Fibre-optics: 21st century communication backbone

The growing need for fast broadband 'connectivity' in society and the economy requires a reliable, affordable, and scalable state-of-the art communications infrastructure network. To accommodate this, considerable investments are needed to expand and upgrade today's communication infrastructure network. This opens up an attractive new asset class for institutional investors: passive telecommunications infrastructure assets – such as fixed-line cabling, communication towers and data centers. These assets have lifecycles and utility-like characteristics with long investment horizons and can offer modest but reliable cash returns to institutional investors, backed by long-term lease contracts with telecom operators. Moreover, by introducing private capital to the world of communication infrastructure, institutional investors can play a vital role in the development of the 'digital economy', thus delivering important economic and social benefits.

However, investing in cable infrastructure nowadays effectively means putting one's money on one specific infrastructure asset: fiber-optics. That might seem a risky thing to do in an era of fast technological change and 'disruption', even if the exposure to technological developments is limited for institutional investors because they would not be investing in the telecom operators themselves. Can institutional investors invest in passive telecommunication infrastructure in the confidence that fiber-optic assets have the 'longevity' that not only provides investors with an attractive cash return during the lease term, but also maintains or even grows long-term capital value? Bouwfonds IM explains in this report that such confidence would be justified: fiber-optic technology has matured over the past two decades and is expected to provide the backbone for global telecommunications for most of this century, if not beyond.

Fiber-optics has become the key 'conductor' in the telecommunications infrastructure

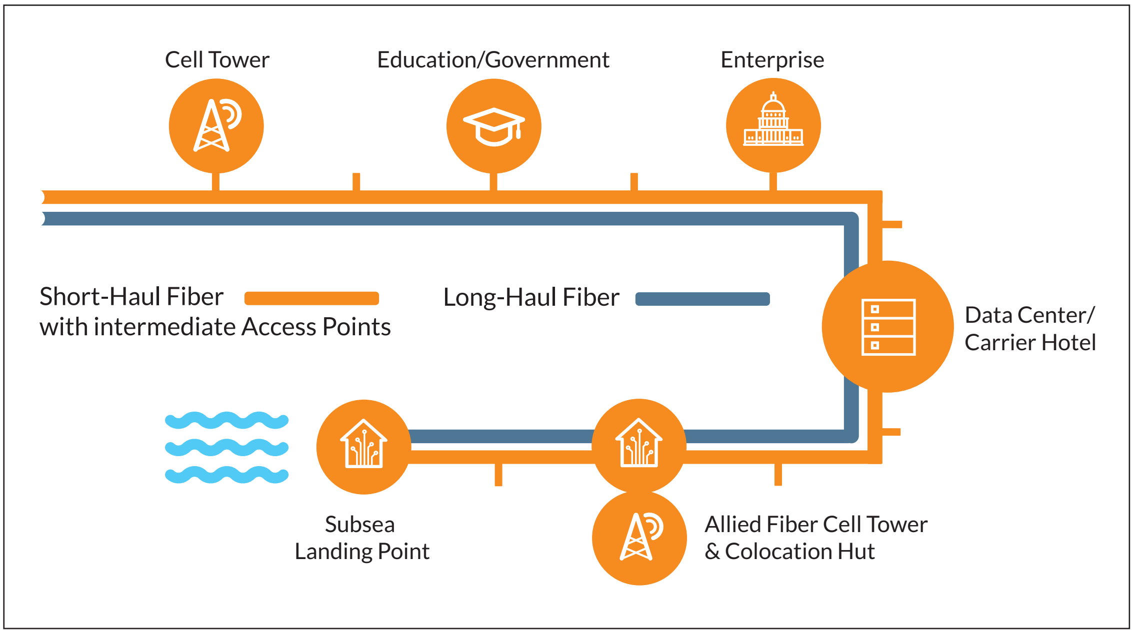
The Internet and wireless communication's rapid penetration in modern society has led to explosive growth in demand for broadband transmission capacity. The share of the world's population with an Internet connection has risen from less than 1% in 1995 to some 40% in 2016, with three-quarters of all internet users in 2014 domiciled in the top 20 countries (internetlivestats.com). As people and businesses have become connected, more and more of their everyday life and work has gone online – from communicating via e-mail, online shopping and watching streaming video to Cloud-based computing and business analysis based on 'Big Data'. In less than two decades, the lives of billions of people have increasingly come to depend on fast broadband 'connectivity'.

To meet this demand, telecommunications providers have been switching to data transmission via fiber-optic cables, first at the core of their networks, and then gradually expanding fiber-optics ever wider. This steady development has been in progress for about a quarter of a century. Consequently, fiber-optics assets are now the indispensable backbone of today's hybrid communication network of fixed-line and mobile infrastructure and data centers.

Fixed-line infrastructure

In leading markets, much of the fixed-line network has already been replaced by fiber-optic cables to benefit from optical fiber's far better performance for broadband services than twisted-copper networks. For example, fiber-optic cables are being used commercially to carry data at speeds of about 2 terabits per second (tbps; a terabit is 1000 gigabits or 1,000,000 megabits). Also, optical fiber has virtually unlimited capacity, low signal attenuation allowing long distances without amplifier or repeater, no exposure to parasite signals or crosstalk, and no electromagnetic interference (EMI). For comparison, while single-line, voice-grade copper systems longer than a couple of kilometers require in-line signal repeaters for satisfactory performance, it is not unusual for optical systems to cover 100 kilometers with no active or passive processing.

That said, the cost of replacing legacy cable networks with fiber-optic cables increases sharply as this work approaches end users (homes and business locations). As a result, fiber penetration to end users varies widely from region to region. In the leading Asian economies, more than 44% of all homes and buildings are already directly connected to the fiber-optic cable network ('Fiber to the Home' (FTTH) or 'Fiber to the Building' (FTTB)); in North America penetration is 8.4%, in Europe 5.6%. Europe's low penetration rate has been a cause for concern for years, because online communication and data traffic are increasingly part and parcel of modern life and considered to be a prerequisite for future economic growth as well as a country or region's international competitiveness. It is estimated that it would take Europe more than a quarter of a century to reach the same fiber-optic penetration rate that leading Asian economies already have today.



Role of fibre in broadband network connecting homes, office buildings, communication towers and data centres.

Mobile infrastructure

In mobile telephony and data traffic, radio signals transport voice and data to and from portable transceivers (mobile phones or other devices). This system relies on a network of 'cells,' each of which is served by a fixed-location transceiver, such as a Wi-Fi access point, or a mobile 'base station,' such as a communication tower. These fixed access points and base stations are in turn connected to a fixed-line cable network. When a mobile device is turned on, it registers with the mobile network and starts 'listening' for the strongest signal received from the surrounding base stations, switching from one site to the next to maintain the signal as the user of the mobile device moves around the network.

As mobile traffic continues to escalate, the 'backhaul' capacity of the cable-based network which supports mobile communications also has to increase. For example, a cell site carrying only GSM voice would typically require a backhaul capacity of about 1.3 megabits per second (mbps), 3G requires about 21 mbps, and LTE necessitates as much as 80 mbps. For many years, operators simply provided more copper leased lines when they needed more capacity, but this approach will no longer suffice as they are insufficient to carry the data load entailed by the introduction of the next generation of mobile technology capacity, 5G.

Operators have already started using optical fiber to connect mobile base stations, but there are still many mobile base stations that depend on 'old' technology which needs to be replaced. And where a new connection is required, optical fiber is installed in view of its superior transmission speed, as well as its potential to expand transmission speed supporting 5G. Hough et al. (2013) note that, 'as wireless and wireline technologies converge and the dividing lines become less clear, the common denominator will be optical fiber. Whether considering fiber-to-the-x (FTTx), WiMAX, LTE or 5G, future access networks will include fiber as an essential part of the network infrastructure'. And German telecommunications industry expert Markus Laqua says: 'a deep fiber network is essential for all future access technologies'.

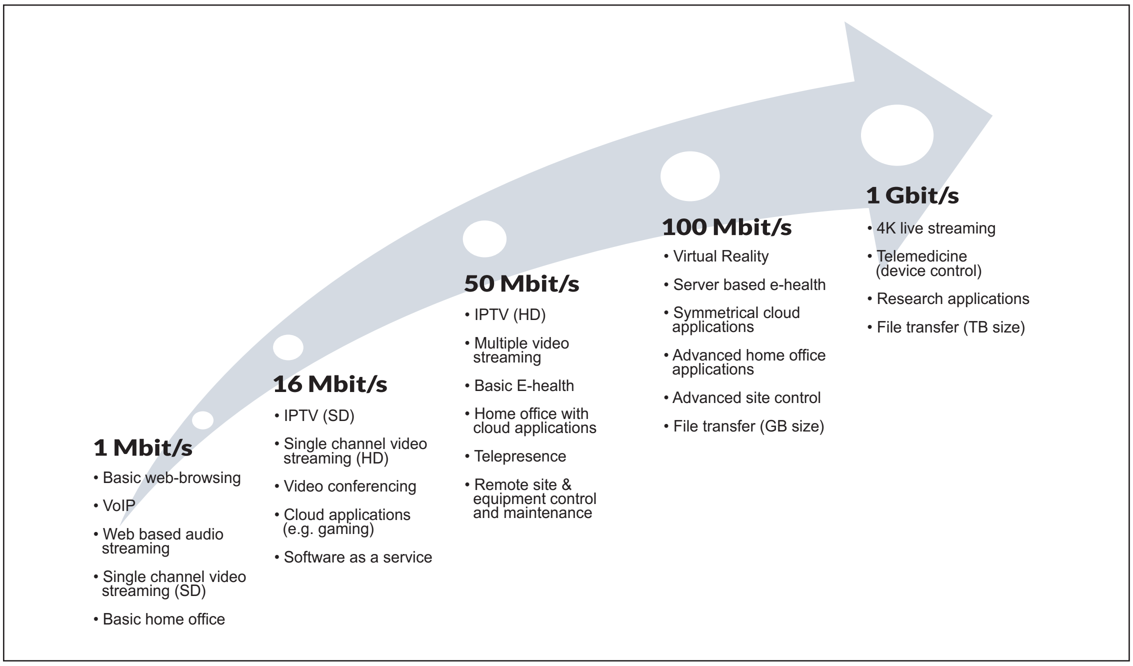
Data centres

With the convergence of service delivery to the IP protocol, more traffic is routed via the data centers using fiber optic technology. At the same time, there is an ongoing shift from local or corporate-managed applications towards cloud-based solutions, whereby users access the application via a web interface. As a result of this trend, data traffic between users and host servers is increasingly manifold. At the same time, new IT concepts (Big Data, Industry 4.0) are multiplying the volume of internet traffic, thereby driving the need to expand data center storage capacity as this has now become an indispensable part of today's hybrid telecommunication ecosystem.

Fiber-optics is the cable-based technology with the highest potential for transmission capacity

As already mentioned, Internet Protocol (IP) traffic has been growing exponentially for years, as human activities are increasingly going online, and there is no let-up in this trend. Services such as HDTV, 3D TV, 4K, video on demand, video conferencing, and new online applications in every profession and business imaginable are all driving further growth in data traffic. So is the explosive growth in wireless communication – smartphones, WiFi, the Internet of Things. It is estimated that by 2019, 54% of the world's total data traffic will run over mobile networks. Ongoing technological developments in all kinds of areas – virtual reality, autonomous driving, the smart grid – will continue to boost data traffic. These developments make a state-of-the-art global communication network even more imperative. Fiber-optic technology has already become the backbone of modern telecommunication infrastructure, and it is highly likely to remain so for most of this century, for the following reasons:

- It is superior to any other cable-based alternatives
- The technology for expanding its transmission capacity through more advanced active components for signal transmission and reception is already being developed



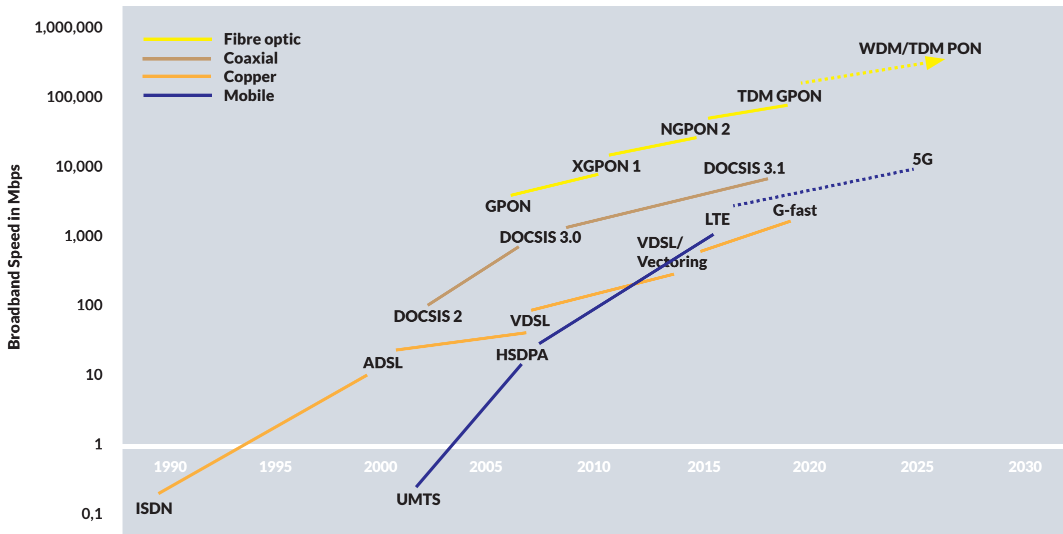
Growing need for capacity - source Goldmedia

Fiber-optic technology is superior to any other cable-based alternatives

Optical fiber lines, consisting of cables of glass fiber, are currently used in most long-haul, high-speed communications systems. In terms of capacity for future broadband, fiber-optic technology is superior to existing copper as well as coaxial technologies because of its unique physical characteristics, allowing information to travel at speeds increasingly approaching the speed of light without interference between adjacent wavelengths. The interaction between glass and light allows low-loss transmission over a broad frequency range, which means the entire transmissible spectrum can be used. Thus, much more data can be encoded and sent with fiber-optics, and the effective bandwidths are always going to be larger. Current equipment based on Passive Optical Network (PON) technology is capable of speeds of more than two gigabits (2 billion bits) per second – 20 times faster than the best consumer broadband technology available in the world today. For example, a single optical fiber can carry over 3 million full-duplex voice calls or 90,000 TV channels, and a cable typically comprises many of these fibers.

For much of the 20th century, the telecommunications industry has depended on unshielded copper twisted pair wire. Traditionally intended for voice only, these wires were subsequently adapted to provide broadband connections using DSL standards. But DSL technology is heavily asymmetrical: upload speeds are generally much lower than download speeds, and this may hamper new services such as cloud computing, videoconferencing, teleworking, etc. For short distances (a few hundred meters) and with good copper lines, new copper-based technologies such as vectoring and G.fast can now deliver fast broadband. But these technologies suffer from the same limitations as DSL, namely limited data rate, high attenuation and crosstalk, and can therefore only provide bridging capacity until a complete fiber-optic cable infrastructure is in place.

Coaxial cables, typically used for TV distribution, offer slightly more opportunities to deliver higher broadband speeds than twisted-copper telephone lines, and further implementation of new standards (DOCSIS 3.1) will allow for higher bandwidths (up to several hundred mbps) to end users. But coaxial cables are typically shared by many users, and when they want to go online simultaneously, the available bandwidth per user drops. Furthermore, this technology does not allow for physical unbundling, and hence service competition. And it has far less development potential than fiber-optic technology.



Sources:
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Technology for expanding fibre-optic transmission capacity is already being developed

Optical fiber networks employ one of two basic architectures: point-to-point (P2P) systems, or point-to-multi-point (P2MP) systems, which are usually referred to as passive optical networks (PONs). P2P networks are usually Ethernet-based networks with download and upload speeds of 1 gbps. In experimental trials with advanced optical devices, transmission values of more than 69 terabits per second (tbps) over a single fiber-optic strand have been reached.

Even more importantly, fiber-optic networks are highly upgradable should greater speeds be required in the future. Once the basic fiber-optic infrastructure is in place, it can be rearranged and the end-point electronics can be upgraded when necessary to deliver even higher capacity. Moreover, this can be done far more effectively than with existing wireless or copper-based systems. Offering an extremely high level of service, fiber-optics is the next-generation technology with capacity to meet the high bandwidth demands expected in the near future. Some examples of developments in the realm of fiber-optics:

- Recent research in the UK has pushed up the transmission speed for large volumes of data in glass optical fibers from below 70% to 99.7% of the optimum speed of light in a vacuum, showing that today's optical fibers have reached a very mature state.
- In 2013, researchers in the US demonstrated ultra-high-speed transmission with a capacity of 1.05 petabit per second (1050 terabits per second), using novel multi-core fiber and advanced multiplexing and signal-processing techniques. If required, current fibers can be replaced by multicore fiber at low cost using the duct and tube structure in place today.

No credible alternatives to fiber-optic cable technology are in sight

As stated above, due to the combination of fiber and glass, fiber-optic technology has a transmission capacity far superior to any existing cable-based technology (copper, coaxial) as well as significant potential for future upgrades. However, could an existing or future wireless technology perhaps disrupt fiber-optic technology? Nothing suggests it could: existing wireless technology is no match; reported new technologies are still at the stage of fundamental research at best; and even if a technologically viable alternative emerges one day, it would probably take decades to make a dent in the incumbent technology of fiber-optics.

Purely mobile is not an option

Wireless networks have become an essential part of modern communications. They have revolutionized the way people use computers and mobile devices, both indoors and outdoors, and enable the Internet of Things. It is a good thing, therefore, that wireless technologies are continually improving and are theoretically capable of speeds that rival – and sometimes even exceed – those achievable in fixed-access networks. Nevertheless, wireless technology is not a potential competitor of fiber-optic technology, and it never will be. When wireless transmission was experimentally pushed over the 6 gbps limit three years ago, fiber-optics had by then entered the realm of 100 gbps. At the current level of technological development, fiber-optics is up to 250,000 times faster than wireless, and in the experimental stages, a single fiber can carry 69,000 times more data than the entire bandwidth delivered by a wireless tower.

Also, the theoretical speeds of wireless networks are never achieved in practice, for a number of reasons: the records are achieved with the best equipment available; real-life performance is lower, because traffic has to include network protocol data exchanges for security and reliability; wireless networks can support either maximum speed or maximum range, but not both at the same time; transmission is affected by environmental factors; and speeds quoted are per cell rather than per user, which means available bandwidth declines as more people use the same cell (if 100 people share a 1gbps wireless network, they will each only obtain 10 mbps). Moreover, there is insufficient radio spectrum to allow wireless to replace fixed networks. Last but not least, wireless network connections are prohibitively expensive: typically 3-4 times more expensive, for less data volume and at a much slower speed.

All these reasons combined explain why not a single country or telecommunications company anywhere in the world is attempting to replace fixed networks with wireless in urban areas, or even planning to do so in the future. Projections show that the majority of all global IP traffic will continue to be delivered via a cable – although it is also expected that half of all that traffic will go wireless for the final meters of transmission, to 'land' on mobile devices via Wi-Fi.

Satellite broadband is no real alternative

Satellite broadband is a high-speed bi-directional Internet connection made via communications satellites instead of a telephone landline or other terrestrial means, and received via a satellite dish on the rooftop. Satellite broadband has several things going for it: it is now comparable with DSL broadband in terms of performance and cost, transmission performance is expected to rise to 30 mbps by 2020, and no regional backbone or area networks are needed. But users will have to buy equipment, only a limited number of users can be served in one region, high signal latency hampers certain applications, environmental factors may reduce signal quality, and data traffic is typically capped monthly or daily in current commercial offers. In view of all these issues concerning quality and affordability of service, satellite broadband, like wireless broadband, is a complementary rather than an alternative infrastructure, even though in specific circumstances (for example very remote/mountainous areas) it may be the only viable alternative.

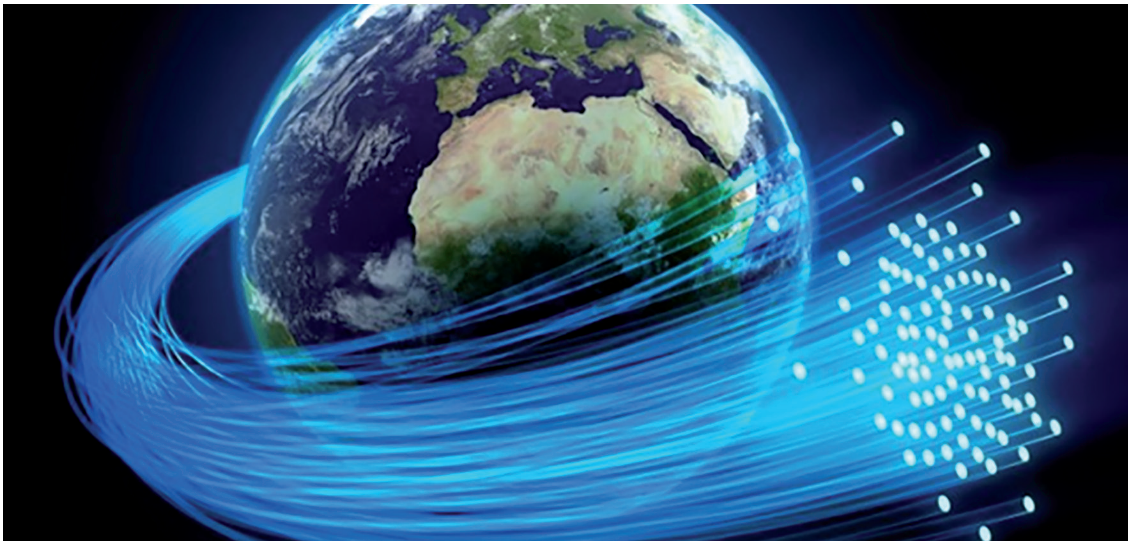
Possible alternative technologies, if any, will take decades to mature

Possible alternatives are only in the very early stages of development. If fundamental scientific discovery were to open the way to a new type of transmission technology, it would probably take decades to develop such technology to the point where it could be applied in the market. The development of fiber-optic technology itself illustrates the point: the telecommunications industry only embarked on its shift towards fiber-optic technology 150 years after the discovery of the physical principle (refraction) that makes fiber optics possible. Examples such as teleportation or DIDO technology are typical of the 'far out' realms of scientific research where budding new technology would have to be found.

Teleportation, the theoretical transfer of matter or energy from one point to another without traversing the physical space between them, was popularized by the Star Trek science-fiction television series ('beam me up, Scotty'). Developments in quantum physics have since led to scientific research into the concept. Experts recognize that extending research on quantum teleportation – which is not a form of transportation, but concerns only the transfer of information – and developing alternative forms of teleportation physics could have a 'high payoff impact' on communications and transportation technologies in the civilian and military sectors. However, advances reported in recent years illustrate just how much quantum teleportation is still at the stage of fundamental scientific research. DIDO, another example, is a technology reported several years ago by a US start-up company which allegedly could overcome one of the limitations of regular wireless technologies: the massive speed reductions that occur as more users join the network. But also in this case, it should be noted that even if the claim of a successful laboratory test could have been verifiably confirmed, various issues identified in this particular case suggest that at least a decade of additional research would still be required to scale up such test results.

Even if an alternative technology were ready for the market, substitution of fiber-optics would again take decades, if not longer

As the above examples of teleportation and DIDO illustrate, it will probably take decades to move any new technology from the fundamental research stage to something that becomes practically relevant. But even if an alternative and practically applicable wireless transmission technology were available, it would still take many years and probably decades for such a technology to encroach upon the already existing (and expanding) fiber-optic networks in any meaningful measure.



Reflecting that 'the world goes fiber-optic'

A comparison with freeways might illustrate the point. Even if freeways were mere bands of tarmac, the cost of replacing them would be phenomenal. But freeways are much more than that: they are ecosystems comprising entry and exit roads, bridges and viaducts, gas stations, and parking areas with catering, hospitality and retail facilities. And, last but not least, they are an integrated part of a society which is fully locked into the very means of transport for which freeways were designed in the first place. As the introduction of electric charging stations illustrates, such 'incumbent' infrastructure is not replaced overnight.

Electric cars themselves provide a further illustration of the obstacles new technology may have to overcome in order to gain so much as a foothold in the market. Originally conceived as far back as the 1830s, electric cars were briefly popular in the early 20th century before being pushed out of the market by gasoline-powered automobiles. Renewed interest in electric vehicles in the 1970s, in response to surging oil prices, proved short-lived. As did GM's all-electric EV1 in the 1990s. Following the success of the Toyota Prius hybrid electric vehicle and the Tesla electric roadster, and aided by improvements in battery technology, cost reductions and a growing range of models to choose from, electric vehicles seem at long last to have become a permanent 'fixture' in the automobile landscape. But large-scale substitution of the internal combustion engine still seems a long way off. For example, a comprehensive US government initiative launched in 2012 to make plug-in electric vehicles as affordable as gasoline-powered automobiles set a target date of 2022 for this ambition.

These examples may serve to illustrate that it takes a long time for 'game changers' to overhaul an entire industry. To replace an existing technology in a market with high entrance barriers, such as telecommunications infrastructure, any disruptive technology will need to deliver a quantum leap in performance, a significant reduction in total cost of ownership, and an affordable migration path concept. As stated, it took 150 years just to move from fundamental research on fiber-optics to the beginning of the industry's transition. That transition has been ongoing for some 25 years now, and in Europe penetration is still less than 6%, largely because of the prohibitive cost involved in replacing the existing cable network down to the 'last mile'. Consequently, that 'last mile' will, in the case of many households and offices, continue for many more years to be covered by copper and coaxial cables – possibly upgraded by new developments such as the aforementioned G.fast, a combination of high-frequency transmission and vectoring which increases copper-based bandwidths to several hundred mbps over a maximum distance of some 250 meter, thus reducing the bandwidth gap with the fiber-optic core of the network.

Considering that a deep fiber network is deemed essential for all future access technologies, Europe's catching-up strategy should be to extend fiber-optics deep into the network, thus providing many investment opportunities for institutional investors with a long-term investment horizon. Investments in fiber optics networks can be structured as core infrastructure investments similar to other core infrastructure asset classes based on long-term lease contracts with the network operator. This results in investments that can offer stable cash returns while limiting exposure to technological development by not investing in the network operator. However, although fiber-optics in itself is considered a long-term stable investment, as discussed in this report, and is often the preferred technical solution, one should always carefully analyze which migration path from legacy technology (copper twisted pair, coaxial) is the most opportune, taking into account local market conditions, the regulatory environment, and the characteristics of the service area.

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Bas van Dongen
Managing Director
Communication
Infrastructure Germany

Hans-Peter Renk
Fund Management

Peter Selgert
Investment & Asset
Management

Heimen Visser
Fund Director (NL) &
Aquisition support
BCIF II (NL)

bouwfonds
investment management