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FIBER FOR A SUSTAINABLE FUTURE

A KEY ENABLER TO LOWER CARBON EMISSIONS

IDATE DIGIWORLD

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Content

1. EXECUTIVE SUMMARY

- **Global greenhouse gas (GHG) emissions have risen dramatically over the last three decades** and are of major concern for our societies. Their malign environmental impact is pushing governments, enterprises, and civil society to reorganize and find cutting edge solutions to meet this challenge.

- The target of our research is to **investigate how ICT technology can contribute to the CO2 emission reduction,** especially thanks to fixed broadband and transmission technologies.

- One of our key conclusions: **fiber is the most energy efficient technology, offering the lowest CO2 footprint.** Fiber consumes three times less energy than xDSL and 10 times less than 4G access technology. Based on the data from GeSI (Global e-Sustainability Initiative) Smarter 2030 study, IDATE estimates that the abatement effect of Fiber will reach 1,6 Gt CO2 by 2030.

- **The impact of fiber network in CO2 abatement goes beyond the telecom industry**. Fiber connections are critical element for the provision of the new digital application by many industries based on either fixed network connection or wireless network. Hence, they would also benefit from deeper and more granular fibre networks to reduce their carbon footprint.

- **All industry players should consider how to integrate fiber networks in its CO2 reduction strategy**. Fiber per se would influence the CO2 abatement of the industry as a connectivity solution requiring less energy consumption. It can also indirectly influence the more efficient use of energy, heating and water consumption thanks to fiber-based metering devices network.

2. ICT TECHNOLOGY AND CO2 ABATEMENT

2.1. Global CO2 emissions background and goals to reduce environmental impact

2.1.1. ICT technology can reduce CO2 emission by up to 20%

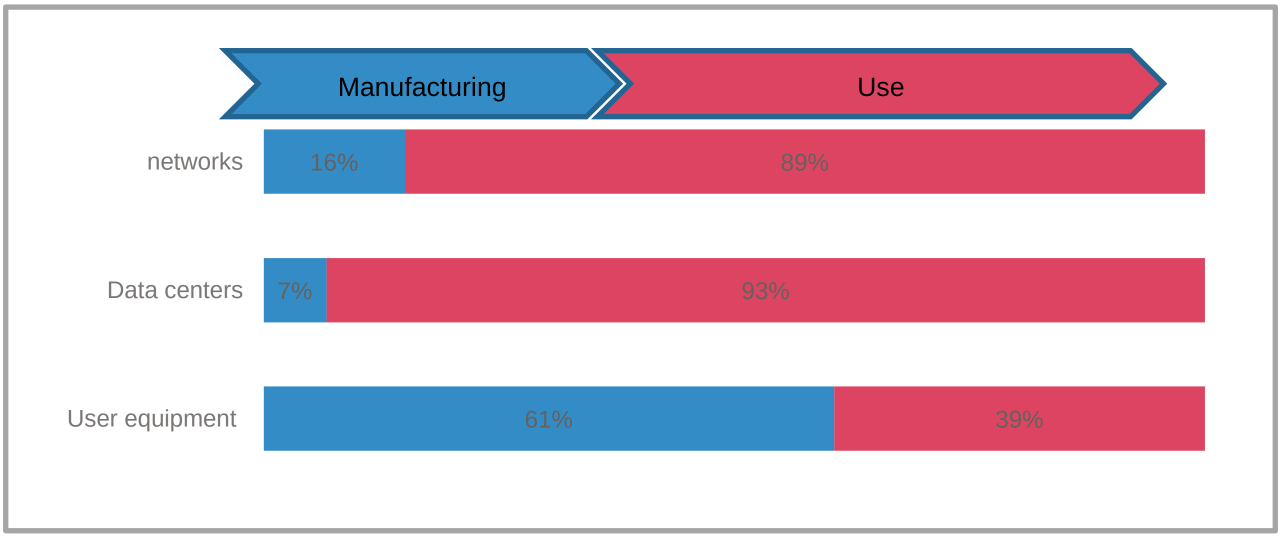
In the past decades, the advent of digital technology radically changes peoples' life and in every sector. ICTs provide the backbone infrastructure to facilitate digital innovation and business models innovations, collaboration, and the exchange of information, while reducing production costs and increasing productivity and efficiency. The broadband internet access became critical to booster economic growth and enable teleworking and in-distance collaboration, especially after the outbreak of COVID -19 pandemic. Internet is also a key enable to support digital innovation, improve the efficiency of business operation process, and create new jobs. The ITU report suggests that every 10% increase in fixed broadband penetration would yield an increase in 1.9% in GDP per capita. Most countries have positioned their ICT industries to fuel their economies growth.

Meanwhile, global warming has become to a major concern around the world. Global greenhouse gas (GHG) emissions have risen dramatically, increasing by 30% over the last three decades. The increase in global average temperatures is very likely driven by the increase in anthropogenic GHG concentrations. The Inter-governmental Panel on Climate Change's (IPPC) 's Climate Change 2021 Report reveal that human influence has speed up the warm the climate at a rate that is unprecedented in the past.

In general, environmental effects of the ICT are a double-edged sword because they have both positive and negative effects.

The ICT sector contributes approximately between 2% and 2, 5 % of GHG emissions, mainly from connected devices, data center and networks. These ICT hardware affect environments throughout the whole lifecycle.

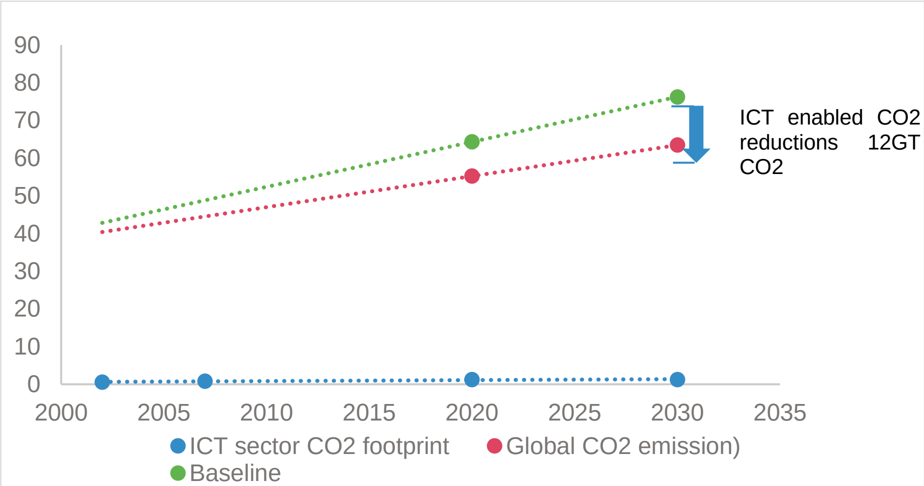
Figure 1: Distribution carbon emissions of ICT hardware



Source: IDATE Digiworld, based on Greenhouse gas emissions balance, 2019.

Digital technologies, the applications enabled by ICT in various sectors such as manufacturing, energies, healthcare and agriculture, is the major driver of digital economy growth and account for almost 40% of the world total. The potential of ICT is leverage it connectivity to reduce the in a large-scale across other sectors, accounting for rest of 98% of CO2 emissions. Through efforts and collaboration from governments, business and customer and the improvement of devices efficiency, ICT enabled solutions could unlock emissions reductions on a dramatic scale. According to GeSI (Global e-Sustainability Initiative) Smarter 2030 study, ICT enabled digital solutions have the potential to slash 12Gt CO2 emission by 2030, equivalent to 20% reduction of global CO2e emissions and nearly 10 times higher than ICT's expected footprint in 2030.

Figure 2: ICT sector CO2 emissions and ICT enabled CO2 (GT CO2)

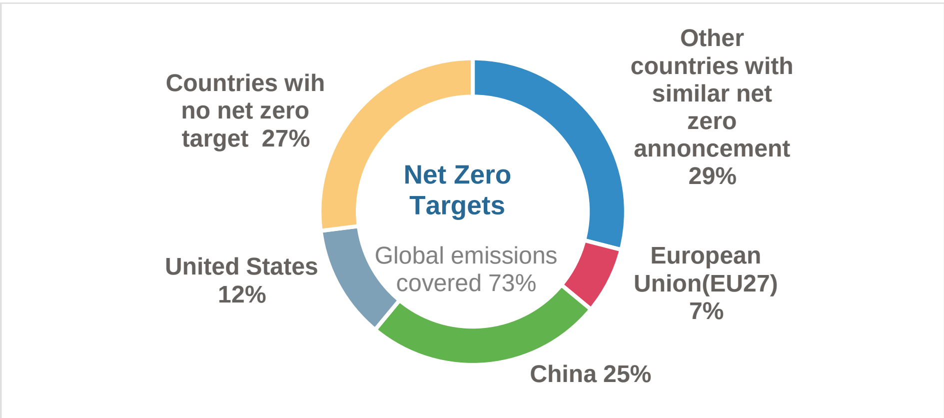


Source: GESI, Smarter 2020, Smarter2030

2.1.2. Governments and organizations set target to reduce carbon emissions

To tackle climate change and limit its negative impacts, many governments and organizations around the world have released climate protection polices and set carbon emission goals. More than 70 countries indicated carbon neutrality goals around 2050. Some counties like France and UK have legally binding net-zero emissions targets. Moreover, about 40 countries and more than 20 cities have already implemented carbon tax regimes.

Figure 3: Net zero target emission target announcements



Source: Climate Action Tracker

In addition, some international organizations have launched climate change related initiates to counties and industries business to combat climate change and lower the carbon emission. For instance, Paris Agreement, as one of major climate protection initiative, have been adopted by 197 counties since December 2015.

Table 1: International organizations climate change related initiates

Organisation	Initiative	Impacts on reduction cabon emmions
United Nations	The Paris Agreement	The Paris Agreement is an international environment treaty adopted in 2015. With the adoption of the UNFCCC, countries across the world set targets to limit global warming to below 2°C, ideally 1.5°C, compared to pre-industrial levels. As of 2021, 190 countries had ratified the Agreement. According to the Intergovernmental Panel on Climat Change(IPCC), global CO2 emissions would need to drop by about 45% from 2010 levels by 2030 to limit a 1,5° rise in 2015.
International Martime Organisation		In April 2018, the IMO's Marne Environment Protection Committe (MEPC) adopted an initial GHS strategy to reduce GHG emissions from international shipping. The initial strategy aims o reduce annual GHG emissions by at least 50% compared to 2008.
Internatak Civil Aviation Orgaization	Aircaft CO2 Emisisons Standard	In 2016, the International Civil Aviation Organization Councile relased a new CO2 emissions standard for upcoming aircraft, requiring a 4% reduction in fuel consumption of new aircraft starting in 2028 compared to 2015. The standard will apply to new aircraft type designs from 2020, and to aircraft type designs already in production as of 2023 and will mandate improvement in fuel efficiency and carbon dioxide emissions.
GSMA	Clilat Action Roadmap	In September 2020, more than 50 mobile operators agreed to start disclosing the environmental impact of their business, as part of new climate action initiative led by industry body GSMA. The initiative aims to develop a climate action roadmap and identify ways for telecom operators to reduce the amount of gaseous carbon compounds. The GSMA-led roadmap will also include development of an industry-wide plan to achieve net zero greenhouse gas emissions by 2050, a target outlined by the Paris Agreement.
GSMA	Science-based Pathway	In February GSMA together with ITU, GESI and SBTI develop a Scient -based pathway that allows ICT companies to set targets in line with the latest climate science. 29 operators groups have already commuted to SBTs; The SBT sets emission trajectory reduction over the decade of 2020 and 2030 for each ICT sub-sector. For example, mobile network operators adopting the SBT are required to reduce emissions by at least 45% over this period.

Source: IDATE Digiworld, data extracted from the related initiatives.

2.2. ICT contribute to reduce carbon emission

2.2.1. ICT is an opportunity to reduce environmental impact

The development of ICT and digital technologies opens many opportunities to tackling the environmental challenges such as climate change and reduction of carbon emission. The higher levels of connectivity that ICTs foster revolutionized every aspect of our life, such as way we communicate, collaborate and work. The digital technologies like AI, big data and IOA, provide the digital tools for monitoring climate change mitigation and adaptation, and also contribute to reduce carbon emissions that emanate from other industry sectors.

The innovations are difficult to quantify because they have not yet been scaled up, while their environmental impacts have already been identified. Nevertheless, Accenture estimates that that widespread adoption of ICT enabled solutions in various industries could offer the potential to suppress 15% /20% of current emissions. Therefore, it is critical to continuously investing in significantly upgrading ICT infrastructures to build ubiquitous high-speed broadband connectivity to address the increasing demand from various sectors.

Figure 4: Fiber empowers various vertical industries

Source: IDATE Digiworld

2.2.2. ICT technologies efficiency speed up CO2 reduction initiative

According to GeSI's SMART 2030 report, the adoption of ICT solutions in essential sectors and services like energy, transport, commerce, and building were to reduce global carbon emissions up to 15% and save up to 600 million EUR while creating 15 million green jobs.[1]

Such efficiency gains are mainly attributed to virtualization innovations like cloud computing and video communication but also to automation in manufacturing processes and smart livestock management. For instance, video conferencing tools could help save more than 100 hours of travel time annually per individual and consequently reduce travel emissions up to 67%[2].

[1] https://gesi.org/public/research/the-enabling-technologies-of-a-low-carbon-economy-a-focus-on-cloud-computing

[2] https://gesi.org/public/research/the-enabling-technologies-of-a-low-carbon-economy-a-focus-on-cloud-computing

An updated version of the report that studies the impact of ICT Solutions for 21st Century Challenges concluded that ICT could enable a 20% reduction of global CO2e emissions by 2030, holding emissions in 2015 levels[3]. While many essential services (i.e.E-Learning tools) are increasingly moving online thanks to cutting-edge ICT technologies, C02 emissions are expected to reduce by 12.1 billion tons by 2030[4].

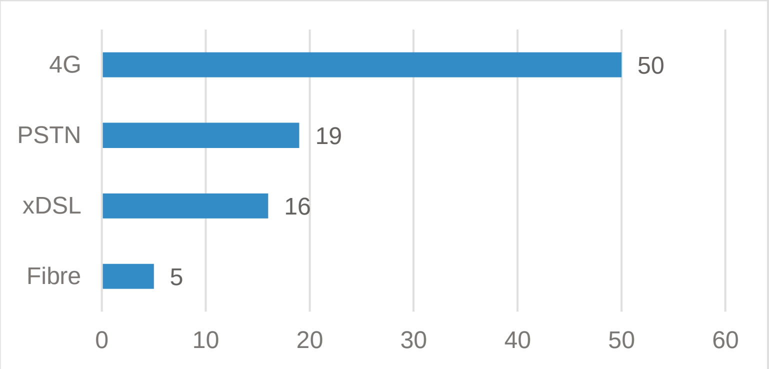
A large part of this impact is thanks to ultra-high-speed broadband solutions that are expected to give 1.6 billion more people access to healthcare and half a billion more people access to E-Learning tools. (i.E. e-governments, edtech, e-health).

2.2.3. Fiber network is the most energy efficient communication solution

The energy consumption of fixed (and wireline) technologies does not depend on data traffic whereas mobile technologies are directly correlated to data consumption. Hence, Fiber consumes 3 times less energy than xDSL and 10 times less than 4G access technology.

Therefore, Telcos play an important role in exploiting energy efficient connectivity solutions. For instance, Telefonica[5] expects to reduce by 85% the CO2 emissions and energy usage thanks to the closure of the copper network in Spain.

Figure 5: Comparison of yearly energy consumption in kWh per line *



Source: IDATE DigiWorld based on ARCEP report (réseau du future, empreinte carbone numérique)
* Based on 7 GB monthly data consumption per line

According to the German Environment Agency, FTTP is the lowest emitter of greenhouse gas emission access network for a HD video streaming: with only 0.5 grams of CO2 per hour compared with 2.5 for VDSL that is to say 5 times more.

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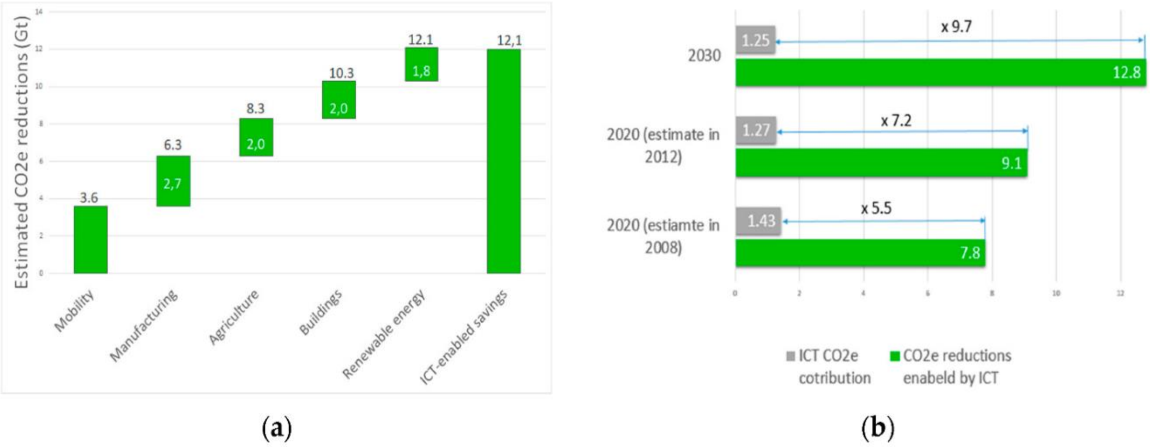
3 http://smarter2030.gesi.org/downloads/Full_report.pdf

4 Idem 6

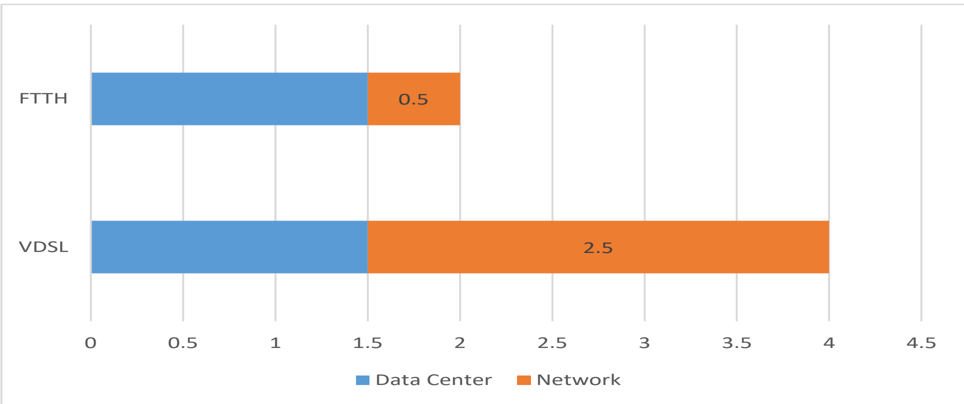
5 Telefonica quarterly results January-June 2021, page 1

Figure 6: (a) Contribution of different industry sectors to global carbon-dioxide equivalent (CO2e) reduction by 2030 (Estimated)[6] (b) ICT sector CO2e "footprint" contribution and enabled reductions to global CO2e emissions expressed in Gt (Estimated)[7]



Source: a) Wu, J.; Guo, S.; Huang, H.; Liu, W.; Xiang, Y and b) Global e-Sustainability Initiative (GeSI). SMARTer2030 Rapport

Figure 7: Greenhouse gas emissions by transmission method (Greenhouse gas emissions HD video streaming, in grams of CO_2 per hour)



Source: German Environment Agency

Moreover, once deployed, FTTP network supports extensive use of homeworking as well as remote healthcare and learning; therefore, FTTP helps to reduce journey times or unnecessary travel, as transport is one of the main contributors to CO2 emissions.

[6] Wu, J.; Guo, S.; Huang, H.; Liu, W.; Xiang, Y. Information and Communications Technologies for Sustainable Development Goals: State-of-the-Art, Needs and Perspectives. IEEE Commun. Surv. Tutor. 2018, 20, 2389–2406.

[7] Global e-Sustainability Initiative (GeSI). SMARTer2030 Rapport—ICT Solutions for 21st Century Challenges; GeSI: Brussels, Belgium, 2015; pp. 1–134.

3. FULL FIBER NETWORK

3.1. Full-fiber network strategy and global fiber development trends

3.1.1. Full fiber network: a future-proof network infrastructure

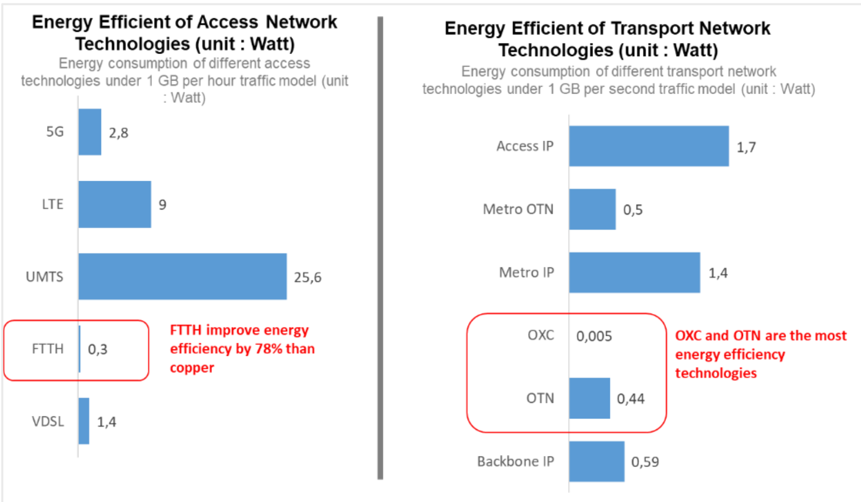
Fiber internet connections are being increasingly deployed across the world. Fiber networks provide high speed internet connection for businesses and households by deploying direct to their buildings and houses. Unlike copper cable, fiber transmits information using lights instead of electric pulses. Since light moves much faster than electricity, it can send a lot more information with less lag time.

Increased data traffic leads to increased energy use. For instance, fixed broadband, consumes around 80-95% of energy in the operational phase (around 90% for fixed networks). Various studies compare the energies efficiency and CO2 emission of different broadband technologies. Fiber is considerably more energy efficient than other traditional fixed cable access technologies.

The future-proof full fiber network decommissions the copper network and decouples the traffic demand with energy consumption. Combining the evolution PON technologies and the improvement of other network hardware and software compounds, full fiber network would drive up to 60 time of energy efficiency. Full fiber network, featuring with high transmission speed and large bandwidth, can provide internet connection to meet multi-service requirements, while keeping the carbon emissions at a low level.

Hence, with the expansion of FTTH network worldwide, networks carbon emissions have decreased in recent years. Since 2000, the fixed-line network energy intensity has halved every two years. In contrast, average internet speeds have increased more than 50 times, from less than 1mbps to 53mbps in 2020. With the evolution of PONs technologies, full fiber network will become faster, more reliable, with lower OPEX and less carbon emission. Therefore, full fiber, as a future-proof network infrastructure, is key to deliver a sustainable future.

Figure 8: Comparison energy consumption of different telecom communication technologies



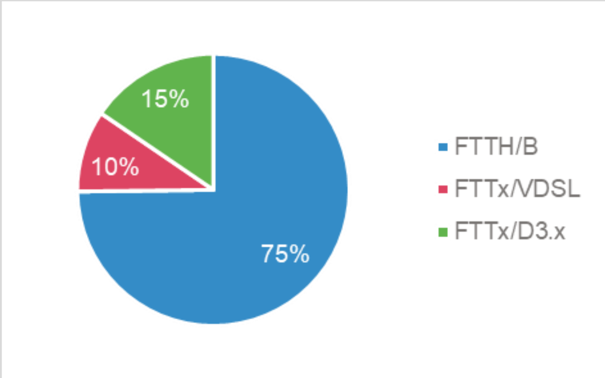
Source: Umweltbundesamt

3.1.2. Fiber coverage has steadily increased worldwide

Key trends worldwide

Superfast technologies represented almost 82% of broadband access subscriptions worldwide in December 2020, 19 points more than in December 2017.[8] On that account, more than 75% of FTTx subscriptions worldwide are based on FTTH/B as of December 2020.

Figure 9: Breakdown of superfast broadband technologies, December 2020



Source: IDATE DigiWorld, World FTTx markets, July 2021

FTTH/B subscriptions growth will continue until 2025, albeit not at the same pace year on year, and will naturally decrease as the markets mature. FTTx/D3.0 represented 15% of FTTx subscriptions in December 2020.

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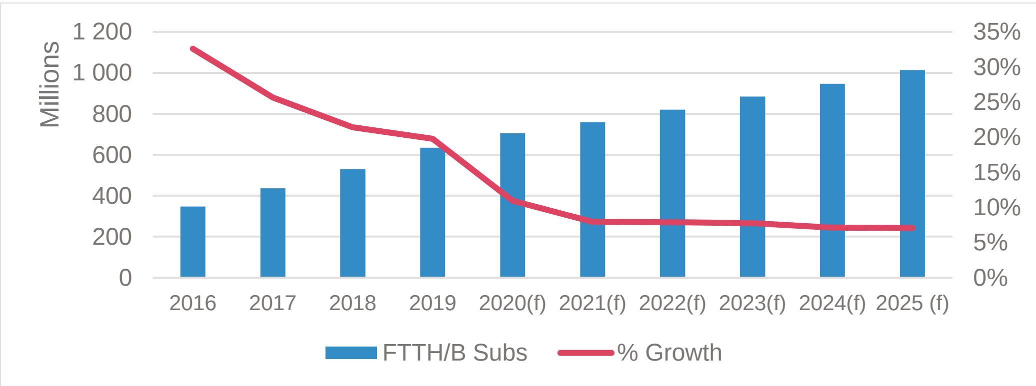
Many cable operators are implementing DOCSIS 3.1 solutions (and trialling DOCSIS 4.0 to be implemented in the near future) while some are migrating towards full-fibre FTTH solutions

Figure 10: Compared growth of VDSL and FTTH/B subscriptions, 2016-2025 (millions and %)



Source: IDATE DigiWorld, World FTTx markets, July 2021

Technology adoption varies among the different regions

FTTH/B networks have been widely deployed and adopted in the Asia-Pacific region. In Europe, FTTH/B is making real strides, but still having to compete with copper-based architectures from many incumbents, that are planning to move towards fibre in the next years.

In North America, strategies are concentrated around legacy copper network switch offs and migrating to FTTH in the coming months and years. In Latin America, major FTTH/B deployments have been observed mainly in Brazil, Mexico and Argentina.

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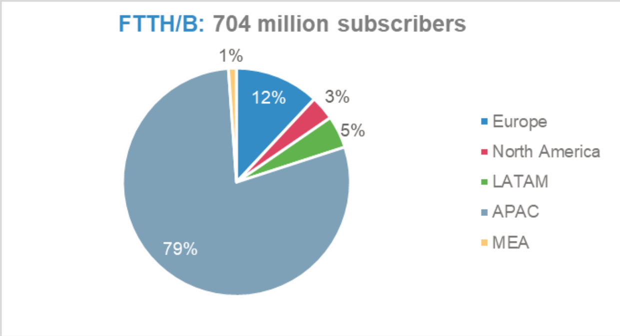
[8] Three main architectures meet our definition of superfast access technology: FTTH/B, FTTN+VDSL and FTTx/D3.x deployed by cable operators

Figure 11: Geographical breakdown of FTTH/B, December 2020

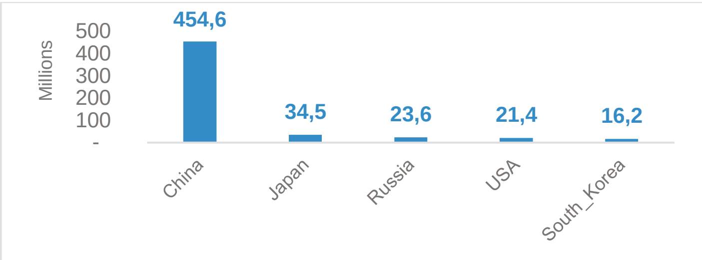


Source: IDATE DigiWorld, World FTTx markets, July 2021

China has nearly deployed FTTH networks nationwide while Japan is the second in terms of FTTH network rollouts. Both countries are now focusing on fibre adoption. The historically cable-based US market is now switching from copper to FTTH deployments, and we predict to see a huge shift in the market in the coming years.

France and Spain in Europe, as well as Brazil and Mexico in LATAM are not part of the top 5 but have also experienced a significant growth in their FTTH/B subscriptions.

Figure 12: Top 5 FTTH/B countries, December 2020



Source: IDATE DigiWorld, World FTTx markets, July 2021

3.2. Fiber as a green ICT technology to help with

3.2.1. Fiber technology significantly improve the communication networks energy efficiency

Fiber network has been wide-scale adoption in many industries of today. The enhanced fiber network features provide the technology keystone for digital innovations, which enable reduce significantly the emission of carbon across sectors. Based on the Life Cycle Assessment methodology, fiber powered digital services can achieve nearly 80-95% of energy saving.

As an increasing number of businesses, demand a strong and reliable internet connectivity to support their network operations. Fiber networks enable these data-driven companies to achieve the level of connectivity needed to changer approach to modernizing IT architecture and reduce the emission of CO2. In the case of cloud computing adoption, IDC estimates that cloud computing could prevent the emission of more than 1 billion metric tons of carbon dioxide (CO2) from 2021 through 2024.

Fiber connections are critical element for the provision of the new digital application by many industries based on either fixed network connection or wireless network. Wireless network such as 5G usually rely on the fiber backhaul network to handle the growing traffics to the core network. For the most typical 5G case, 5G small cell model brings connectivity closer to the end user. This model is usually supported by the fiber-based backbone in order to deliver reliable internet connections. The 5G promise to support a wide range of business innovations in different industrial sectors. These digital innovations alongside with emerging technologies such as AI and IOT can optimize energy consumption structure, improve the business efficiency and reduce carbon footprint.

3.2.2. Three concrete examples of how Fibre networks reduce carbon footprints

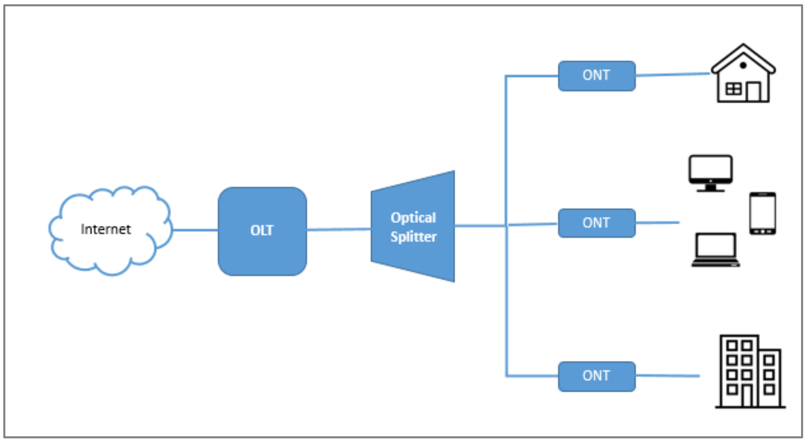
Improving the entire optical network energy efficiency does not only mean to substitute copper network with FTTx. technologies, but also reshaping transport network through technologies innovation, such as replace legacy SDH with OTN and the adoption of OXC.

In other words: replacing old technologies by state-of-the-art fiber technology does not only improve the network efficiency but also impact both the direct and indirect CO2 emission.

FTTx to replace copper network

In the access network, fiber based FTTx brings high capacity of optical fiber networks closer to the end users is the mainstream trend. Among all known FTTx technologies, Passive Optical Network (PON) technology uses optical fiber as a transmission medium and has high access bandwidth and full passive optical transmission characteristics.

Figure 13: FTTx network architecture



Source: IDATE DigiWorld

Compared to copper-based access network, FTTx has obvious advantages in terms of bandwidth performance, service provision, and bandwidth allocation strategy and network flexibility and construction costs in addition to delivering significant environment benefits:

- Less energy consumption: the migration from DSL to FTTx technologies-based access network replace active devices by passive devices that do not require any form of electrical power to operate. As attenuation is significantly lower for optical fibre than copper, Fibre optic cables can carry signals with much less energy loss. Studies show copper-based DSL consume about 1.8 Watt per user, fibre reduces this energy to 0.5 Watt per user. Multiplying by the number of broadband uses, these energy saving can be substantial. Furthermore, optical network equipment OLT (Optical Line Terminal) and ONT (Optical Network Terminal) are more compact and create minimal heat output, requiring less cooling power consumption

- Sustainable material: Replacing DSL by FTTx, technologies minimize the use of copper cable, since copper is a precious rare metal mining. The extraction of copper mining is harmful to the environment and dangerous. In contrast, fiber cable is composed of silicone, which is renewable resource and also tone of the most abundant element on Earth. In addition, the production and disposal of copper wire has a negative environmental impact much more than significantly the production and disposal of fibre optic cable. The production process for 1 km of copper generates on average 10,8 kg CO2, while only 3,07 kg for 1 km of fibre cable.

- Longer lifecycle: the transmission speed of fiber cable can reach up to 10 Gbps, while the transmit capacity of each category of copper cable is different. For instance, for 10BASET Ethernet, the maximum data transfer speed of 10BASET Ethernet (CAT 3) limite to 10Mbps, but a Cat7 cable has a maximum speed of 10 Gbps.

Among various FTTx technologies, FTTH is the ideal choice for green home access network, since it requires installation of optical fiber cables closer to the end-users. Because of passive ODN access, the energy saving of FTTH can attend 60~70% compared to xDSL and 70-80% compared to Coaxial DOCSIS. For every 10,000 access connections evolved to FTTH GPON, daily energy saving can reach 1500 KWH.

Table 2: Operators replacing copper by FTTx stories

Operator	Replace copper by fiber network	FTTX Benefits(environmental benefits)
European top telecom operator	Operator started its network transformation process since 2016, with the aim of decommissioning all copper plants by 2025,	The operator has removed sold 65 000+ tons of cable, recycled 7000+ tons of waste (i.e. electrical equipment). In term of energy saving, operator has saved around 1000 GWH.
European top telecom operator	Launched in 2020, the decommissioning of the copper network will be completed by 2030	The operator will remove 80 000 tons of cable that will be recycled. Important energy savings are also expected. The level of these savings has not yet been evaluated
European top telecom operator	Copper switch-off will be performed alongside the development of FTTH network. The deployment of FTTH network will be driven by the consumer demand	Energy savings is a key environmental benefit. Recycling of copper is not yet considered as an option since its reusability may be questionable
APAC region top telecom operator	Since 2008, operator has begun to replace legacy copper network with fiber network. At current stage, FTTH and FTTB have achieved high coverage rates and copper coverage is less than 1%.	Fiber networks simplify the entire network architecture. The flat network architecture and the enhanced performance of network equipment have reduced network deployment complexity of the number active network devices, making the entire network more energy efficient and effective.

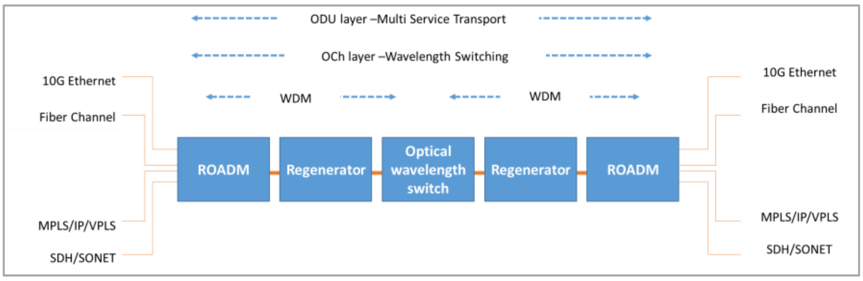
Source: IDATE DigiWorld

Transportation network: OTN replace legacy SDH

With the rapid growth of bandwidth demand and advances in optical technology, Legacy SONET/SDH (Synchronous Digital Hierarchy) network architecture have become a significant barrier to growth. Existing SONET/SDH networks can't scale to meet the demands of multimedia traffic as well as bandwidth-intensive digital apps and services. In addition, most SONET/SDH networks have been running for decades and are close to reaching saturation capacity, suffering higher failure rates. Most important, the aging SONET/SDH infrastructure equipment have high power, space and cooling requirements, lead to high maintenance costs and eco-unfriendly.

The OTN (Optical Transport Network) emerges as the solution by using WDM and DWDM (Dense Wavelength. Division Multiplexing) to overcome the bandwidth limitations and energy efficiency issues of SDH and SONET. Structurally, the technology is based on a multi-layer structure, including optical wavelength switch, regeneration and ROADM. The latter guarantees that data is inserted, extracted or transferred transparently. The OTN technologies, in conjunction with technical innovation, like replacing ROADM with OXC, re-structure network architecture, enabling the migration from multi-service and multi-bearing technologies to multi-service access and unified physical layer – the same fiber cable, simplifying the network architecture and reducing power consumption.

Figure 14: The multiple layers of the OTN network3



Source: Metaswitch

- **Optical cross-connect (OXC)** is a multi-functional OTN transmission device that combines multiplexing, wiring, protection/recovery, monitoring, and network management. Unlike to ROADM, OXC can integrate multiple independent boards and eliminates a large number of fiber connections between sites to realize the fiber-free connection in the rack. Compared with the traditional ROADM based on separate boards, OXC adopts a minimalist structure and use integrated interconnection to builds an all-optical switching resource pool, enabling effectively save communication room space by 90% and reducing power consumption by 60%

- **Optical service unit (OSU)** technology can divide ODU into smaller bandwidth granularities to implement flexible OSUflex pipes with adjustable bandwidths ranging from 2 Mbit/s to 100 Gbit/s, allowing services based on the OTN, SDH, PKT, and PCM service planes to seamlessly share line transmission bandwidth. The approach simplifies the service processing process, reduces the number of board kinds, and reduces power usage by 40%.

- **Mesh network** architecture is becoming a promising solution to meet solve the network congestion issue. A mesh architecture complements the dynamic, distance-independent, multipoint-to-multipoint nature of Internet traffic. The mesh can be organized into many logical architectures, permitting flexible configurations that can support various traffic and protection requirements across large networks. OTN allows network operators to evolve to backhaul networks into mesh networks to achieve multipath access and reduce the numbers of network layers and equipment hops. The mesh networking architecture and one-hop connection at the optical layer reducing the complexity of fiber optic connections, enabling to cut off the energy consumption by 50%.

Table 3: Operator OTN Replacing legacy SDH Stories

Case	Issues of legacy network architecture	OTN Benefits (environmental benefits)
APAC region top telecom operator	SDH Upgraded to E2E OTN: Most of SDH equipment have been used over 10 years. SDH technology required a considerable server room space, power and fiber resources as well as high OPEX while providing limited bandwidth	Operator retired 924 SDH devices (including 121 SDH aggregation device and 803 SDH access devices), reducing electricity bill by 30%, equivalent to over 1 million CNY (140 thousand EUR) in electricity consumption costs. Moreover, 130 racks were removed to release 400 square meters of space, reducing space usage by 26%. In addition, 11,600 km core fiber cable has been released, cutting optical cable cost 3,6 million CNY (502 thousands EUR)
Europe region top telecom operator	Massive network of obsolete SDH equipment nearing the end of its lifespan, plagued by frequent failures, a scarcity of spare parts, and excessive power consumption. The legacy SDH network lacked the capacity required for growth and was prohibitively expensive.	In comparison to a conventional SDH network, the multiservice OTN saved 70% of CO floor area and 60% on energy consumption. Additionally, just 10% of the initial SDH network investment was required to upgrade to a multiservice OTN.
European region top telecom operator	It is obvious that SDH equipment will be replaced by OTN equipment. Outdated SDH will have to be replaced once their lifecycle will be reached. OTN will then replace SDH progressively at all levels of the network. This upgrade will be made progressively in line with the Group investment strategy.	OTN equipment will clearly reduce the power consumption of the network. The higher reliability will also reduce the need of maintenance and hence the carbon footprint associated.

Source: IDATE DigiWorld

OXC

The optical network of metropolitan area networks (MANs) are mainly concentrated in metropolitan areas, and are used to connect the local central office (CO) and various network nodes. The explosion in service requirements from 5G, HD video, and enterprise leased lines has created an immense challenge for MAN architecture.

Making full use of the MAN limited technical room space and maximizing the reduction of energy consumption while meeting the multi service requirements has become critical. OXC featuring large granular service scheduling capability and low latency can meet the network requirement of various digital service, especially service with low latency requirement, while achieving sustainable network goals.

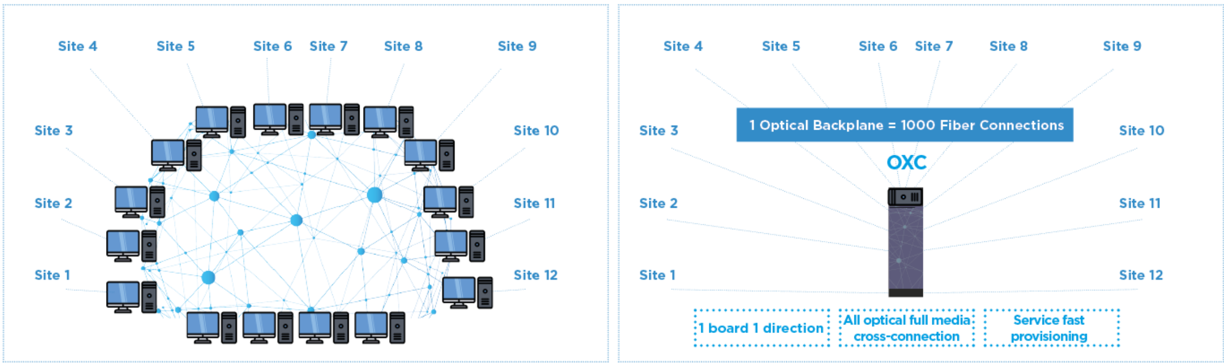
In the past, traditional ROADM were mainly used for cross-scheduling processing for large-granular services. With the increasing internet traffic, this method faces challenges in many aspects:

- Waste Space: Traditional ROAD M requires multiple devices to support high-dimensional service scheduling, which occupies a lot of cabinet installation space resources and power terminal resources of power distribution system.
- High energy consumption: Traditional ROADM nodes have low integration and high power. As the optical dimension increases, the power of the server room cannot meet the power demand, which affects the network expansion.

- Difficulty of maintenance: Service opening requires full-loop manual fiber hopping on the station, which is a large workload and easy to make mistakes. The service activation is not time-efficient, and it is difficult to meet the urgent or unexpected activation demand of business clients.

Optical Cross-Connect is a multifunctional OTN transmission device that combines multiplexing, wiring, protection/restoration, monitoring and network management. Compared with traditional ROADM (reconfigurable optical splitter and multiplexer) based on separate boards, OXC uses integrated interconnects to build all-optical switching resources, achieving highly integrated, fibreless all-optical cross-connection and effectively improving the switching efficiency of large granular services.

Figure 15: Comparison between ROADM and OXCwork3



Source: IDATE DigiWorld

OXC uses optical backplane technology to integrate complex optical fibers into a single optical backplane to improve integration **and** interconnect the optical backplanes within the OXC site. The optical backplane is a set of ribbon optical

fibers automatically printed into a flexible plate to form a fiber network, which is small in size and easy to install, and can realize the full network interconnection among the OXC boards.

Compared to conventional ROADM, OXC show environmental benefits in several aspects:

- Space and power savings: Unlike to ROADM, OXC can integrate multiple independent boards and eliminates a large number of fiber connections between sites to realize the fiber-free connection in the rack. Moreover, compared with the traditional 20-dimensional ROADM system, OXC supports 32-dimensional ultra-high dimensionality, and the efficiency of site expansion will be greatly improved. OXC adopts a minimalist structure, realizing the structure simplification from traditional optical layer with multi racks to a single board, from multiple cabinets to a single cabinet, greatly reducing the floor space. And save communication room space up to 90%.

- Save energy consumption: The electric crossover equipment single cabinet power consumption is generally in the range of 4000 to 7000W, which has high requirements for power supply and heat dissipation in the server room. In contrast, the overall power consumption of OXC equipment is only a few hundred watts, significantly power consumption and enabling to reducing power consumption up to 60%.

- Improve O&M efficiency: OXC integrated interconnection builds an all-optical switching resource pool, eliminating board links, and greatly reducing O&M difficulties with a few plug-and-play single boards. Also, OXC separates access-side and line-side modules for optical layer services, so that branch boards can be interconnected with any line boards, greatly simplifying the difficulty of expansion and maintenance, and resolving wavelength conflicts.

Table 4: Operator's OXC adoption examples

Case	Operator's challenges with legacy network	OXC Benefits (environmental benefits)
Major telecom operator in APAC region	The traditional ROADM solution takes up a large amount of equipment room space and uses complex inter-board fiber connections. The system capacity is insufficient to maintain business expansion; IDC expansion demand is urgent, need to achieve new services quickly online	*The introduction OXC in 12 core network simplifies site deployment and save space by 60% and reduce power consumption by 45%.* *The solution enable operation save an average 250,000 kWh per year, equivalent to planting 2000 trees.*
Major telecom operator in MEA region	With the deployment of 5G, conventional transport network faces huge challenges due to the complex multi-dimensional structure and limited bandwidth. In addition, MAN core network with limited capacity is not capable to support a wide diver of services with very different performance requirement.	*OXC enables simplifies the complex network structure to a 3D backbone network, reducing TTM by 50% and saving power consumption by 60%. Meanwhile, the deployment of OXC equipment reduce the quantity of device and fiber connection significantly, enabling to save saves 90% of MAN's equipment room space.*
Major operator in South Asia region	Internet data traffic has surged thrice in the last few years as LTE users have increased. Residential and business broadband customers have raised the demand for network connectivity performance. Operator needs to upgrade the transport network to a simplified architecture with a lower per-bit delivery cost	OXC can achieve metro network and backbone network cross-connect scheduling in one rack, simplifying network architecture and lower costs.

Source: IDATE DigiWorld

3.2.3. Fiber network is a critical digital infrastructure to support CO2 abatement and its impact goes beyond the telecommunication industry

Fiber infrastructure is key to support digital innovation and the adoption of cutting-edge technologies. Hence, ultrafast full fiber broadband is crucial for settings and solutions relying on new technologies like Artificial Intelligence, Edge Computing, and Internet of Things.

All industrial sectors are today impacted with the digitalization of our society.

In manufacturing, a combination of ultra-fast broadband and IoT would enable innovative applications and solutions like 3D printing, smart sensors and automation that hold the potential to reduce CO2 emissions up by 2.7 – 3.3 million tons annually.[9]

[9] Three main architectures meet our definition of superfast access technology: FTTH/B, FTTN+VDSL and FTTx/D3.x deployed by cable operators

In all services industry, the upgrade of buildings to smart buildings leveraging to its full capacity IoT sensors monitoring energy, water consumption, heating, waste management and even internal transportation will impact carbon emission. The development of very capillary fibre network inside smart building and campuses will allow both an efficient low carbon emitting communication network (direct effect) and create major indirect CO_2 savings (indirect effect).

Altogether, the combination of cutting-edge technology and the need for better connected industrial processes is also contributing in many sectors to optimize energy consumption and reduce CO_2 emissions.

4. FIBER NETWORKS CO2 SAVINGS BEYOND TELECOM

4.1. How fiber can improve energy efficiency in the industry

The fiber is going to play a huge role in future Information and Communication Technology. Fibre networks provide the essential backbone support for the 5G technology and various FTTx environments. In addition, Fiber provides unlimited bandwidth to support long-distance communications and enable a board range of industry digital applications.

Fiber network has been wide-scale adoption in many industries of today. The enhanced fiber network features provide the technology keystone for digital innovations, which enable reduce significantly the emission of carbon across sectors. More and more business demands a strong and reliable internet connectivity to support their network operations. Fiber networks enable these data-driven companies to achieve the level of connectivity needed to changer approach to modernizing IT architecture and reduce the emission of CO2. In the case of cloud computing adoption, IDC estimates that cloud computing could prevent the emission of more than 1 billion metric tons of carbon dioxide (CO2) from 2021 through 2024.

Fiber connections are critical element for the provision of the new digital application by many industries based on either fixed network connection or wireless network. Wireless network such as 5G usually rely on the fiber backhaul network to handle the growing traffics to the core network. For the most typical 5G case, 5G small cell model brings connectivity closer to the end user. This model is usually supported by the fiber-based backbone in order to deliver reliable internet connections. The 5G promise to support a wide range of business innovations in different industrial sectors. These digital innovations alongside with emerging technologies such as AI and IOT can optimize energy consumption structure, improve the business efficiency and reduce carbon footprint.

As discussed in the previous chapters, ICT is key enable to achieve carbon neutral target. The reports "SMARTer2030 and the previous versions estimated that the ICT sector can reduce greenhouse gas emissions by 20% by 2030 and ICT enabled digital technologies have the potential to cut 12 Gt of CO2 emission by 2030 across various sectors. Based on our interview result with world leading telecom operators, taking the amount of ICT-enabled carbon emission savings as a whole, fibre technologies contribute to more than 50% of this effect.

Figure 16: Summary of GESI's Smart Reports (left) and IDATE DigiWorld Fiber technologies enabled carbon emissions reduction effect estimate (right)

	Smarter 2030
Estimation of the abatement effect of Digital (Gt CO2e)	12
Global emissions projected with this abatement (Gt CO2e)	51,5
Global emissions in reference (Gt CO2e)	63,5

	Smarter 2030
Estimation of the abatement effect of Fiber (Gt CO2e)	1,6
Global emissions projected with this abatement (Gt CO2e)	61,9
Global emissions in reference (Gt CO2e)	63,5

Source: GESI SMARTer2030, IDATE DigiWorld

4.2. How fiber networks save CO2 in various domains

4.2.1. Smart Home

Turning our home into smart home is key to reduce CO2 emission. Smart metering of energy, water, heating and waste are key drivers when it comes to reducing households' footprints. These smarter metering devices requires capillary networks connecting all relevant appliances and devices. Intelligence of the smart house require a nervous system that fibre networks can provide in the most CO2 efficient way.
.

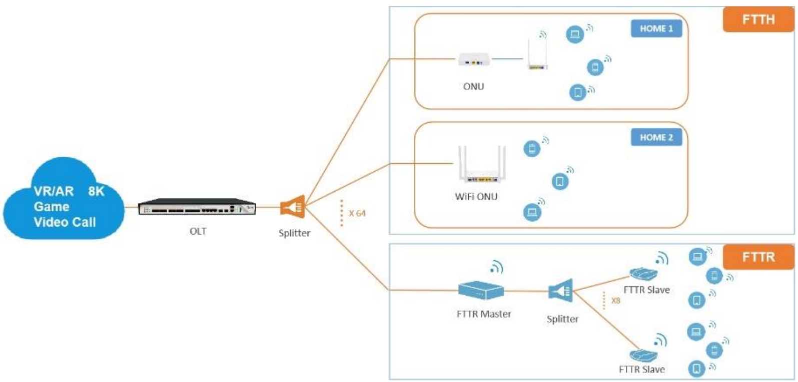
Although FTTH is the most prevalent fiber deployment technology, the technology has some limitations. With the FTTH, that fiber is configured and managed through routers for whole-house networks, which can have dead zones in large house with insufficient signal coverage to provide a consistent network experience throughout the house. In addition, when there are technical problems, such as lagging and dropped connections with home network, it is usually very slow and costly for the operator to come to the home for repair.

FTTR (Fiber to The Room), is new type of in-premise fiber technology based on FTTB (Fiber to the FTTB and FTTH and bring fiber connection to every room to achieve whole-house gigabit(s) network speed – so that every corner gets a stable internet coverage with wired and Wi-Fi.

The FTTR solution replaces the indoor network cable with optical fiber to break through the physical limitations of the network cable. It adopts a master and slave optical router integrated machine, supports the latest Wi-Fi 6 technology, and can directly deliver high-speed gigabit broadband directly to users.

Compared with the traditional FTTH networking mode, FTTR present numerous benefits, such as high bandwidth, signal stability and less susceptible to interference, corrosion resistance and high reliability, long lifetime, support remote operation and maintenance. Through the fiber optic and main optical cat connection to avoid Wi-Fi through the wall performance degradation, identification and avoidance of interference channels, with seamless roaming Wi-Fi and unified intelligent operation and maintenance platform for the entire home network remote tuning. FTTR avoids the performance degradation caused by Wi-Fi through the wall by connecting to the main optical cat through fiber, identifies and avoids interference channels 100%, and works with seamless roaming Wi-Fi in the whole area and a unified intelligent operation and maintenance platform to remotely tune the whole home network.

Figure 17: Comparison FTTH & FTTR Network

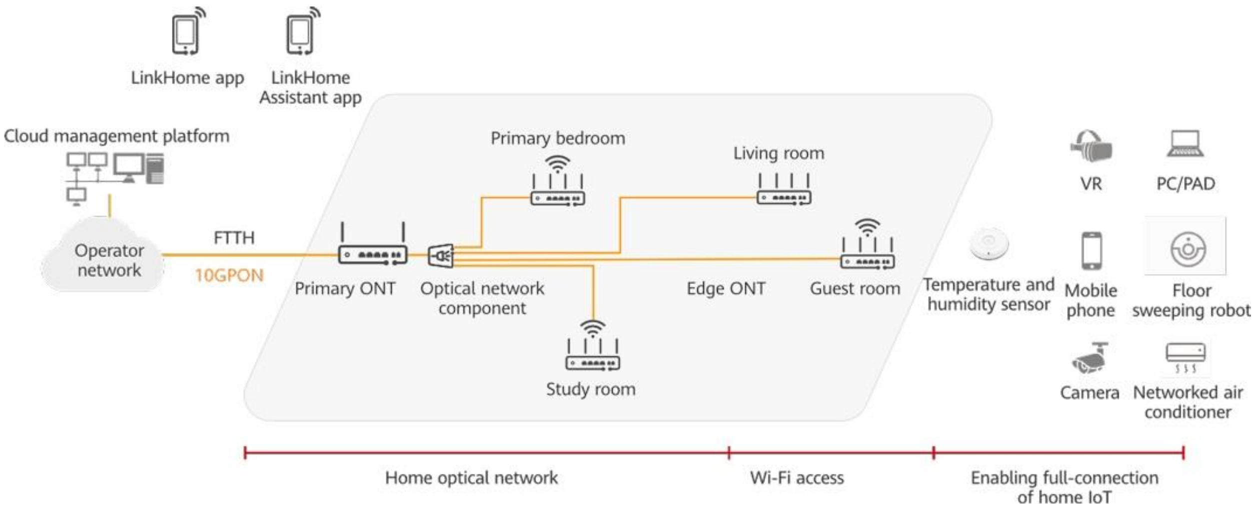


Source: Cdatatec

Different from current fiber-based technologies, FTTR technology networking architecture consist of FTTR optical gateway, edge ONT, supporting fiber components.

- **FTTR optical gateway** is FTTR unique network equipment type and located between OLT and edge ONT. Compared to FTTH networking, FTTR optical gateway provides greater flexibility for networking.
- **Edge ONT:** Connected to user devices. It can provide more accessible and higher quality access guarantee according to the requirements of service based on the positioning of the room, such as exclusive game edge ONT, learning edge ONT.
- Supporting fiber components include **optical sockets, butterfly optical cables, prefabricated cables with small micro connectors, optical expanders (splitters), ATB (Access Terminal Box), etc.**

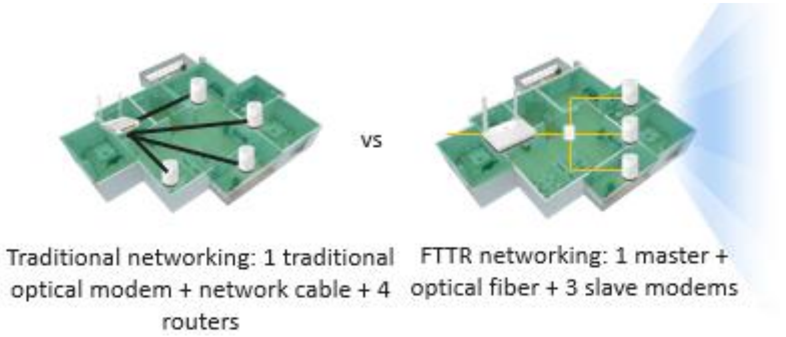
Figure 18: FTTR deployment solution



Source: Huawei, Innovative FTTR Solution

Compared to conventional fixed broadband access technologies, FTTR-based full-fiber internet access is based on the innovative technologies that enable consume less energy and reduce the dependence on non-renewable resources like copper to achieve the reduction of carbon footprint target. The rollout of FTTR indoor can deliver higher speed and more reliable internet connection while making the internet connection more environmental-friendly.

Figure 19: Traditional network architecture versus FTTR based networking



Source: Huawei

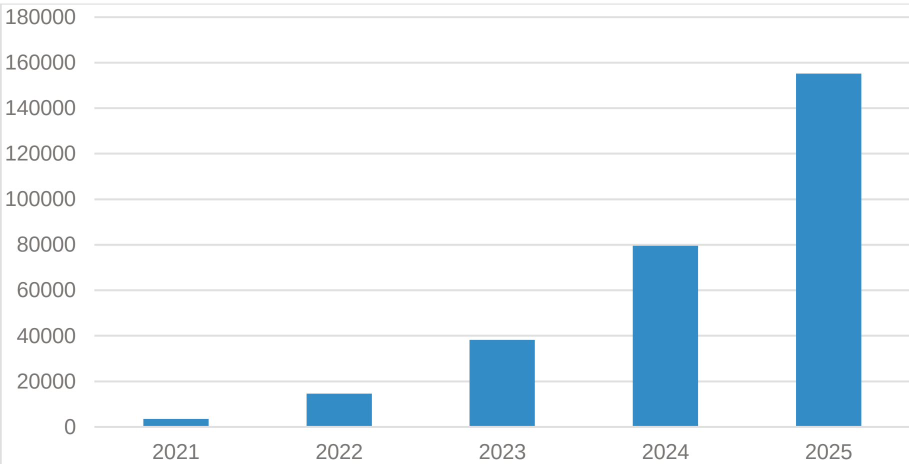
FTTR is the extension of FTTH to extend the fiber cable connection to each room instead of using network cable to connect traditional optical modem with router in each room. Based on the passive nature of PON network architecture, **fiber copper enables to save energy consumption up to 30%** than the traditional copper-based network cable.

Furthermore, fiber optical cable, made of a particular type of glass, offers a big benefit in terms of the flexibility of bandwidth and reliability. In addition, because of physical features of fiber cable, such as more durable and less susceptible to harsh environmental conditions as well as lightweight and compact in size (the size of fiber cable is only 15% of traditional copper cable), there is no need to replace the existing indoor optical fiber cable when upgrading the network. A full-fiber network can save mineral resource use and waste, reducing climate and environmental risks.

Last but not least, with FTTR, the master optical modem of each line integrates the functions of optical modem and WIFI router to reduce the number of electronic devices in use whilst saving energy consumption by 50%. The annual energy consumption saving of a typical master optical modem can reach 105 KWh per year. In addition, the power consumption of panel type slave modem is also ultra-low, barely 1 KWh of electricity for 5 days. Each slave modem can save 38 KWh per year, reducing 30% of power consumption than traditional modem. In a typical FTTR configuration scenario with one master modem and 3 slave modems, all the electric equipment can economize nearly 220 KWh of electricity per year for one household, 114 KWh from three slave modems power consumption saving and 105 KWh from master optical modem.

FTTR based full fiber technologies is a key enabler to help operators to accelerate the pace for the carbon natural target in 2025. FTTR take-up trends will be higher in countries or in areas of countries in which fiber connection or FTTH has a good level of coverage. At the first phase, the new connection technologies will be installed in some new residential buildings across the world. The take-up rate will be higher in the countries of APAC region with a high level of FTTH coverage than other regions. With the progress the technology and the mature of standardization of the technology, FTTR will reach more and more residences and business around the world to continuously help operators develop premium broadband services. The following figure describes the CO2 reduction impact of worldwide FTTR deployment:

Figure 20: Worldwide FTTR Deployment cumulated CO2 savings **(Since 2021, CO2 tons)**



Source: World Bank, IMF, OECD, IDATE, Telecom operator's interviews, Telecom equipment manufacturer's interviews

4.2.2. All optical smart Campus

Today, digital transformation is making a wave of change spreading multiple sectors. Digital technologies and new digital use cases are increasingly used in business operations. In addition, COVID-19 has accelerated the digital trend toward telecommuting and video conferencing. The new trends drive the industry campus network should meet the need for more bandwidth, especially on the backhaul. Traditional campus network generally uses LAN technologies and can hardly meet today's business connectivity requirements, as the access technologies faces various challenges, include, high energy consumption, high CAPEX/OPEX, limited coverage range, unsuitable for mobile use cases.

Passive Optical LAN (POL), an all-fiber LAN solution that operates on a Gigabit Passive Optical Network (GPON), is a leading alternative to the traditional LAN to address traditional campus challenges, while more energy-efficient and environmentally friendly

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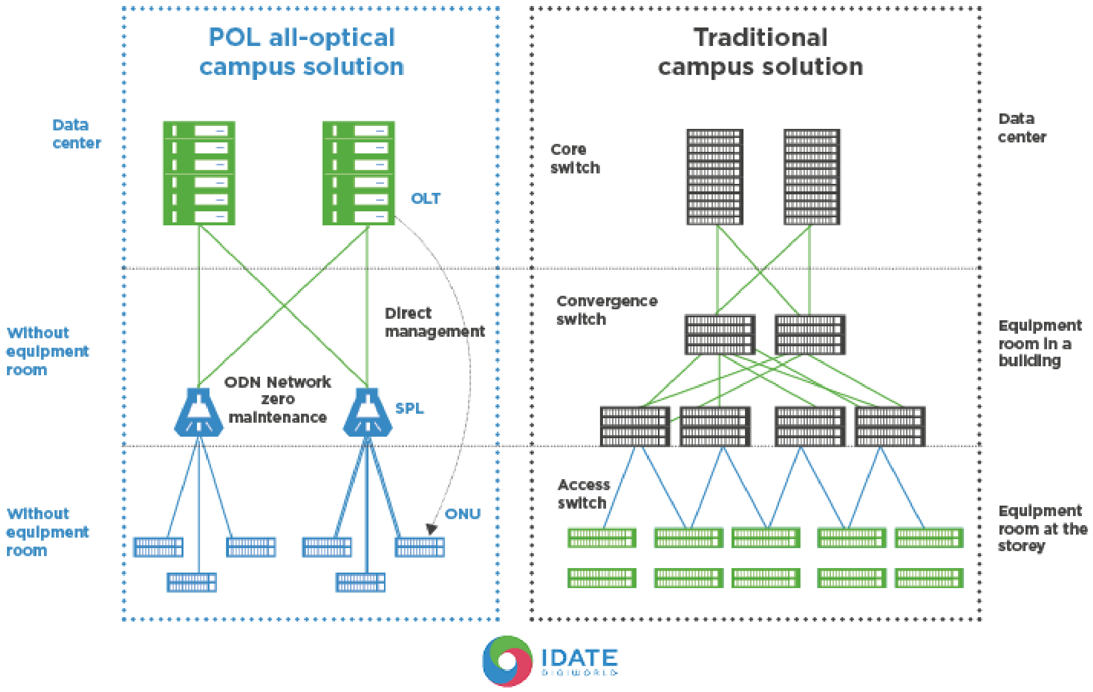
Figure 21: Device selection comparison: POL versus traditional campus solution



Source: IDATE DigiWorld

Compared to traditional LAN technologies, POL offers diverse energy, sustainability benefits for smart campus:

- **Space Saving for less GHG footprint:** with OLAN great aggregation capabilities, fiber-based Optical LAN leverages the inherent benefits of PON, using a single-mode fiber (SMF) to carry as many as 128 gigabit Ethernet connections across a single cable. By occupying less rack area, the solution can significantly save physical technical room space, reducing the need for air conditioning, fire suppression systems, security surveillance, and other building material. In addition, POL solution reduces the complexity of the campus network to two layers. As the network structure is simplified, fewer rooms for IT equipment are required, resulting in decreased device power consumption and ventilation in equipment rooms.

- **Material Reduction:** Optical LAN uses fiber cable in place of copper cable, which reduce the environment impact, since copper is a rare metal that has a terrible environmental track record due to its destructive mining practices. Furthermore, SMF cable use 60% less plastic jacketing based on its smaller circumference, limiting the quantity of plastics and PVCs burdening on environment.

- **Energy saving:** By using OLT and ONTs instead of a traditional copper-based Active Ethernet, Optical LAN can reduce energy consumption by up to 30% to 65%. Based passive optical network, Optical LAN require less electricity energy consumption. In addition, using less space can eliminates the need for air-conditioning, reducing the energy consumption.

- **Longer life cycle:**

the lifespan of fiber optic cable is much longer than copper, with a warrantee that lasts 25-30 years. In addition, Unlike Copper cable with limited transmission capacity, fiber optic cables superior durability and a longer life and do not need to replace to each network upgrade.

Hospitality industry use case

In the traditional hotels, each room needs to install multiple copper cables to connect to each end-user's device. These make the deployment complexes, bringing so much burden for the deployment and maintenance.

POL optimizes the LAN's basic cable and network structure. It replaces aggregation electronics and associated copper cables with passive optical splitters and single-mode fibers. This technology inherite all the PON network's benefits, including high bandwidth, high reliability, flatness, ease of deployment, and ease of management. The POL network can deliver broadband, voice, video, WiFi, CATV, and other services consistently.

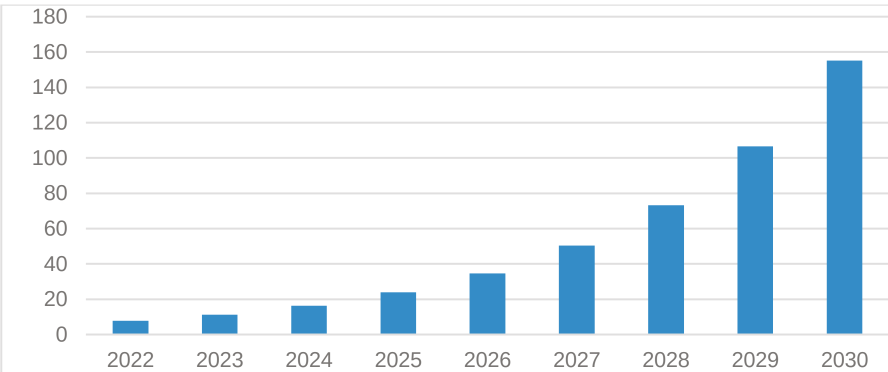
A famous 5 stars hotel in China, has adopted the POL solution to re-innovate the hotel network infrastructure. Because of the long-distance transmission and the variety of services available, the network can support Wi-Fi, voice, HD TV, and intelligent control, thereby reduce the copper and eliminating the need for hundreds of separate equipment rooms. 40 km fiber cable is used to replace more than 400 km copper cable and eliminate 8 ELV rooms. Moreover, equipment power consumption reduced 50% and total power consumption reduce by 35%.

The main outcome from the Smart Campus Use Case is the potential reduction in energy use at building end-user level as a result of smart metering and intelligent energy management, leading to associated CO2e emissions and cost savings from reduced energy consumption. Moreover, ICT and fibre in particular can help reduce water consumption from buildings and reduce wastewater generated.

The main levers for CO2 abatement will be the energy saved and the better management of water. Wastewater will be reduced in smart campus thanks to automatic default detection and other monitoring systems. Water consumption will be reduced too, due to similar systems previously mentioned. In terms of energy, the reduction in smart campus will be driven by a better energy management, automatic default detection diagnosis, building supervision.

Fibre networks will be essential for the deployment of the various monitoring devices required and to allow a lower energy consumption than using other ICT technologies.

Figure 22: Worldwide Fibre network Smart Campus cumulated CO2 savings
(Since 2022, CO2 megatons)



Source: IDATE Digiworld, GESI, Industrial players interviews

4.2.3. Smart grids relying on Fiber allowing major CO2 abatement

The existing grid was designed decades before personal computers and internet networks were conceptualized. One of the most common tactics utilities are pursuing to improve their reliability and overall power delivery is the integration of advanced protection equipment to replace conventional devices. These “smart” solutions can monitor the grid, respond to temporary faults and automatically restore power.

Many of the advanced protective devices on the market come equipped with built-in communication options to make data collection, device coordination, and remote operation possible with the click from miles away. That is why many utilities are turning to fiber-optic connections to serve as the backbone of their communication systems. Shifting to these advanced solutions reduces the duration and frequency of outages, and simultaneously benefits a utility’s bottom line by reducing unnecessary operations and maintenance costs.

Installing fiber optic cable along distribution lines using current towers is quite common among electrical utilities. Leading power equipment suppliers are introducing faster equipment, including switches and routers, which in turn require the use of optical fiber, the only transmission medium capable of the extremely high bandwidth, information-carrying capacity and transmission speed required by the smart grid.

There are many ways to install fiber optic cables on these towers. One choice is optical power ground wire (OPGW). This conductive cable is run at the top of the tower or pole to be the ground conductor and protect the power cables from lightning. OPGW is simply a metallic power cable with a stainless tube in the center that contains a number of fibers. OPGW is an obvious choice when installing a new transmission line. However, utilities that installed OPGW decades ago are not be capable of handling modern communications speeds.

Another option utilities use widely is to run all-dielectric self-supporting (ADSS) fiber optic cable underneath the power conductors. This is a cheaper way to add fiber to a transmission line and does not disrupt the power delivery. All that is necessary is adding the ADSS supports to the towers and pulling the cable. By and large, fiber optics brings many benefits to the smart grid including:

- **Higher bandwidth** that supports higher data rates over longer distances: A typical bandwidth-distance product for multimode fiber is 500 MHz/km, so a 500-meter cable can transmit 1 GHz, while twisted pair optimized for high data rates (Category 6) can transmit 500 MHz over only 100 meters.

- **Lighter weight and smaller diameter** than traditional copper cables: Fiber weighs less and needs much less space than metallic conductors with equivalent signal-carrying capacity.

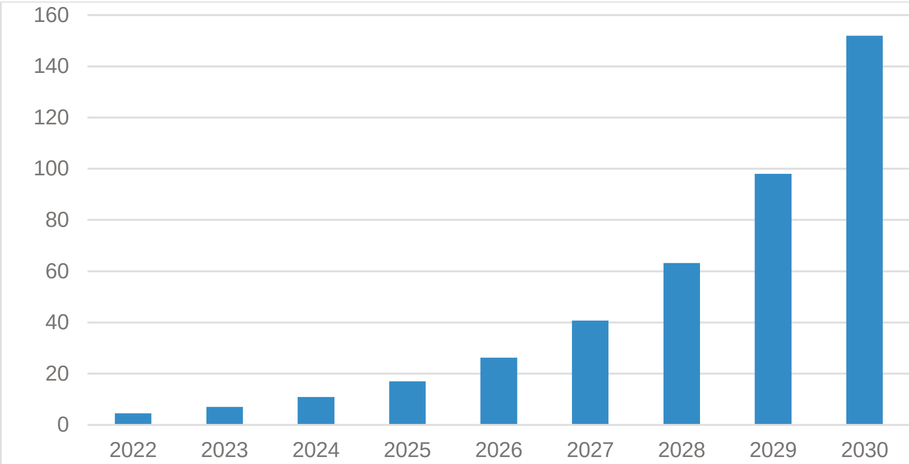
- **More secure data communications:** Because copper cable transmits data using electricity, data may be intercepted more easily by hackers connecting taps to a line to pick up electronic signals. Tapping fiber cables will likely result in breaking the glass fibers and potential hacks can be quickly and easily discovered.

- **Efficient power grid faults management.** Thanks to the Hard Pipe Technology fiber optics reduces the Two-way delay to less than 5 ms.

- Last but not least, fiber optic cabling solutions are designed for **minimal environmental impact.** Fiber optic connectors are chosen to provide the lowest loss, minimal cost and ease of termination. The overall fiber infrastructure reduces the overall energy consumption thanks to instantaneous fault location and switchover, reducing thus invalid power distribution.

In summary, Smart Energy is the potential reduction in energy production, due to energy management systems, the increase and integration of renewable energy to the grid and the improvement of the efficiency of the grid, avoiding loss of the energy already produced. All of these can lead to associated CO2e emission abatement.

Figure 23: Worldwide Fibre network Smart energy cumulated CO2 savings (Since 2022, CO2 megatons)



Source: IDATE Digiworld, GESI, Industrial players interviews

4.2.4. Smart Manufacturing

Smart Manufacturing refers to a new global industrial method that relies heavily on the latest technologies in connected production facilities. In other words, it is about setting up systems in factories in which machines are connected to each other and, above all, to the Internet in order to ensure optimal control of production processes.

The central element of this type of organisation is data. The data is first collected directly from the equipment. Then it is analysed to make the right decisions for manufacturing performance. Smart manufacturing is one of the applications of IoT, or more specifically IoT, which is the Industrial Internet of Things.

Applications of Smart Manufacturing

Smart and connected industrial devices will transform the way factories operate, sites are managed, or vehicles are maintained and operated, using the data generated to improve operational excellence, resource efficiency and time to market.

Future applications of Smart Manufacturing include:

- *Applications that enable efficiency gains in resource usage:*

- Virtual Manufacturing: Smart factory "units" will be able to determine and identify their own fields of activity, configuration options and production conditions, as well as communicate independently with other units through CPS (Cyber Physical Systems) optimized production processes. They will also be able to detect their failures, change production lines and repair themselves without any downtime thanks to preventive and corrective maintenance. Finally, they will dynamically adapt to customer needs and may even eventually enable virtual production networks, where companies can send their product design to any factory in the world and have their product 3D printed or produced instantly.
- Circular supply chains: Smart Manufacturing introduces the circular model by tracking and tracing products and components throughout their life cycle. At the end of life, products are returned to the factory for reuse, repair or refurbishment, resulting in significant resource savings and supply chain risk management.

- *Applications for real-time adaptation to demand:*

- Customer-centric production: Smart Manufacturing allows mass-produced items to be tailored to specific needs at an affordable price. It allows the customer to track all stages of their order in real time, enabling them to better optimize their own supply chain planning and requirements.

- Smart services: offerings are increasingly moving towards servicing. By 2030, we will see the development of cross-sector service ecosystems with backward and forward integration, where products can be produced on demand, anywhere and anytime, facilitating immediate responses to changing market conditions.

Smart Manufacturing will leverage technological advances in big data and machine learning to automate industrial processes. In order to realize its full potential, automation must rely on a cohesive network infrastructure where information flows through all parts of the industrial process rather than on segmented solutions.

Fibre optics is the backbone of Smart Manufacturing automation in that it facilitates ultra-fast data sharing and allows separate segments of the business to be connected, analyzed and processed to implement actions without human oversight. Huge volumes of data are generated in the industrial supply chain. Connecting this data, processing and analyzing it in real time requires flexible and scalable IT infrastructures, and fibre optic networks are best placed to provide this infrastructure. They communicate data by light pulses, which makes them exceptionally fast. They do not generate electromagnetic noise as other systems do. In addition, fibre optic cables are lightweight and flexible, allowing them to take up much less space than other cable networks.

The requirements of industrial automation systems are much higher than those of traditional networks. They require networks that can withstand harsh environments, such as extreme temperatures, weather conditions and hazardous locations. Copper cannot be used with confidence in such circumstances, whereas fibre optic circuits can. For this reason, highly reliable fibre optic cables have become commonplace in industrial automation applications to minimize network failures and unscheduled production downtime. As a result, industry leaders have doubled their investments in fibre optic networks in recent years. This trend will be accentuated by the implementation of 5G networks, generating a rapid expansion in the number of connected devices and facilitating Smart Manufacturing.

Without fibre networks, these new technologies could not be reliably implemented in industry. New applications such as mobile robots, autonomous vehicles or AR/VR applications for maintenance would push traditional networks to their limits. Coupled with 5G technology, fiber networks offer unprecedented reliability, extreme throughput and high reliability which are essential for Smart Manufacturing. In the coming years, we will see fibre optics being even more widely adopted in industry along with Smart Manufacturing worldwide.

Environmental impact

The introduction of automated and self-sustaining smart processes has the potential to create energy savings of 4.2 billion MWh and save 81 billion liters of water through more efficient production processes. The global emissions reduction potential of Smart Manufacturing is thus equivalent to 2.1 Gt CO2e with a potential of 1 Gt CO2e by 2030(Source: GeSi Smarter 2030) .

The deployment of all-optical networks smart plants would contribute to a significant part of this reduction potential. Smart Manufacturing can improve production costs and quality, while minimizing environmental impact, natural resource use and energy consumption.

- *A use case example:* Fujitsu's Virtual Product Simulator, saving time, money, resources and emissions

This solution allows manufacturing companies to create virtual prototypes of their products, machines or other items instead of having to physically manufacture them. This simple design solution, using 3D-CAD data, allows prototypes to be designed, defects to be detected and design quality to be improved in the early stages of product design.

The benefits of this simulator are improved quality by detecting 50-80% of design errors, a 50% reduction in development time and associated costs, and a 30-40% reduction in the amount of man hours required. In addition, the reduction in resources used for prototyping reduces CO2e emissions by 30%.

- *Another use case example: Smart inverters*

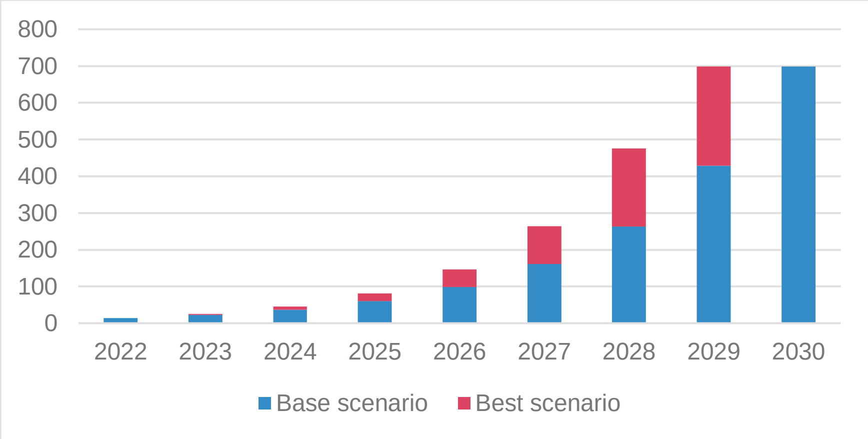
The solar cells and panels used to generate solar energy are produced in photovoltaic (PV) power plants with inverters at the heart of the plant. They convert the direct current generated by the PV modules into usable energy for the grid. In addition, the inverters control and monitor the plant and the grid to ensure optimum safety.

Huawei developed a smart PV solution for a 7.8 MW solar park in Germany, using smart inverters instead of traditional inverters. The application of this solution has resulted in a 5% higher yield and 50% improved maintenance efficiency for the German PV plant. Smart inverters are a good example of how the combination of advanced hardware and technology with ICT-based solutions can enable better integration of renewable energy into the grid.

The deployment of fibre all-optical networks in the manufacturing sector will allow to better monitor the energy consumption and reduce waste in the use of various input materials and water use.

In more details, the outcome from the fibre-based Smart Manufacturing is the reduction in industrial operating costs, as a result of reducing the energy, optimizing the resources use due to process automation, for both, heating and cooling, and engine optimization. This reduction leads to an associated reduction in CO2e emissions and water use.

Figure 24: Worldwide Smart Manufacturing cumulated CO2 savings (Since 2022, CO2 megatons)



Source: IDATE DigiWorld, GESI, Industrial players interviews

While running the interviews with various representatives of the manufacturing sectors, we have noticed various level of CO2 reduction strategy maturity. Especially when it comes to the use of ICT technologies, we have observed a high level of polarization. By polarization, we mean that some manufacturing companies are very advanced when it comes to the use of ICT and fibre networks to reduce their CO2 footprint while another group is less focused on these levers. This observation is very different from the other sectors where we felt a more homogeneous approach to fiber and ICT.

Hence, we have built two scenarios to assess the CO2 cumulated savings coming from the manufacturing sector.

A first scenario, named “based scenario”, is calculated on the current trends and taking in account these two very polarized ways of ICT approach in the CO2 reduction strategy.

A second scenario, named “Best case”, takes the hypothesis that a group of the less ICT intensive manufacturing companies adapt their strategies to the ICT intensive ones. In that second case, a reasonable modeling shows a much faster take off in CO2 abatement.

The manufacturing sector could save one to two years to reach the full potential of CO2 abatement considered.

Our calculation shows that the manufacturing sector should not overlook the role of ICT and fibre networks as a trigger to reduce their CO2 footprint.

Considerable amount of CO_2 may be saved earlier thanks to a better understanding of its potential by the sector.

In the world debate on CO_2 reduction, we know that timing is key to meet the challenge, we have here identified a strong lever where small actions can have significant impact.

5. CONCLUSION

5.1. ICT technologies are key drivers to meet the challenge of global CO2 abatement

Global greenhouse gas (GHG) emissions have risen dramatically over the last three decades and are of major concern for our societies. Their malign environmental impact is pushing governments, enterprises, and civil society to reorganize and find cutting edge solutions to meet this challenge.

The telecommunication industry is undergoing through important changes that aim to lower the overall CO2 footprint through innovation and cutting-edge solutions. Hence, ICT technologies and innovation of digital networks are at the core of these changes.

The higher levels of connectivity that ICTs foster revolutionized every aspect of our life, such as way we communicate, entertain, collaborate and work. On that account, the widespread adoption of ICT enabled solutions in various industries could offer the potential to suppress from 15% to 20% of current emissions

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5.2. Fiber is the most energy efficient technology

Notably, among all communication technologies, Fiber is the most energy efficient one, offering thus the lowest CO2 footprint. Fiber consumes three times less energy than xDSL and 10 times less than 4G access technology. Based on the data from GeSI (Global e-Sustainability Initiative) Smarter 2030 study, IDATE estimates that the abatement effect of Fiber will reach 1,6 Gt CO2 by 2030.

The telecommunication industry has already started its migration to full fiber networks. Fibre networks provide the essential backbone support for the 5G technology and various FTTx environments. A full fiber network, featuring with high transmission speed and large bandwidth, can provide internet connection to meet multi-service requirements, while keeping the carbon emissions at a much lower level than any other communication technologies.

That said, there are still several levers it may use to keep reducing CO2 emission thanks to upgraded equipment and more capillary fibre networks. From replacing copper networks and legacy equipment, the race to rip the benefits of Fiber differs among the different regions. FTTH networks have been widely deployed and adopted in the Asia-Pacific region while Europe is making real strides, but still having to compete with copper-based architectures. In North America, strategies are concentrated around legacy copper network switch offs and migrating to FTTH in the coming months and years.

5.3. Fibre networks CO2 abatement potential impact all industries

The impact of fiber network in CO2 abatement goes beyond the telecoms industry. Fiber connections are critical element for the provision of the new digital application by many industries based on either fixed network connection or wireless network. Hence, they would also benefit from deeper and more granular fibre networks to reduce their carbon footprint.

This reduction should not be overlooked. First, fiber per se would influence the CO2 abatement of the industry as a connectivity solution requiring less energy consumption. Second, it would indirectly influence the more efficient use of energy, heating and water consumption thanks to fiber-based metering devices network.

Many use cases have been identified where deeper fibre network would reduce CO2 emission. From smart homes to larger settings like optical smart campuses (let it be airports, hotels, university campuses, etc.) as well as smart grids and factory floors, we have identified a long list that industrial should consider.

For instance, in manufacturing, a combination of ultra-fast broadband and IoT would enable innovative applications and solutions like 3D printing, smart sensors and automation that hold the potential to reduce CO2 emissions. By and large, these digital innovations alongside with emerging technologies such as AI and IoT can optimize energy consumption structure, improve the business efficiency and reduce carbon footprint.

Hence, we conclude that industrials should better consider the use of fibre. While all industrial are now developing their CO2 strategy roadmap, we want to stress the importance to consider ICT fibre networks as a key lever.