.42	29%	4.81%	3.50%	48%	52%	4.13%
NBN Netlink	2.50%	5.50%	0.23	17%	3.77%	3.50%	87%	13%	3.74%
Average									**3.93%**

Source: Refinitiv (via AskBrian, Duff and Phelps, own analysis

Description

We start with the standard textbook formula for the weighted average cost of capital (WACC), which is based on the capital asset pricing model (CAPM). The WACC is an opportunity cost and is calculated as a weighted average of the cost of equity and the cost of debt (the latter after corporate taxes).



This simple formula is sufficient for our purposes[38]:

$$WACC := r_E \cdot \frac{E}{E+D} + r_D \cdot (1-t)\frac{D}{E+D}$$

whereby:

r_E := nominal cost of equity

r_D := nominal cost of debt

t := marginal tax rate on net financing costs

D := market value of debt and $D\% := \frac{D}{E+D}$

E := market value of equity and $E\% := \frac{E}{E+D}$

The cost of equity is given by the standard formula[39]:

$$r_E := r_f + \beta \cdot (r_M - r_f)\,,$$

whereby:

r_f := risk-free rate (ie. yield of top rated government bonds)

r_M := return of the market portfolio (i.e. all investable securities)

β := a company or project-specific risk scaling factor (market portfolio =1)

We rewrite the cost of debt to show a split in a risk-free rate and a spread component[40]:

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[38] We ignore debt betas.

[39] See, for example, Copeland, T.E./Weston, J.F (1988), p.450.

[40] As mentioned above, we ignore debt betas

$$r_D := r_f + (r_D - r_f)$$

In the context of valuing listed companies, it is also common to value the value of the tax shield explicitly. This value originates from the fact that interest expenses are tax deductible (whereas dividends as the returns to equity holders are not). This approach is advisable if a company cannot utilize tax shields due to low profitability, significant tax-loss carry forwards or Thin Capitalization Rules that prevent tax advantages of high-levered firms in M&A transactions. In the context of valuing projects, detailed analysis of the tax code and explicit modelling of tax charges and payments is standard.

The capital structure can be more complex and contain more financial instruments than straight equity and debt: convertibles or hybrid bonds, for example. For each instrument (or class of instruments) a cost of capital needs to be derived and market-value weighted. The logic remains the same, the formula only becomes more complicated.

To add some precision, all returns are annualized, nominal and expected returns. Discounted cash flow (DCF) models run by investors are typically based on nominal numbers discounted at nominal rates. Theoretically, it is also possible to discount real numbers at real rates. We highlight that it is not uncommon that regulators set real, pre-tax WACCs in contrast to nominal after-tax WACCs used by investors. Other variants are so-called “vanilla” WACCs, which use real numbers but ignore the tax shield effect. Thus, it is imperative to look at the definition of a WACC used.

Some expected returns are observable, the risk-free rate of (quasi) risk-free government bonds for example, others such as the expected return of the market portfolio must be inferred from statistical analysis[41]. How the cost of equity is structured is intuitively clear: investors want to be compensated for risk so they demand a risk premium

$$= \beta \cdot (r_M - r_f)$$

above the risk-free rate r_f. If an investor invests in the market portfolio, the β is 1 and the equation becomes $r_E = r_M$, for example.

In financial theory, the β is measure for risk and calculated by regression analysis of past data[42]. And in fact, most WACC estimates presented in this report are based on statistical analysis. We also see the β as a risk measure but would prefer a so-called fundamental β approach: The β is not the result of relative past stock price movements but a measure of business risk, based on fundamentals. These reflect aspects such as size, degree of competition, market growth, operational leverage etc. These aspects are quite close to the factors that rating agencies use to rate debt.

[41] As we deal with market expectations, it must be clear by now that there is no single correct measure for most of the variables.

[42] Even when β is calculated using regression analysis, there is no one true value: Fernandez (2010), p.4, gives an overview of β estimates by different service providers. The results range from 0.31 to 0.80 for Coca-Cola and from 0.13 to 0.71 for Wal-Mart, for example.

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