NOKIA

Broadband Zero

Zero emissions and zero people excluded from broadband

White paper

At Nokia, we embed environmental considerations into everything we do, and we believe in an inclusive diverse world where nobody is left behind.

Within an end-to-end telecommunications network, broadband is a significant contributor to greenhouse gas emissions. Yet the use of broadband actually contributes to a net reduction in emissions as it enables efficiency gains, reduced transportation, and a host of other benefits. Nokia is committed to bringing the socio-economic and environmental benefits of fixed broadband to as many people as possible. In doing so, we set ambitious sustainability goals on our own business operations and on the design of broadband products and services that help our customers reduce energy consumption in their networks.

Our goal is Broadband Zero: a fixed network that helps to achieve net zero emissions and excludes zero people from high-speed broadband.

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Introduction

Climate change is by far the greatest challenge of our time. At Nokia, we believe it is the duty of every government, business and citizen to do what they can to minimize their impact on the planet. Some changes can have a big impact, others only small. The important thing is that whatever the change, big or small, we should maximize our positive impact on the planet and all that live on it. We are at the beginning of the decisive decade and we all must act now.

As a leading telecommunications provider, we develop and enhance network solutions and technologies that improve lives and provide greater opportunities for people and the planet. Our products inevitably affect the environment because making, distributing and operating them uses energy and other resources. To reduce our environmental impact, we set ambitious sustainability goals on our own business operations and on the design of products and services that help our customers reduce energy consumption in their networks.

The role of global digitalization

Today, the ICT industry is responsible for around 5-9% of electricity consumption and 2% of global greenhouse gas emissions, equivalent to that of all air traffic[1]. However, ICT technologies have the opportunity to help other industries reduce global greenhouse gas emissions. Despite its own carbon footprint, ICT carries a 7-fold net positive effect on the world's greenhouse gas (GHG) emissions due to the savings it creates; reducing global CO_2 emissions by up to 15%. Digitalization in general and broadband in particular contribute by cutting transportation, creating gains in productivity, efficiency, and boosting economic growth for individuals, countries, cities, and society as a whole.

Figure 1. ICT helps other industries reduce global greenhouse gas emissions

2% ICT's footprint
equivalent to that of all air traffic

15% ICT's impact
ICT, including broadband, can enable a 15% reduction of global CO_2 emissions.

Smart grids

Smart logistics

Videoconferencing

Teleworking

E-learning

Smart buildings

Health monitoring

Telemedicine

Gaming and eSports

Industrial process

1   Source: European Commission fact sheet, "Supporting the green transition", February 2020

The environmental benefits of digitalization are at their greatest when there is innovative cross-collaboration in the tools and solutions we create. Nokia continues to play its part in improving energy efficiency and circularity in order to encourage the ICT sector in limiting in its own emissions. And we continue to minimize our own ecological footprint while also maximizing the beneficial handprint of the fixed broadband technology we produce, allowing every household not just to work or play from home, but also access vital digital services.

- **Transportation**. eCommerce, eLearning, telemedicine, homeworking and video conferencing, all reduce the need for transportation. Whether it's a shopping trip to the mall, your local postal or delivery driver, or a massive global distribution network involving land, air and sea freight, electronic transactions lead to fewer physical displacements. Smart Roads and Smart Cities rely on broadband connectivity to regulate traffic flow, also contributing to lower GHG emissions.

- **Production**. The last 30 years have seen many physical products digitized: movies and music, newspapers and books, through to invoices and receipts. Digitization leads to significant savings in the use of plastics, minerals, paper and other physical materials and of course the energy required in the manufacturing process. None of these savings could be made without broadband being available to consumers and businesses.

- **Smart Grids**. The Smart Grid minimizes electricity wastage by providing accurate real-time insight into demand, regulating both production and consumption, and encouraging more responsible usage. The Smart Grid depends on robust and reliable broadband connectivity across the whole electricity network.

- **Internet of Things**. The ability to connect anything to anybody enables both automation and the sharing of data for better decision-making, reducing physical displacements, saving time and creating efficiencies.

Our sustainability commitments

Nokia is committed to reducing the carbon footprint of broadband connectivity. Why does this matter? The peripheral parts of the network dominate the overall power consumption. Numerous studies point out that home and access infrastructure are the most energy-consuming segment in a telecommunications network and, that they dominate in the energy intensity of the Internet over core and metro networks. The total network energy consumption still represents more than all data centers in the world, or more than the national energy consumption of some countries.

Our priorities have been set to meet key frameworks like the United Nations Sustainable Development Goals and the European Green Deal, where specific objectives include decoupling economic growth from resource use, and leaving no person and no place behind. The European Green Deal aims to achieve greenhouse gas neutrality by 2050 with an intermediate target of 50% reduction in GHG emissions by 2030. In the fall of 2020, China and Japan followed Europe's initiative and announced to reduce net emissions to zero and also the US seeks to rejoin the Paris accord to boost international climate action.

Embedding science-based targets as a fundamental component of sustainability management practices is crucial in achieving this. In 2017, Nokia became the first telecommunication equipment supplier to join the Science-Based Targets initiative, which provides companies with a clearly defined pathway how much and how quickly they need to reduce their GHG emissions.

In September 2019, at the United Nations climate summit, we joined a select group of companies in committing to recalibrate our existing climate targets in line with the 1.5°C scenario. Our current science-based targets are set to reduce scope 1 and 2 GHG emission by 41% and reduce absolute scope 3 GHG

emissions by 75% between 2014 and 2030. Scope 1 and 2 cover emissions from our activities as an organization which we can reduce, for example, through using renewable and self-generated electricity, reducing electricity consumption for our real estate and low emission company car policies. Scope 3 covers emissions from customer use of our products, which is by far the greater part of our total carbon footprint.

Figure 2. Nokia was the first telecommunication equipment supplier to join the Science-Based Targets

Setting greenhouse gas emission reduction targets in line with climate science is a great way to future proof growth

In 2020, Nokia achieved the A listing for climate change performance in the Carbon Disclosure Project. We encourage our suppliers to report their climate impacts and set carbon reduction targets through CDP and work with them to build improvement programs. Nokia is committed to expanding the environmental transparency and coverage of corporate responsibility topics. If you want to learn more, please consult our Sustainability webpage and download the Nokia People and Planet report. Our sustainability priorities relate to product safety, product misuse, environmental concerns, health, privacy, security and risk of non-compliance with regulations.

Enabling sustainable living with ubiquitous broadband

Fast and widely available broadband is a key ingredient for growth and prosperity. Yet, a substantial number of citizens and companies do not have sufficiently fast broadband at their disposal. Nokia is committed to bring better broadband to more people as quickly as possible.

According to independent market analysis and consulting firm Broadbandtrends, there are still more than 1.4 billion households in the world with no or with slow broadband. While it is not evenly distributed, "white spot" areas also exist in highly developed countries and are often eligible for a subsidized broadband deployment. National and local government initiatives, like the EU's Digital Agenda for Europe and the Rural Digital Opportunity Fund (RDOF) in the US, are designed to improve broadband connectivity for underserved regions.
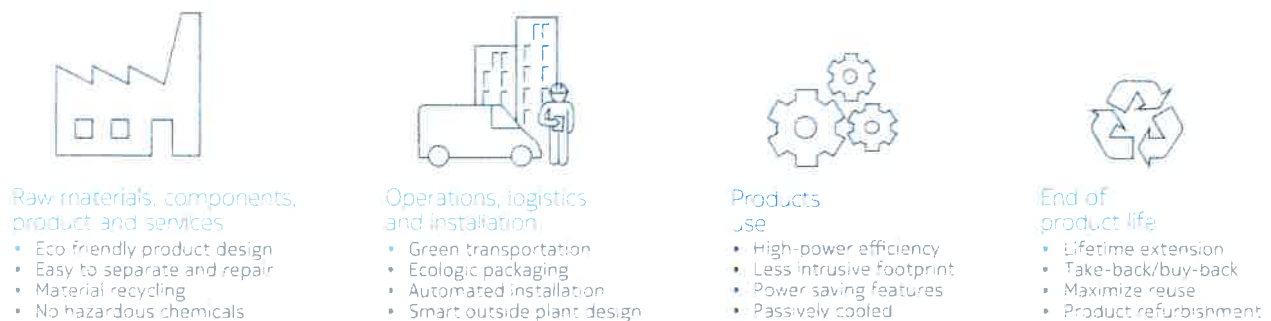
Without a reliable high-speed fixed connection to the internet, it makes it more challenging to enable economic welfare and provide access to basic human rights such as good healthcare and education. It is evident that households without broadband are extremely vulnerable, both socially and economically, as shown during the COVID-19 lockdowns, due to reduced access to information, essential services and connectivity to others. In light of this, fixed broadband connectivity programs must be accelerated. First, every household without a fixed broadband connection must be connected; second, minimum service levels need to be guaranteed to give every household the same opportunities.

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Nokia Design for Environment: a circular approach

Operators have been building networks for years to deliver broadband services to enterprises and residential customers. In the recent past, a "design-to-cost" mantra drove the reduction of direct costs, through lower power and eliminated central office real estate. Now, operators are increasingly turning their attention to fully sustainable development goals. They are striving to become carbon neutral by reducing emissions and executing on renewable energy plans. Using green technologies becomes increasingly important when building fixed access networks.

As the original equipment manufacturer of broadband solutions, Nokia maintains well-established circular lifecycle practices that keep products at their highest value and quality for multiple uses and the longest time possible. Our Design for Environment approach ensures we create technologies that take into account all sustainable aspects. Lifecycle thinking is a key component of this approach: it helps us reduce our environmental impact and improve material and energy efficiency across our production, operations, product use-time and takeback, and through to our suppliers.

Figure 3. The lifecycle in Nokia's Design for Environment approach

Raw materials, components, product and services
- Eco friendly product design
- Easy to separate and repair
- Material recycling
- No hazardous chemicals

Operations, logistics and installation
- Green transportation
- Ecologic packaging
- Automated installation
- Smart outside plant design

Products use
- High-power efficiency
- Less intrusive footprint
- Power saving features
- Passively cooled

End of product life
- Lifetime extension
- Take-back/buy-back
- Maximize reuse
- Product refurbishment

Compliance with relevant environmental regulations is an important part of our environmental policy. Extended Producer Responsibility regulatory programs strive to decrease the environmental impact of products by making the manufacturer responsible for the entire lifecycle of the product, especially end-of-life management through product takeback. We have 25+ years of OEM-quality remanufactured products where we offer takeback, repair, refurbish and recycle services to maximize the value of the obsolete equipment. Remanufacturing used products versus building new ones avoids a minimum of 40% of CO_2 emissions.

Circular product passport

Nokia is working with leading operators on sustainable product initiatives, such as circular product passports, eco-cost calculations, and recommendations for improvements in raw materials used and recyclability. Based on the Recycling and Reuse Metric that we pioneered with the iNEMI organization, we are now better able to evaluate new product designs with an eye towards improving materials choice, ease of parts and materials liberation, and available recovery technology in countries where the products are sold.

Hazardous chemicals

Materials and restricted substances are another key part of our Design for Environment program. We give extreme importance to the preservation of the environment through the implementation of production standards approved by the United Nations.

Global legislation or regulations ban or restrict several substances that are hazardous to either humans and/or the environment. These substances must not be present in our products, components, and materials that are selected during the product design phase.

We comply with all applicable substance requirements from environmental laws and regulations such as the EU RoHS Directive (2011/65/ EU), WEEE Directive (2012/19/EU) and REACH Regulation (EC 1907/2006). These European-based initiatives have helped electronics companies to move away from lead-soldered products and introduce solder alternatives that are more environmentally friendly. A ban on halogens has resulted in looking for alternative materials for our cables: materials containing halogens release toxic elements if they catch fire.
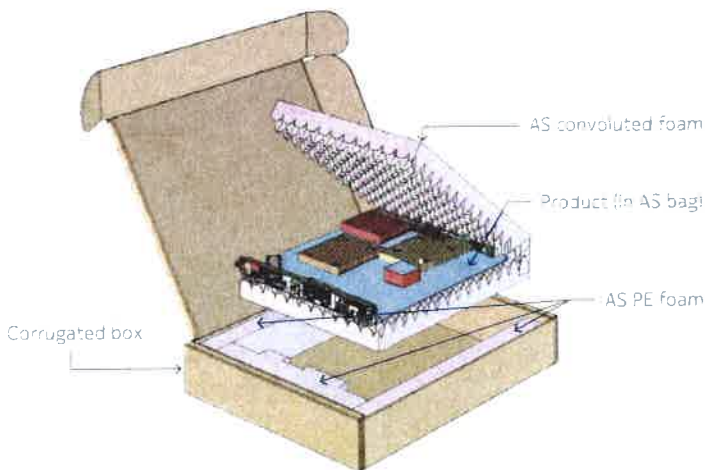
Transportation

In product transportation and distribution, we aim to cut airfreight transportation and choose greener transportation modes. Air transportation is a big GHG contributor with a CO_2 factor of 9 kg per tons-kilometer. Road haulage (with the evolution to electric engines), rail (low use of space, low energy and low noise levels) and sea (sustainable fuel) have over 85% lower emission factors. We also continue to improve our demand planning accuracy and buffer stocks on long lead time components to better anticipate market dynamics and reduce express shipments.

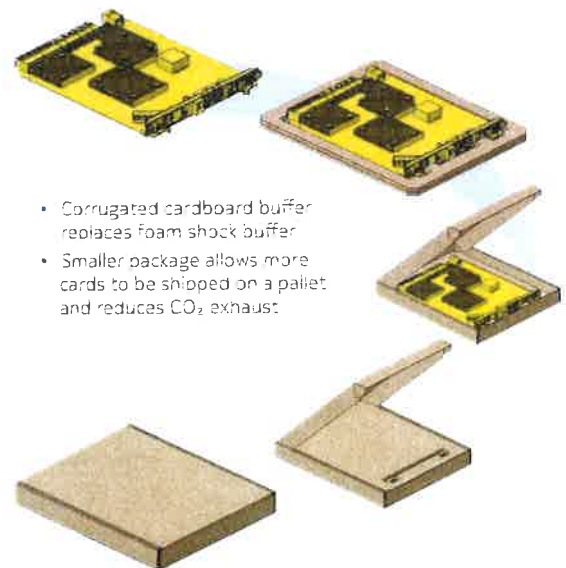Figure 4. Improvements in Nokia product packaging

Current package
External dimensions box: 330 mm x 260 mm x 60 mm

New package
External dimensions box: 252 mm x 303 mm x 36 mm

AS convoluted foam

Product (in AS bag)

AS PE foam

Corrugated box

- Corrugated cardboard buffer replaces foam shock buffer
- Smaller package allows more cards to be shipped on a pallet and reduces CO_2 exhaust

We always aim to save space, reduce the amount of packaging materials used, and maximize our transport efficiency through pallet or container load optimization. This minimizes the number of trucks or containers required on both inbound and outbound shipments. We also maximize the use of eco-packaging materials fit for the circular economy. We have started to replace traditional foam shock buffers with corrugated cardboard buffers and are investigating the use of biodegradable Electrostatic Discharge (ESD) bags. A smaller total package allows more cards to be shipped per pallet, reducing the overall carbon footprint.

Circularity

The practice of recycling is as old as humankind and has proven its value in the reuse of materials from items that have reached the end of their life or use. We look to use as much recycled material as possible and so avoid using newly sourced raw materials.

Thorough investigation has proven that stainless steel is the most ecologically-sound material to use for the chassis of our modular network equipment (Nokia FD/FX/MX portfolios). No other material is comparable when considering the environmental cost to build and re-use it. Stainless steel is the best choice for containing radiation, minimizing interference, conducting heat, and giving the right mix of strength and rigidity. It is easily recycled, and the recovered raw material can be used for new products.

End-user products are usefully built from plastic. We have applied best practices from other industries in the re-use of plastics for new products. Plastic that is no longer used is granulated and sorted and can be reused, partially or fully. Exercises are ongoing to determine how much re-used plastic can be applied to our equipment designs.

The most challenging components to be made circular are printed circuit boards (PCB). These complex stacks of copper and fiberglass are difficult to disassemble and hence recycle or re-use. Nor are there suitable alternative materials to manufacture PCBs. PCBs remain an area of investigation for the ICT industry.

For our end-user products such as gateways, optical network terminals and Wi-Fi devices, Nokia pays particular attention to the environmental impact with high device recyclability potential and eco-packaging (100% paper and cardboard). Where possible, our products are easy to dismantle via commonly available tools and parts requiring separate treatment are easy to disassemble. Products allow easy repair, on-site configuration changes, remote software downloads and extension of the capacity of existing product features.

Figure 5. Separable components of a Nokia Wifi Beacon

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Broadband energy consumption

When we measure our carbon footprint from our operations through the complete lifecycle of our products—design, manufacture, distribution, use, and treatment at end of life—we find that product usage and energy consumption accounts for about 89% of the total carbon footprint. This is why we invest heavily in power-saving innovations to reduce this impact.
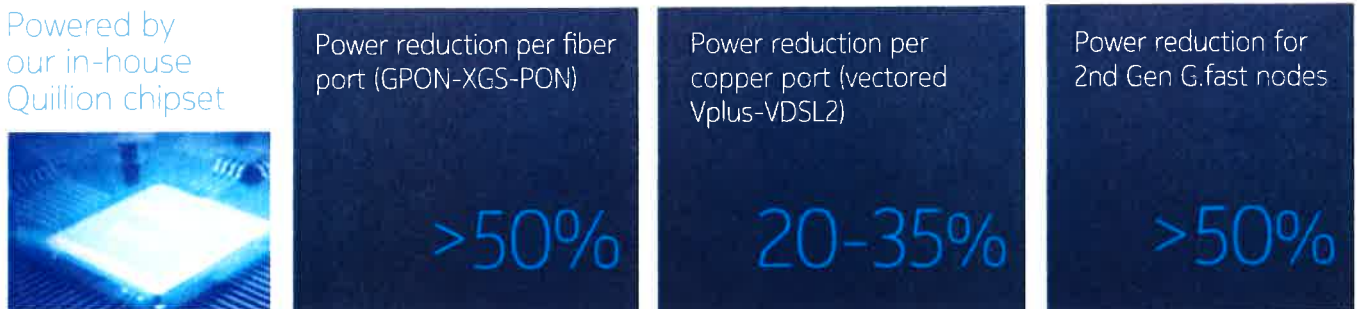
Figure 6. Comparison of GHG emissions through the product lifecycle of fixed access nodes

| 10% | 2% | 89% | ~1% |
| Production | Transportation | Usage | End-of-life |
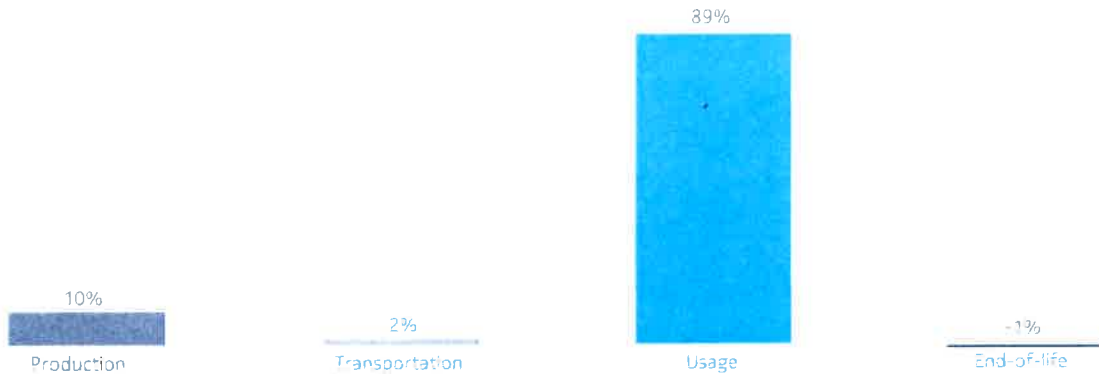
One example is with our proprietary Quillion chipset, designed and developed in-house. The power consumption of fixed network telecom equipment is mostly driven by the chipsets used. Quillion allows us to build power-optimized line cards for fiber and copper broadband with higher port density, integrated energy-saving features and higher throughput per watt. Quillion includes advanced features such as powering down unused optics (saving up to 1.5W for GPON optics) and improved intelligent fan tray control algorithms to reduce energy consumption and cooling when not required. Our G.fast nodes have next-gen processors with more functionality embedded, which reduces the number of components and bring power savings of more than 50%. The G.fast nodes only draw power for ports that are in use, with smart SR2 reverse power feeding (RPF) coming from the customer premises. One active user requires only 7W of power, equivalent to powering a single LED lamp.

More power-efficient chipsets lead to smaller power-optimized nodes, which occupy less space, use less power and can be passively cooled (up to operating temperatures of 65°C). This also reduces the installed battery capacity. When installed in street cabinets, they require less grid protection equipment, smaller power supplies and only "heatwave days" fan ventilation backup.

Figure 7. Energy savings with power-optimized line cards and next-generation processors

Powered by our in-house Quillion chipset

| Power reduction per fiber port (GPON-XGS-PON) | Power reduction per copper port (vectored Vplus-VDSL2) | Power reduction for 2nd Gen G.fast nodes |
| >50% | 20-35% | >50% |

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We apply the same energy-efficiency mindset to our end-user products. The Wi-Fi 6 technology in our Nokia WiFi Beacons allows new power saving modes with scheduled sleep/wake times for longer battery life and up to 67% lower power consumption. Our home devices also operate up to 45°C without any additional cooling.

We apply the same energy-efficiency mindset to our end-user products. Our products help save energy and support WMM Power Save certifications. The Wi-Fi 6 technology in our Nokia WiFi Beacons allows power saving modes with scheduled sleep/wake times for longer battery life and up to 67% lower power consumption for end devices. We are also an EnergyStar-certified supplier. When shopping for small network equipment, look for the EnergyStar logo, which means that the model uses 20 percent less power than a conventional unit. Our home devices operate up to 45°C without any additional cooling.

Fiber for Broadband Zero

New fixed broadband networks are now predominantly based on fiber optic technology. Most operators are also in the process of upgrading older copper and cable networks to deep fiber or full fiber-to-the-home networks. Fiber is a significantly more sustainable technology than other types of fixed broadband as well as being more cost- and power-efficient to operate.

Since 2009 we have annually reported product energy consumption according to the Code of Conducts for Broadband Communication Equipment from the European Commission. The figures show the per subscriber power consumption of various technologies over time and illustrate the significant differences between technologies. One note: VDSL17 & VDSL30/35 2020 targets for network equipment are in practice higher, amounting to about 2W with improvements like vectoring and long-range high transmit power evolutions.

Figure 8. Power consumption per subscriber by technology
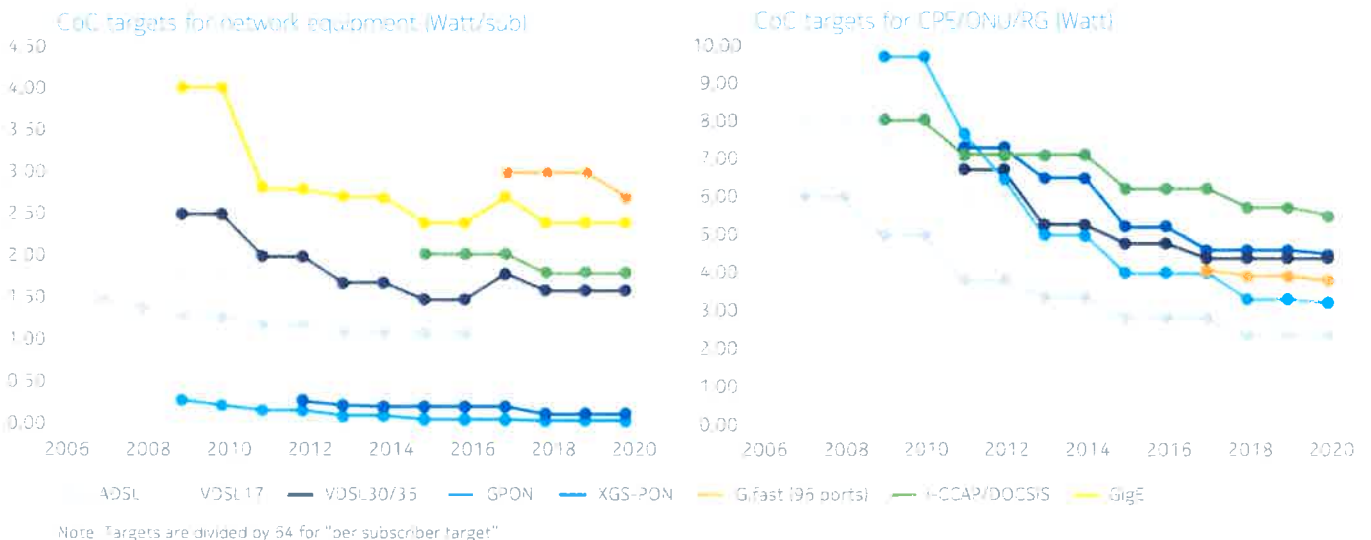
Future-proof scalability and higher capacity make full-fiber networks the most energy efficient solution. Since 2007, power consumption has been reduced by 38% while broadband speeds have increased by a factor of 64. This trend is important as it shows that the explosion in demand for data does not necessarily lead to a massive increase in emissions; emissions have actually decreased in recent years since the shift

![NOKIA]

from copper to fiber. The results of a study by Nokia Bell Labs (see Figure 9) show that fiber-to-the-home (FTTH) with XGS-PON consumes x2 more energy for 4x the speed of GPON for the access network. This means that FTTH XGS-PON is the most power efficient broadband technology. The fiber extension technology G.fast is able to deliver similar broadband speeds as GPON but consumes 1.6 times more energy in the end-to-end network. With reverse powering from the home, the power of FTTB is at the same level as FTTH GPON on operator side.

Fiber is clearly the green technology for the future. With the shift to fiber and passive power splitting, fewer ports and active electronics are needed to serve end users, requiring less power provisioning in the network. Fiber has extremely low attenuation (0.2 dB/km) due to the purity of the glass and the confinement of light emitted by the laser inside the core of the fiber cable. Passive fiber networks deliver the lowest ecological footprint. Point-to-point fiber technologies like GigE and 10GigE are competitive in power per bit, but they cannot benefit from the same infrastructure sharing efficiencies. It makes PON technologies the ideal fit to deliver mass-market enterprise services and robust fiber transport for many 4G and 5G cell sites.

Reduced energy consumption and increased network reliability (through absence of active network elements in the field) mean that the FTTH network costs less to run and operate. Moving to a full-fiber network allows also to consolidate central offices, again reducing energy consumption. The network also has a longer lifespan. A more reliable network requires fewer field support staff and less travel to network locations to carry out maintenance and repairs. This results in a better customer experience in the form of superior service quality (bandwidth, latency, etc.), higher reliability and lower OPEX. FTTH combines the lowest energy requirements and GHG emissions with superior scalability and bandwidth evolutions to 25G, 50G and beyond.

Figure 9. Power consumption comparison for fiber and FWA technologies
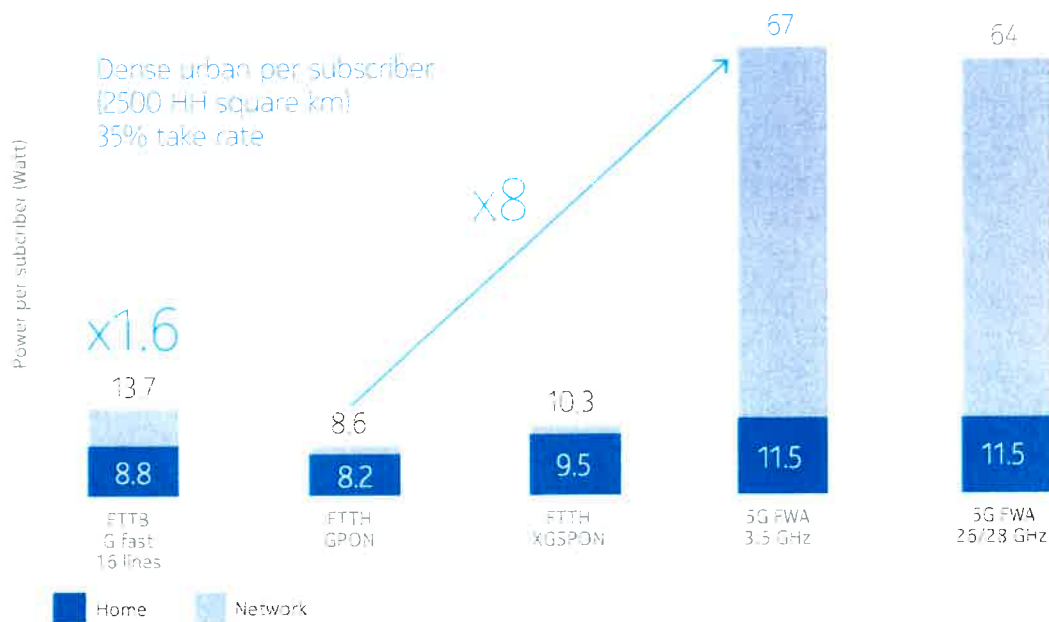
Fixed wireless access to bridge the digital divide

Being the most future-proof and energy-efficient infrastructure, full-fiber networks are key contributors to reducing power consumption in the telecoms sector. But another goal of broadband networks is to close the digital divide as fast as possible.

Fiber broadband solutions will reach 860 million households worldwide by 2024, yet that represents only about one third of all households. The primary reason for unserved and under-served populations is economics. The coverage gaps tend to be the hard-to-reach locations and areas with low population density, making it more challenging to generate the revenues to make fiber broadband investment viable. In these situations, fixed wireless access (FWA) technology has a strategic role to play as there is no physical last mile connection to deploy.

However, 5G FWA is 8 times less power efficient than GPON. This comes as no surprise as power consumption is largely determined by the channel attenuation, which is much higher for radio compared to wireline communication and exacerbated by any obstacles they must penetrate, e.g. foliage and walls. As a consequence, only a small fraction of the energy transmitted arrives at the receiver. This is unavoidable for mobile communication, where there is no prior knowledge of where the radio antenna and user are in relation to each other.

Nokia mitigates these factors in the design of its FWA solutions. We use high-gain antennas, 5G massive MIMO and outdoor receivers to improve throughput and radio efficiency. High-gain antennas confine the radiation from an omnidirectional pattern, as used in cell phones, to a beam that is directed towards the cell site. High gain antennas also limit interference, because of their directivity. Within the radio access network, the massive MIMO arrays of 5G help radio efficiency in a similar way. The use of outdoor or window mount devices ensures that first wall penetration losses are avoided, strongly contributing to radio efficiency and, hence, power efficiency. This creates a 30 dB improvement in signal loss and five times better energy efficiency compared to mobile cell phone communications.

Constructing broadband networks

Constructing a broadband network inevitably results in GHG emissions and other environmental damage. It is therefore extremely important to build robust network infrastructure that can cope with future demands in a sustainable way.

Fiber is created from simple materials (glass, silica, quartz, plastic). This means production can be carried out locally from start to finish and does not require the highly polluting extraction and transportation of ore from all over the world. For the roll-out of the fiber cables, alternative trenching methods, trenchless technologies and, co-deployment in non-telecommunication infrastructure have been developed that slash the carbon emissions of deployment, with less waste, less backfill material, and less time consumption.

Nokia offers special outside plant design services with benefits for the environment in resource optimization and waste reduction. Smart outside plant design maximizes the utilization of all reusable existing infrastructure to reduce the direct environmental impact as well as the cost and duration of the rollout: for example, a greenfield underground deployment can be up to three times the cost of brownfield deployments.

Material selection is another important criterion, and we exclude non-desired materials. For example, we use recyclable HDPE instead of harmful PVC for pipes. We also manage material purchasing to avoid inventory waste, reduce logistical costs and limit truck rolls to sites.

In areas where multiple FTTH networks are not viable, overbuilding should be avoided. Network sharing and slicing can help to connect all users in those areas without resource waste. This relies on an incumbent operator or alternative infrastructure provider who builds a FTTH network and gives wholesale access to various virtual network operators, who don't need to deploy duplicate infrastructure. At the same time, this may also be the best business model to ensure that a maximum number of end users are connected with full-fiber networks, attracting even more interest of responsible investors in future-proof fiber infrastructure.

Where FWA is deployed, there are no civil works for the last mile connectivity. Nokia enables easy guided self-installation of the FWA gateways and receivers using user-friendly web portals to minimize truck rolls, cost per activation and travel to end-user premises. FWA can generally be deployed more quickly and easily than fiber, helping an operator trend to 100% coverage and increase take up-rates which, again, pushes down the power consumption per subscriber.

Finally, it should be noted that - as fiber is a more efficient technology in operation than FWA - the CO_2 emissions of a FTTH construction are compensated within 4-7 years when compared to FWA using existing macro towers[2].

Conclusion

If money were no object, and time were not a factor, fiber would be used for every broadband connection. From all the technologies available, fiber is the least power-hungry means of transporting high data rates. However, commercial considerations and regulatory mandates drive the increasing trend for operators to mix different broadband technologies: it ensures the digital divide does not widen between those who have access to fiber and those who do not.

Being a champion and market leader of fiber technology, Nokia is committed to reduce the environmental impact of all the technologies we develop and all the projects we serve, because we believe in the power of broadband to transform the quality of life for people, economies, and the world in which we live. In product design and manufacture, packaging and transportation, usage, and end of life recycling: at every stage in the lifecycle of our products we are taking meaningful action to reduce our own environmental impact and help the operators and consumers using our products to reduce theirs.

Through initiatives such as Design for Environment, power-saving innovations, circular economy principles, and our commitment to bridging the digital divide, we are pursuing Broadband Zero: zero emissions networks where zero people are excluded from high-speed broadband.

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2   Source: Lifecycle Analysis performed by Nokia Bell Labs

Who we are

NOKIA

October 2021

Nokia at a glance

€21.9bn

Net sales
2020

€129bn
in R&D investment
(past two decades)

#1
in 5G standard
essential patents[1]

World's record
in 5G speed

#1 in telco
software[2]

Leader in private
wireless networks
globally[3]

[1] Independent study by IPLytics, April 2021
[2] Analysys Mason September 2020 report (2019 market share)
[3] Futurum Research webcast, August 2021

Public

NOKIA

An unrivalled track record of innovation
led by Nokia Bell Labs

9 Nobel Prizes	7 Emmys	5 Turing Awards	2 Grammys	1 Oscar

Foundations of …

- The entire electronics industry
- The internet, networking and optics
- Mobile and fixed communications

Transistors

Satellite comms

Laser/fiber optics

Unix/C/C++

Solar cells

Coherent optics

Charge-coupled devices

Super-resolution microscopy

     Public   **NOKIA**

Our licensees leverage our innovations to help connect the world

3,500[+]
patent families declared essential to 5G[1]

20,000[+]
patent families

1,500[+]
new inventions patented in 2020

Patent licensing
Enabling others to build on Nokia innovations and our contributions to industry standards

Technology licensing
Helping customers to differentiate their products with next-generation audio solutions

Brand partnerships
Licensing the Nokia brand to consumer device manufacturers around the world

As of Q4 2020, announced in Nokia

NOKIA

With our customers, we create the critical networks that bring together the world's people, machines and devices, sensing and acting in real time.

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Four strategic commitments define our focus

To be the trusted partner for critical networks

To focus on technology leadership that lowers costs and simplifies digitalization

To help drive new value through cloud and new business models

To shape the next technology window through long-term research

Public

NOKIA

We are building technology leadership across the industry

Mobile Networks

Connecting the world through mobile networks and driving leadership with 5G, Single RAN, Cloud RAN and O-RAN

- Radio Access Networks (RAN)
- Microwave Radio Links (MWR)
- Related network management software and services

€10 bn net sales 2020
~36,000 employees

Network Infrastructure

Becoming the world's most trusted systems partner driving digitalization through tech leadership in silicon, software and automation

- IP networks
- Optical networks
- Fixed networks
- Alcatel Submarine Networks

€7 bn net sales 2020
~19,000 employees

Cloud and Network Services

Driving value creation for CSPs and enterprises through cloud-native network software, cloud-based solutions and as a service delivery

- Business applications
- Core network solutions
- Cloud and cognitive services
- Enterprise solutions

€3.1 bn net sales 2020
~19,000 employees

Nokia Technologies

Accelerating digitalization by managing, monetizing, and growing the value of our intellectual property

- Brand licensing
- Patent licensing
- Technology licensing

€1.4 bn net sales 2020
~400 employees

Public

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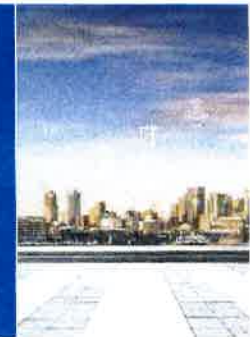
We deliver mission, business and society-critical networks to asset-intensive industries and the public sector

Purpose-designed networks built for Industry 4.0 digitalization and beyond

1550+
Mission-critical network customers*

Transportation
200+

Energy
350+

Public sector
600+

Manufacturing & supply chain
400+

380+
Private wireless network customers

*Updated annually, includes private wireless and all other network technologies.

NOKIA

Present across the globe in ~130 countries

North America

where we have been at the heart of the Bell system for a hundred years

Europe

where we are rooted and headquartered

Middle East & Africa

where we are present in more than 50 countries

Greater China

where we showcase six R&D innovation centers

India

where we have the largest single country employee base

Asia-Pacific

where we are supporting our customers in 14 countries

Latin America

where we are present in 14 countries

Public

NOKIA

Working as a trusted partner with our customers

189 Commercial 5G deals

72 Live 5G operator networks

North America
AT&T, AVIN, Bell, cspire, dish, Shaw), T Mobile, TELUS, uscellular, verizon

Latin America
antel, Cnl, Movistar, SETAR, TIM

Europe
5G Playground, A1, ABP, ARENA2036, BASF, BT, CARGOTEC, citycom, DB, elisa, Fraunhofer, free, MiRA, iliad, KIT, KONECRANES, KUKA, lmt, NOS, O2, plus, proximus, Industrie 4.0, SAAB, SALZBURG, SANDVIK, TELE2, Telefonica, T2, telemach, telenet, Telia, vodafone, VIVACOM

Middle East & Africa
du, etisalat, Mobily, ooredoo, stc, Safaricom

Asia-Pacific
docomo, docomo pacific, dtac, KDDI, kt, LG U+, OPTUS, QTnet, Softbank, SK, tpg, RUTS, vodafone

Greater China
CBN, 中国移动, 中国电信, China Unicom, DITO, Globe, Gt, Taiwan Mobile, 台湾之星
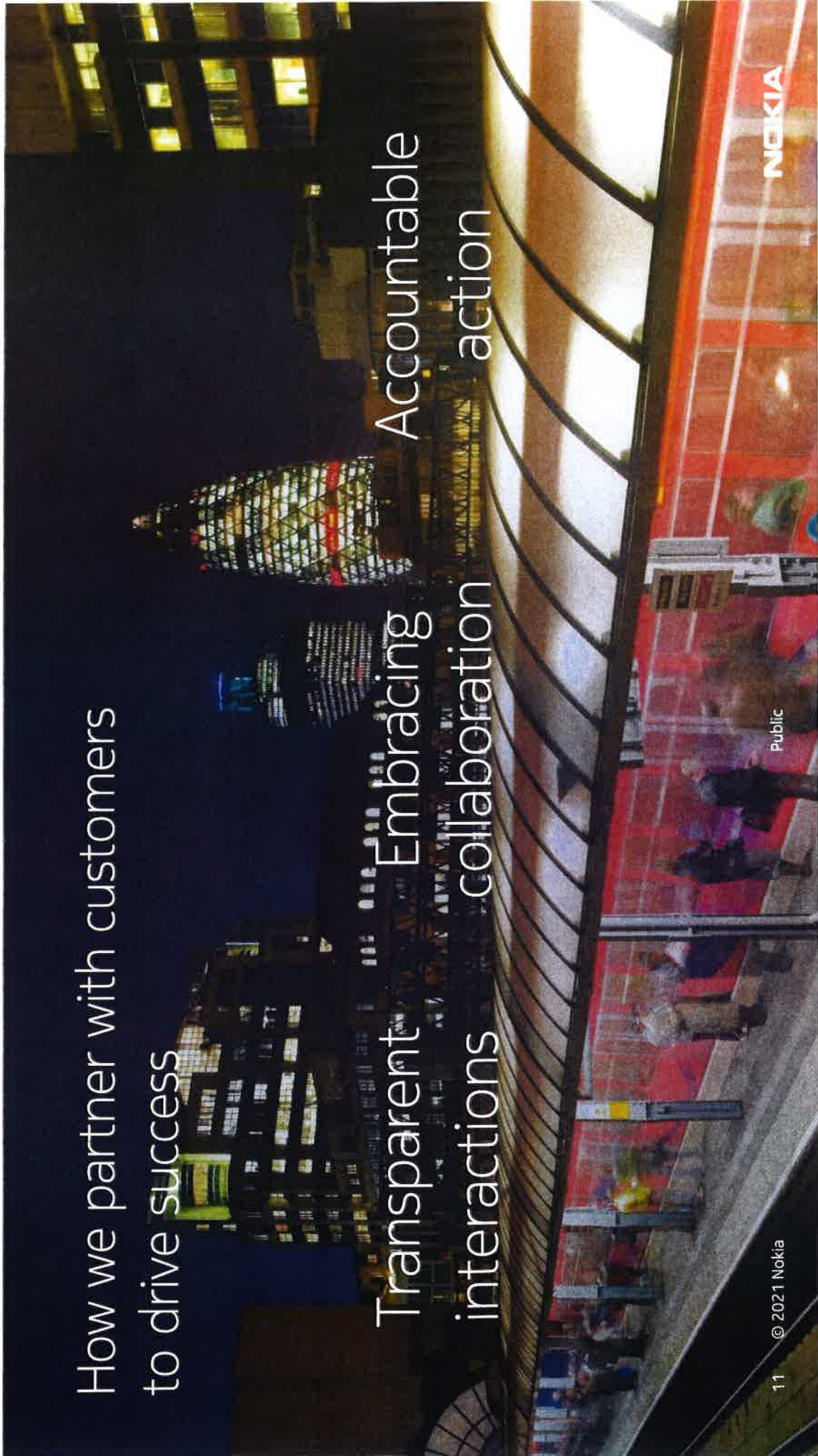
Logos reflect public operator and enterprise customers

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How we partner with customers to drive success

Transparent interactions

Embracing collaboration

Accountable action

11

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Driving sustainable progress, with integrity

Creating technology that helps the world act together

CLIMATE · CULTURE · INTEGRITY

50% target to reduce emissions from 2019-2030

26% minimum target of external female hires in 2021

2021 WORLD'S MOST ETHICAL COMPANIES™
WWW.ETHISPHERE.COM
5-TIME HONOREE

* "World's Most Ethical Companies" and "Ethisphere" names and marks are registered trademarks of Ethisphere LLC

Public

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Broadband Portfolio & Final Mile Technology strategy

Michael Brayen

Sr. Director Community Broadband

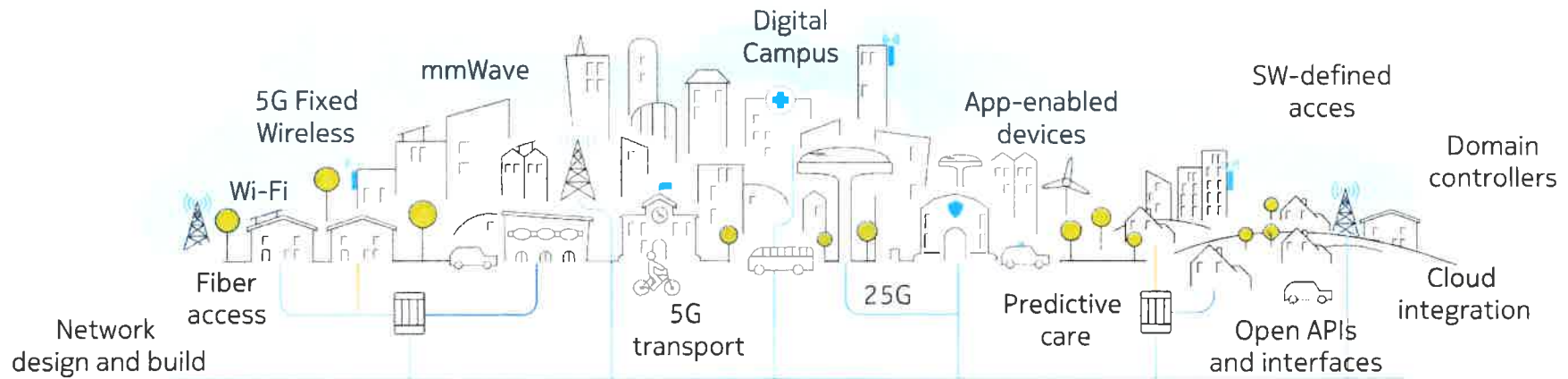# Broadband Zero – Nokia's portfolio strategy

Zero left behind
Connect everyone
and everything

Zero limits
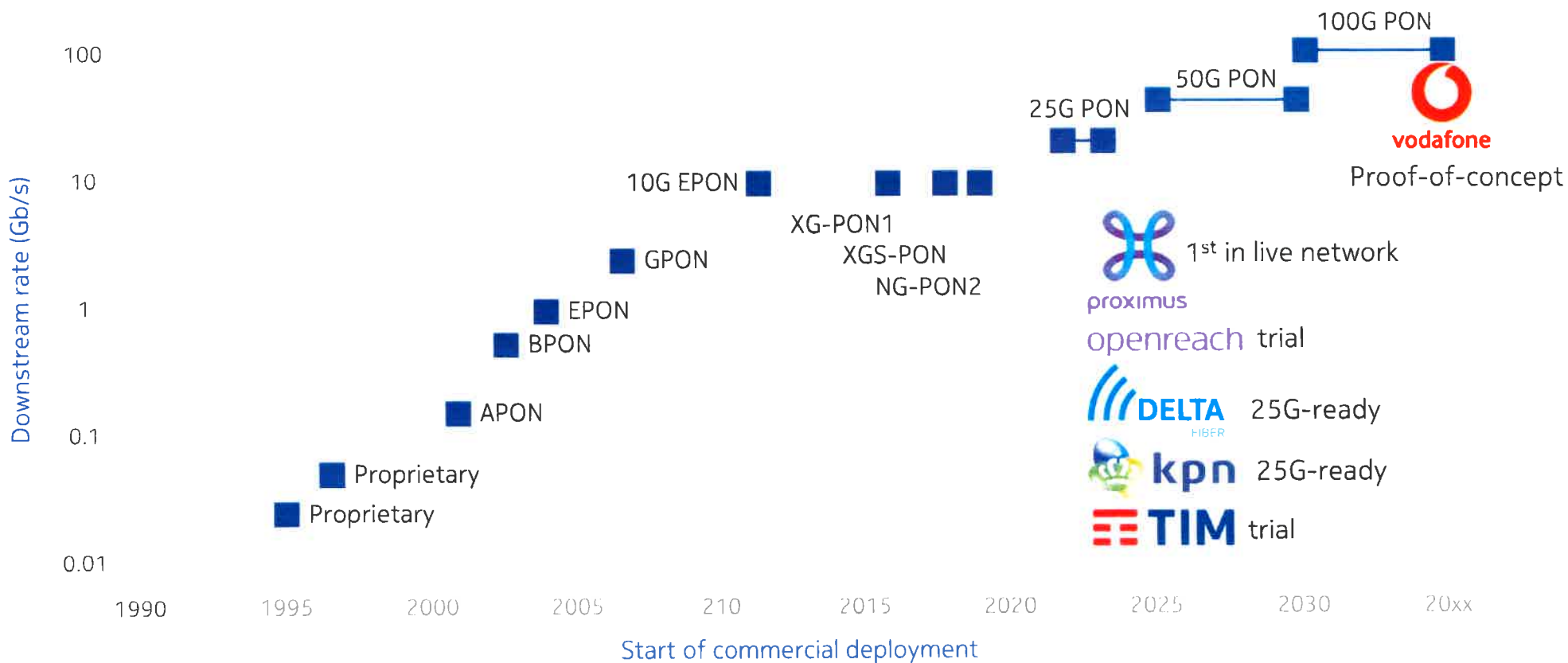Innovative technologies for new
use cases and business models

Zero touch
Automate and optimize
the network

mmWave

5G Fixed
Wireless

Digital
Campus

App-enabled
devices

SW-defined
acces

Wi-Fi

Domain
controllers

Fiber
access

5G
transport

25G

Predictive
care

Cloud
integration

Network
design and build

Open APIs
and interfaces

Zero waste
Delivering the benefits of broadband while minimizing environmental impact

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Fiber technology continues to evolve

Downstream rate (Gb/s) vs Start of commercial deployment

- 100G PON
- 50G PON
- 25G PON
- 10G EPON
- XG-PON1
- XGS-PON
- NG-PON2
- GPON
- EPON
- BPON
- APON
- Proprietary
- Proprietary

proximus — 1st in live network
openreach trial
DELTA — 25G-ready
kpn — 25G-ready
TIM trial
vodafone Proof-of-concept

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The Use Cases: Broadband speeds drive use cases from residential to business and 5G transport

100 Mbps   2.5 Gbps   10 Gbps   25 Gbps

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The case for Fixed Wireless Access as a Complement to Middle Mile Fiber and Fiber to the Home FTTH

Rural coverage
Basic broadband where fiber economics don't add up

Compete out-of-territory
Quickly build footprint and grab share in adjacent areas

Complement fiber access
Use 5G FWA where the fiber cost or TTM is prohibitive

Fast time-to-market for fiber services
Instant coverage with 5G (mmWave); build fiber later

Mobile CSP

Converged CSP

Compete with FTTH
Deliver a fiber-grade service with 5G (mmWave)

Grab broadband market share
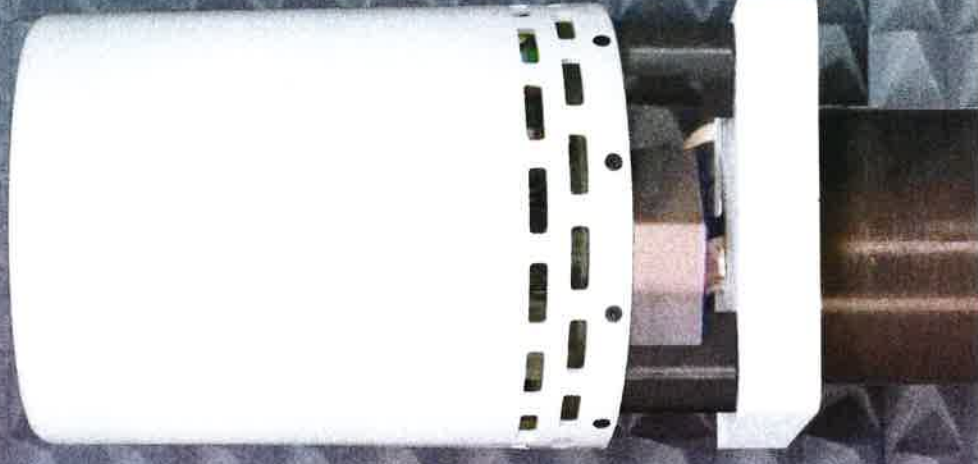Fast TTM, low start-up cost, instant gratification

© 2020 Nokia

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The mm Wave challenge(s)

- Signal can come from any direction
- Signal will be weak due to losses
- Changes as people and objects move

Reflection loss

Penetration loss

Diffraction loss

Propagation loss
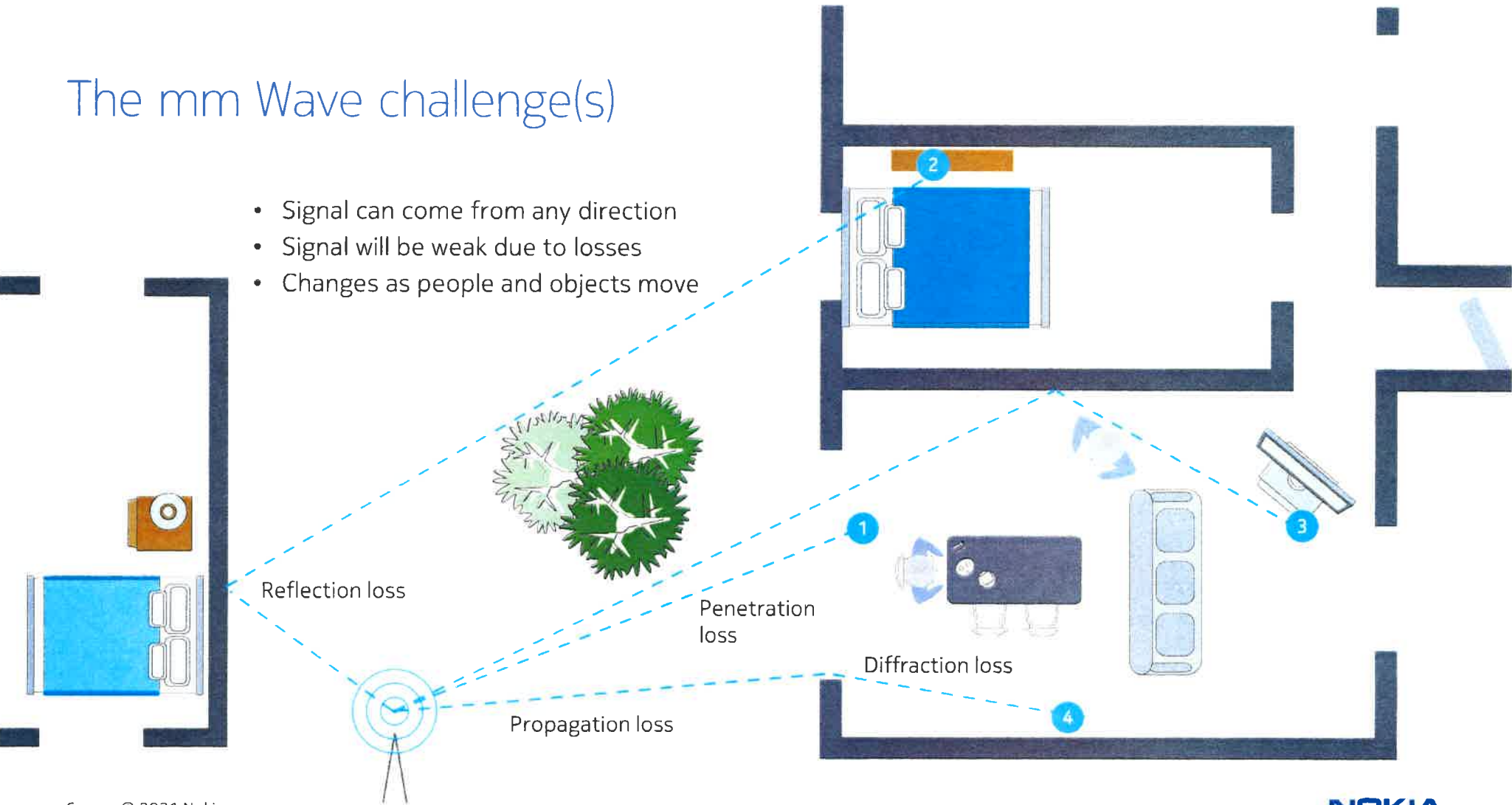
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NOKIA Solving the mm Wave challenge

Making mm Wave 5G FWA viable for cost-effective, indoor deployment

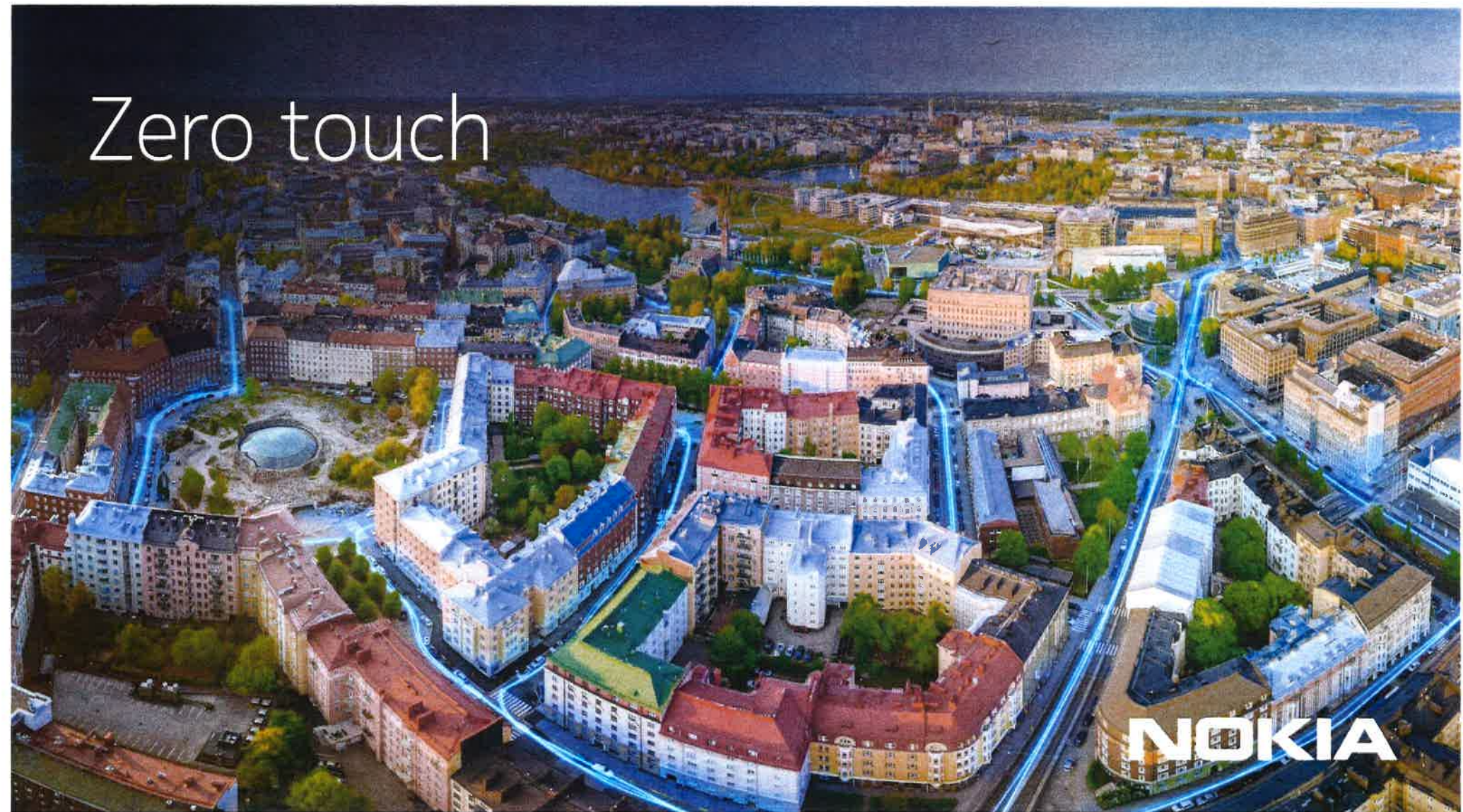- 360 degrees
- High Gain
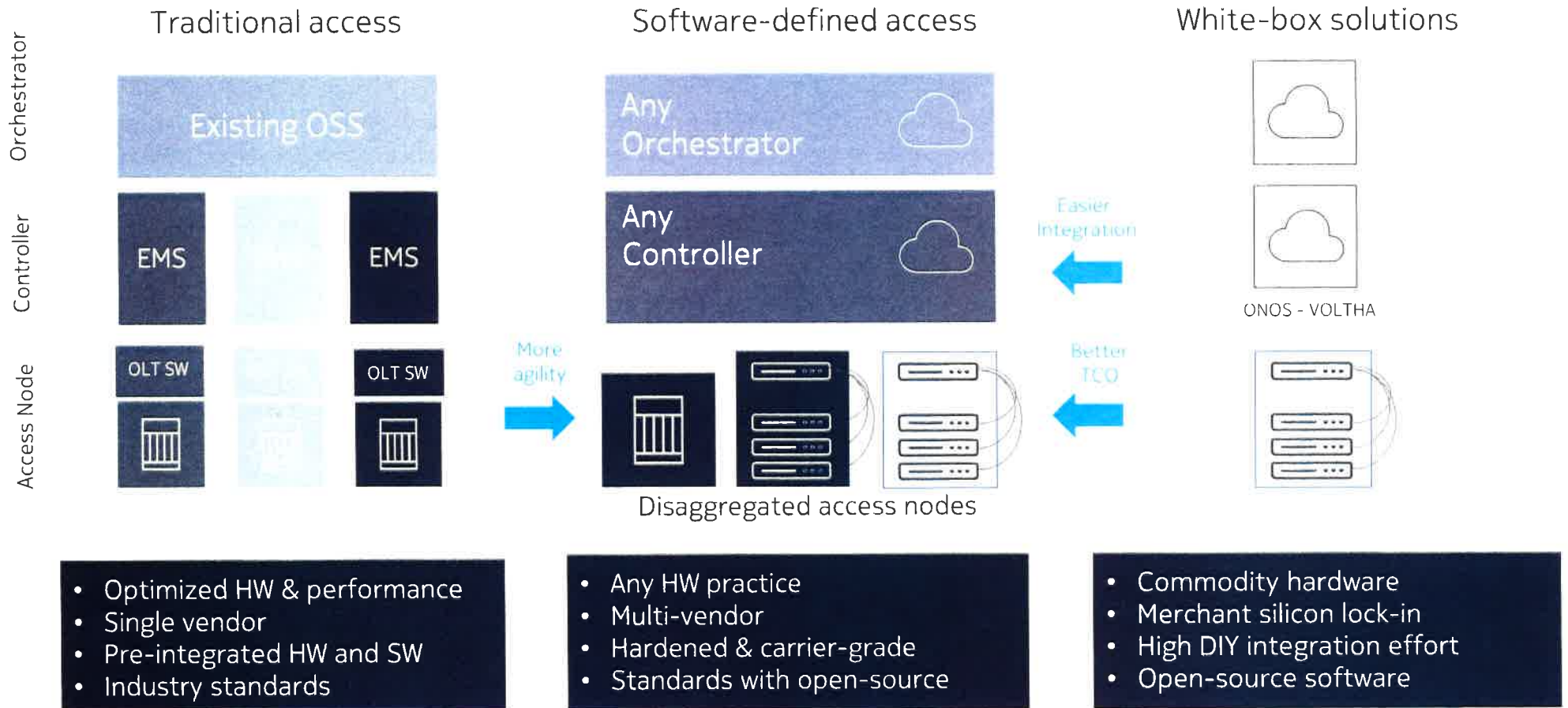- Dynamic optimization

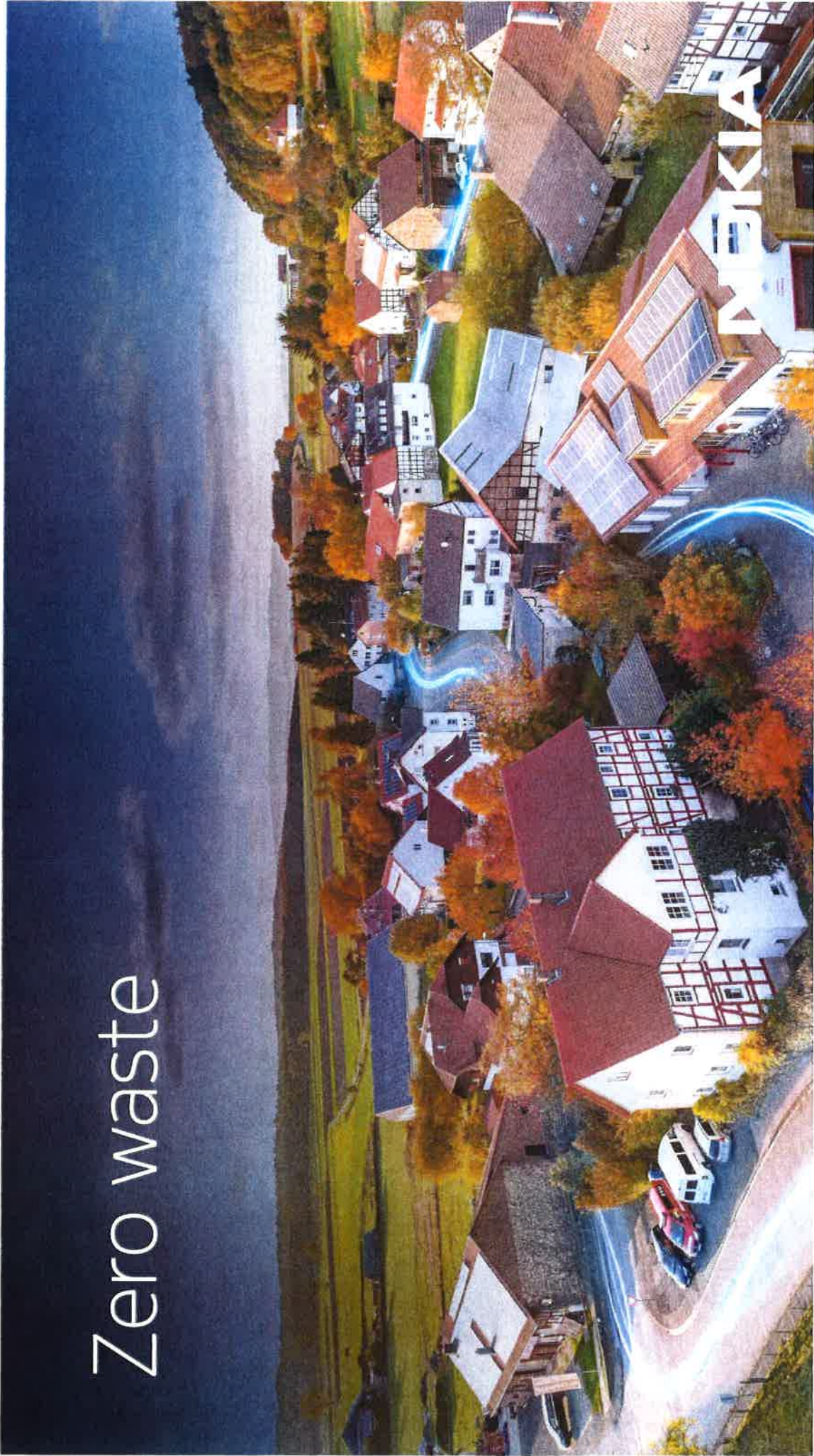proof of concept trial CPE

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Zero touch

Combining the best of traditional & whitebox access

	Traditional access	Software-defined access	White-box solutions

Orchestrator

Existing OSS | Any Orchestrator | (cloud)

Controller

EMS | EMS | Any Controller | ONOS - VOLTHA

Easier Integration

Access Node

OLT SW | OLT SW

More agility

Disaggregated access nodes

Better TCO

- Optimized HW & performance
- Single vendor
- Pre-integrated HW and SW
- Industry standards

- Any HW practice
- Multi-vendor
- Hardened & carrier-grade
- Standards with open-source

- Commodity hardware
- Merchant silicon lock-in
- High DIY integration effort
- Open-source software
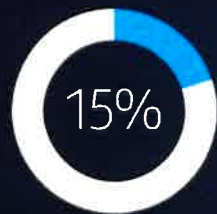
Zero waste

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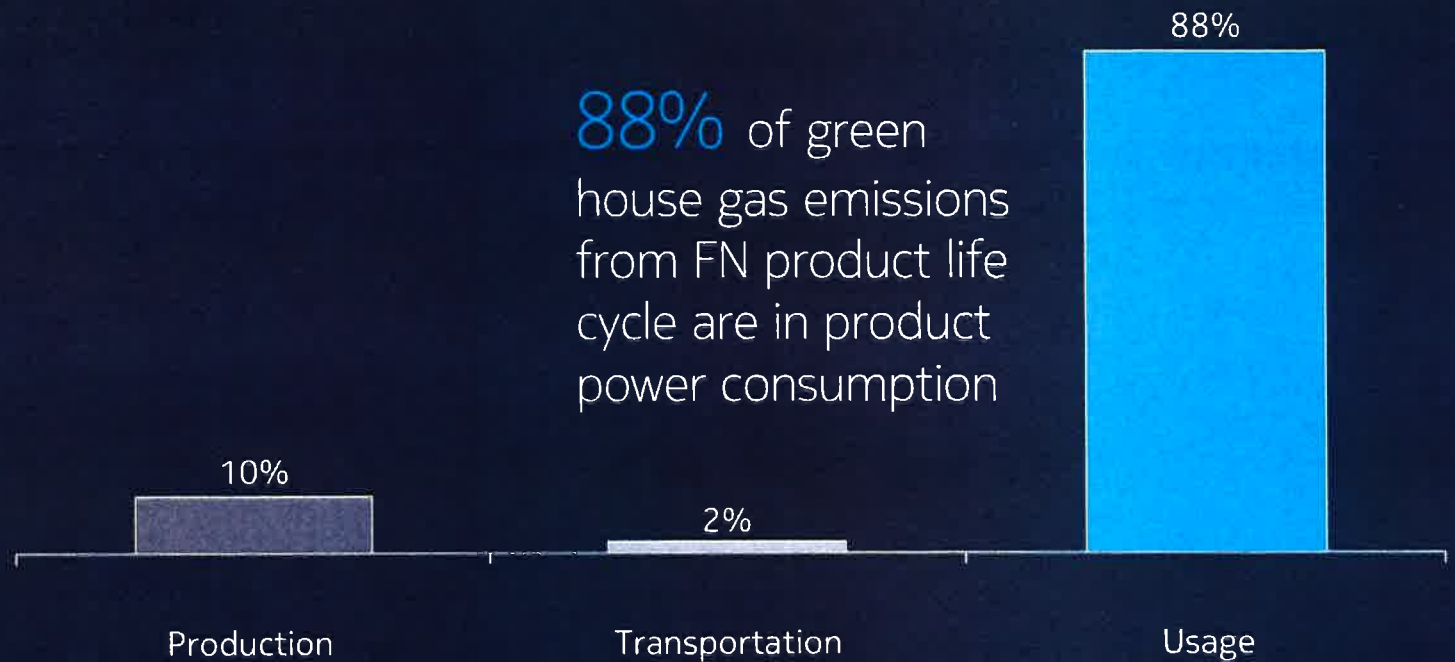# ICT & Broadband networks can (help) save the planet

2%

ICT's footprint
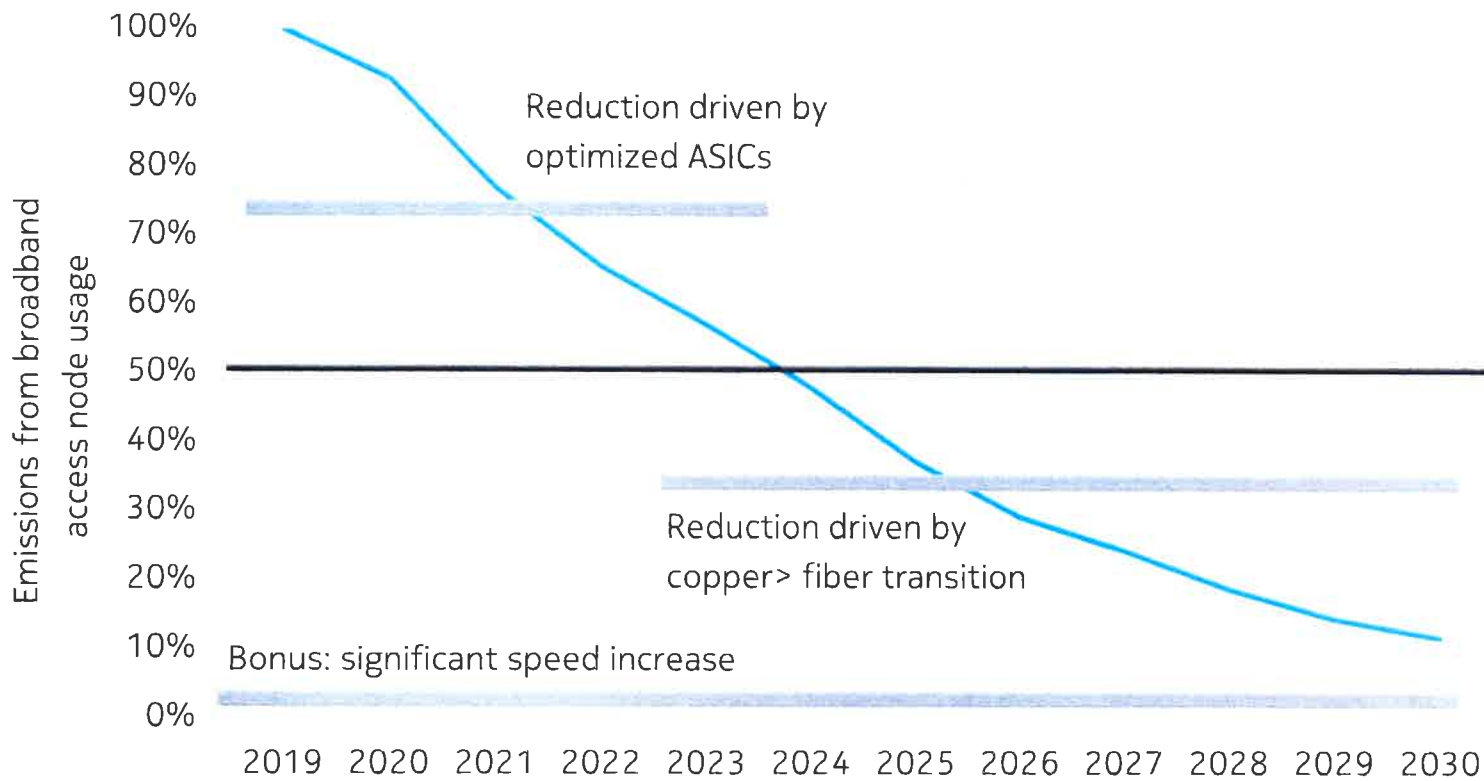
equivalent to that of all air traffic

15%

ICT's impact

ICT, including broadband, could enable a 15% reduction of global CO2 emissions by 2030.

88% of green house gas emissions from FN product life cycle are in product power consumption

10%

2%

88%

Production

Transportation

Usage

Broadband network equipment on track to meet Science-Based Targets

Emissions from broadband access node usage

Reduction driven by optimized ASICs

Reduction driven by copper> fiber transition

Bonus: significant speed increase

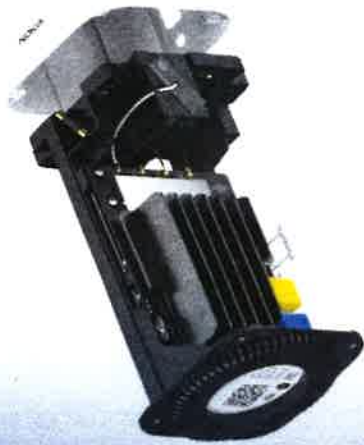2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

SCIENCE BASED TARGETS

DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

-50%

Nokia targets -50% reduction in emissions from product usage from 2019 to 2030

© 2021 Nokia
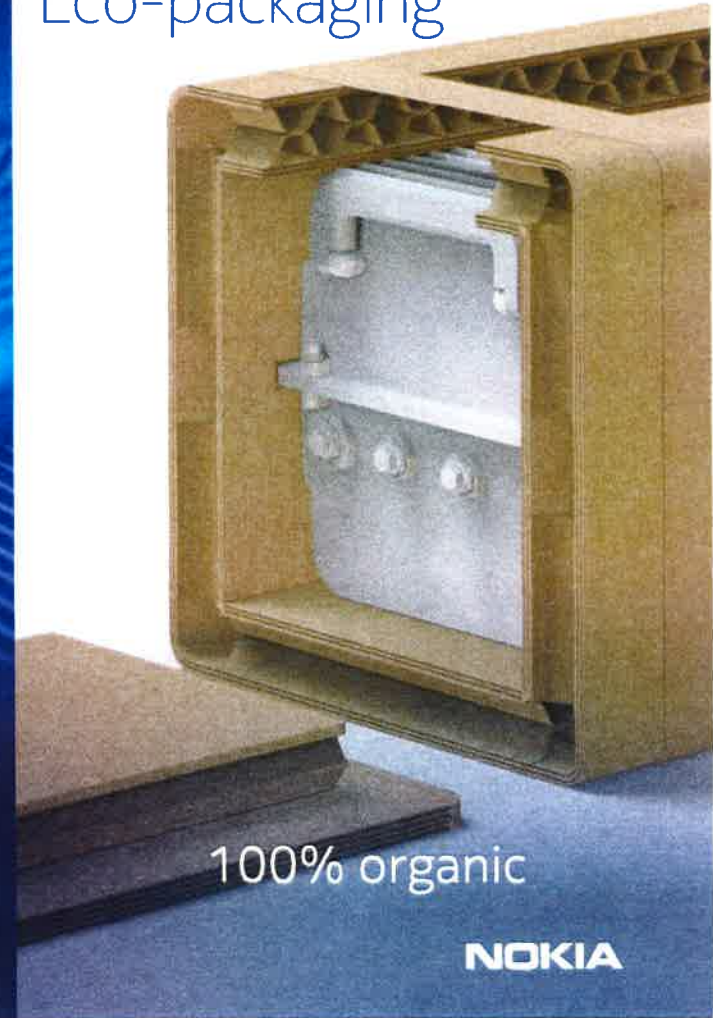
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Designed for recycling

70% recyclable

Low power

50% power reduction
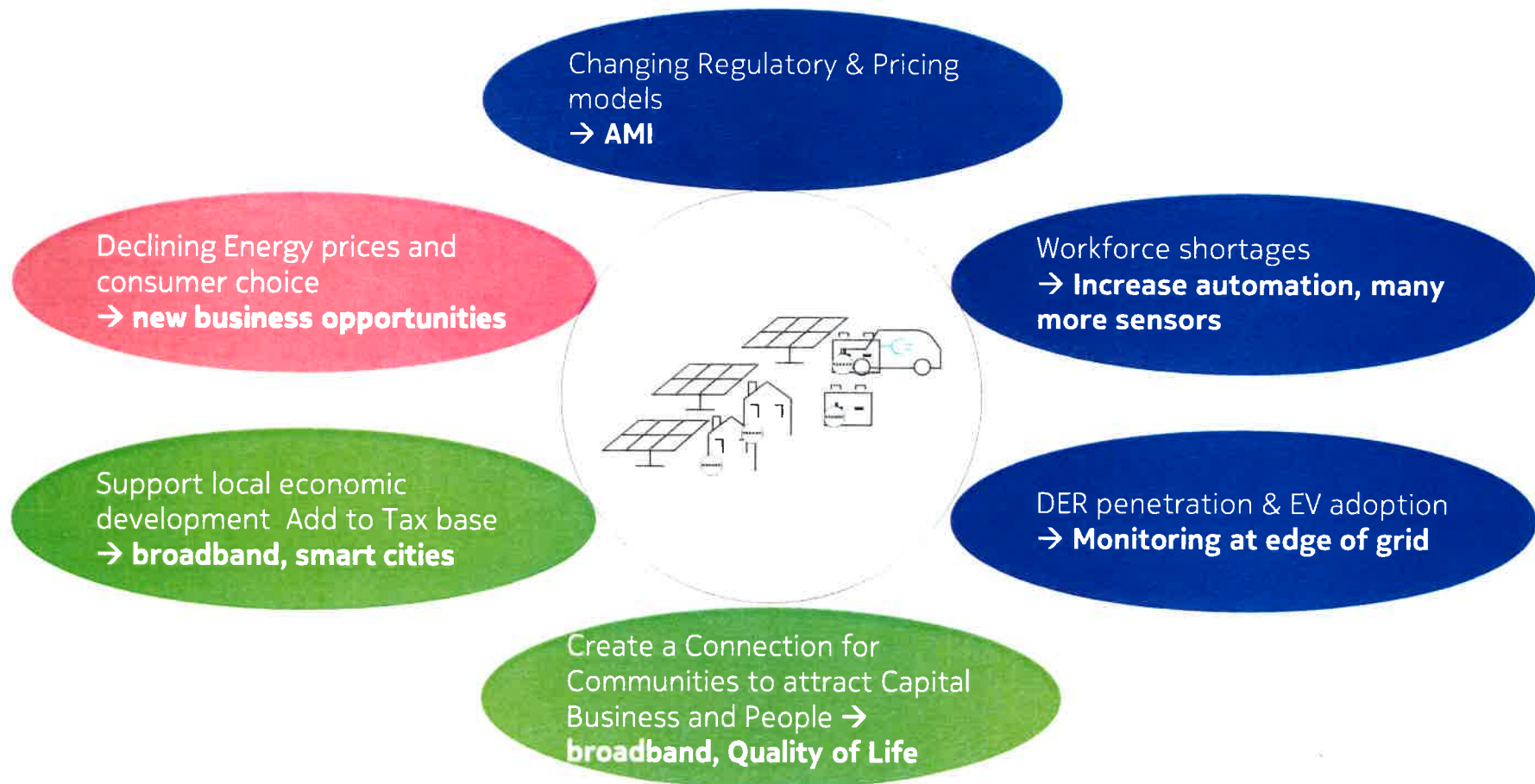
Eco-packaging

100% organic

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NOKIA

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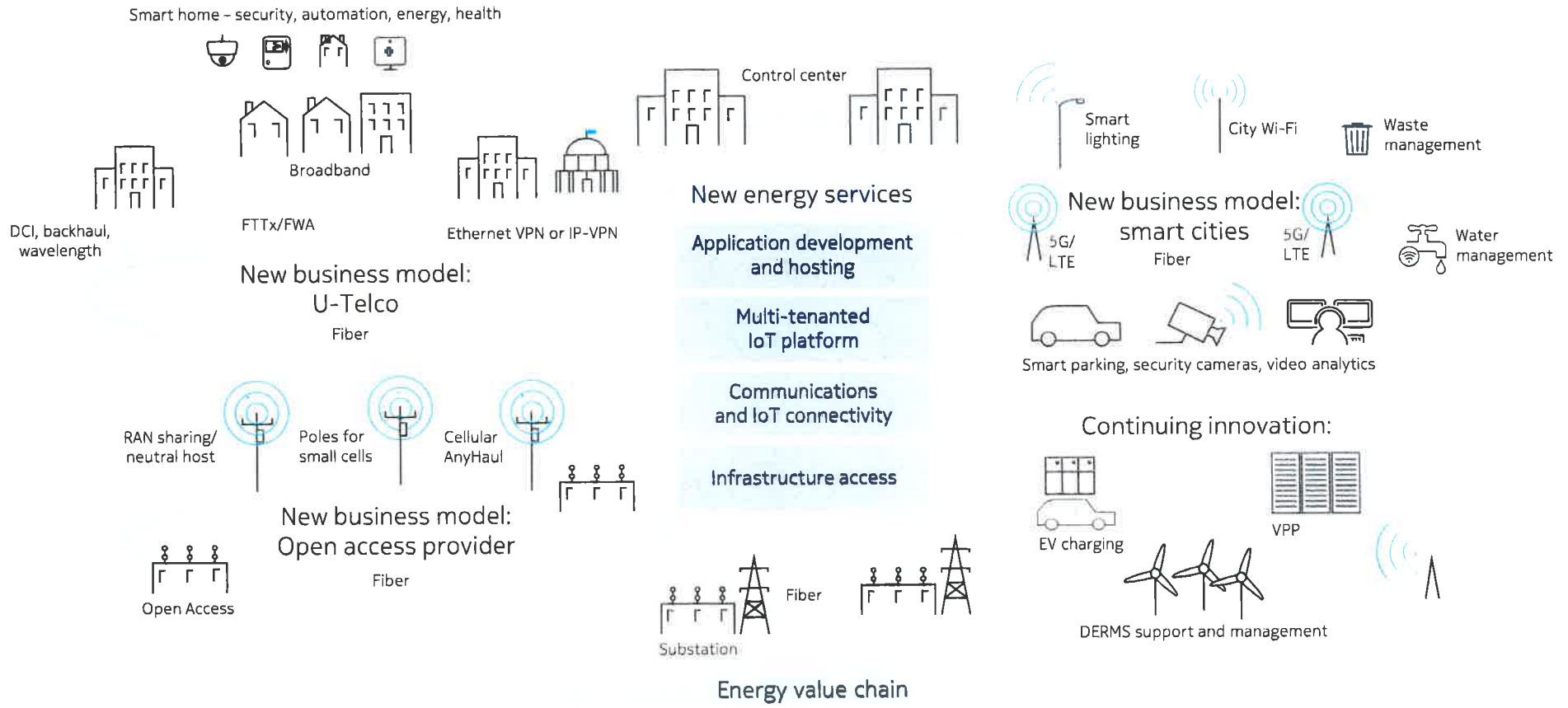# Fiber access for Utility and Municipal Broadband transformation

Michael Brayen, Community Broadband– North America

09 November 2021

The Utilities and Municipal business challenges

Changing Regulatory & Pricing models
→ **AMI**

Declining Energy prices and consumer choice
→ **new business opportunities**

Workforce shortages
→ **Increase automation, many more sensors**

Support local economic development Add to Tax base
→ **broadband, smart cities**

DER penetration & EV adoption
→ **Monitoring at edge of grid**

Create a Connection for Communities to attract Capital Business and People →
broadband, Quality of Life

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New services, revenues, and Infrastructure to Attract Business & People

Smart home – security, automation, energy, health

Broadband

DCI, backhaul, wavelength

FTTx/FWA

Ethernet VPN or IP-VPN

New business model: U-Telco
Fiber

RAN sharing/ neutral host

Poles for small cells

Cellular AnyHaul

New business model: Open access provider
Fiber

Open Access

Control center

New energy services

Application development and hosting

Multi-tenanted IoT platform

Communications and IoT connectivity

Infrastructure access

Substation

Fiber

Energy value chain

Smart lighting

City Wi-Fi

Waste management

New business model: smart cities
5G/LTE   Fiber   5G/LTE

Water management

Smart parking, security cameras, video analytics

Continuing innovation:

EV charging

VPP

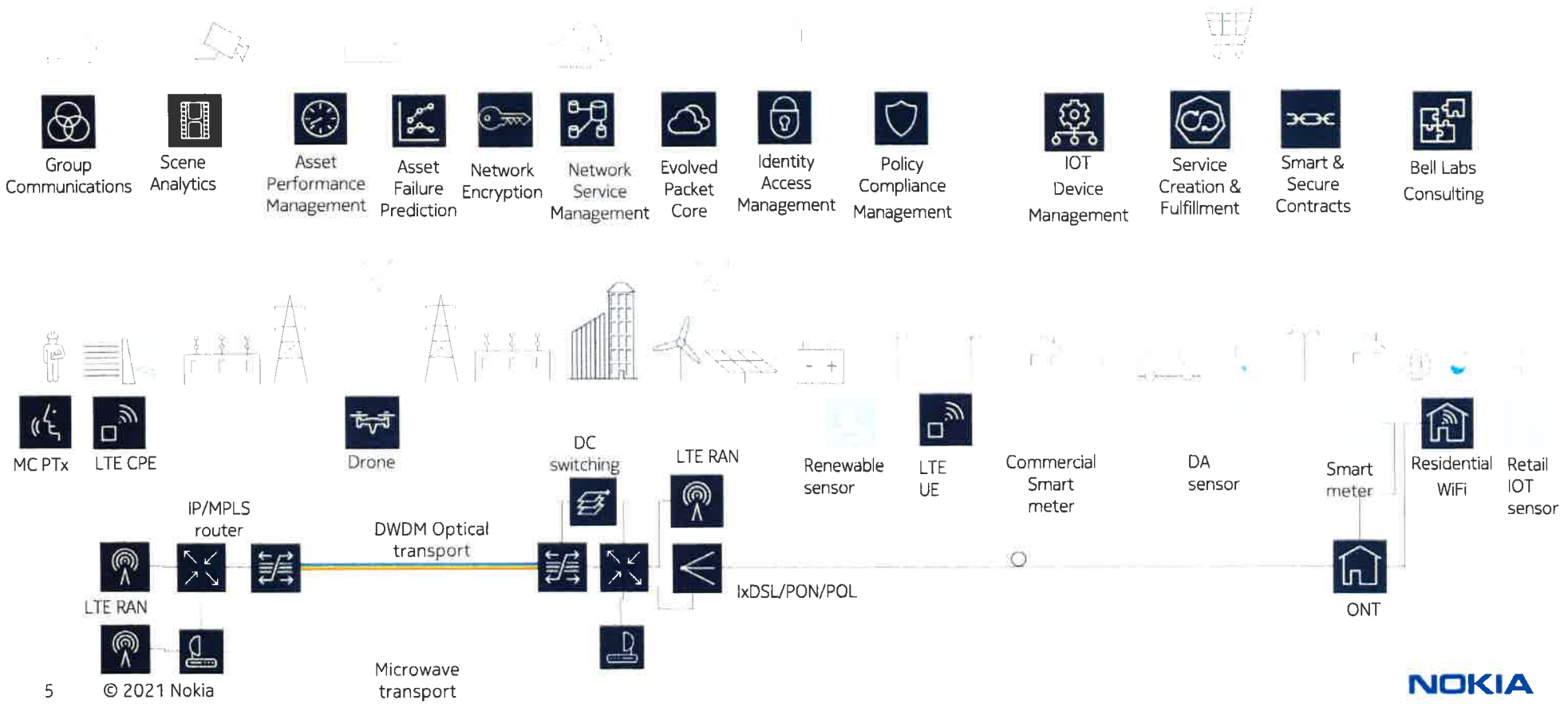DERMS support and management

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For Utilities: Pervasive fiber connectivity
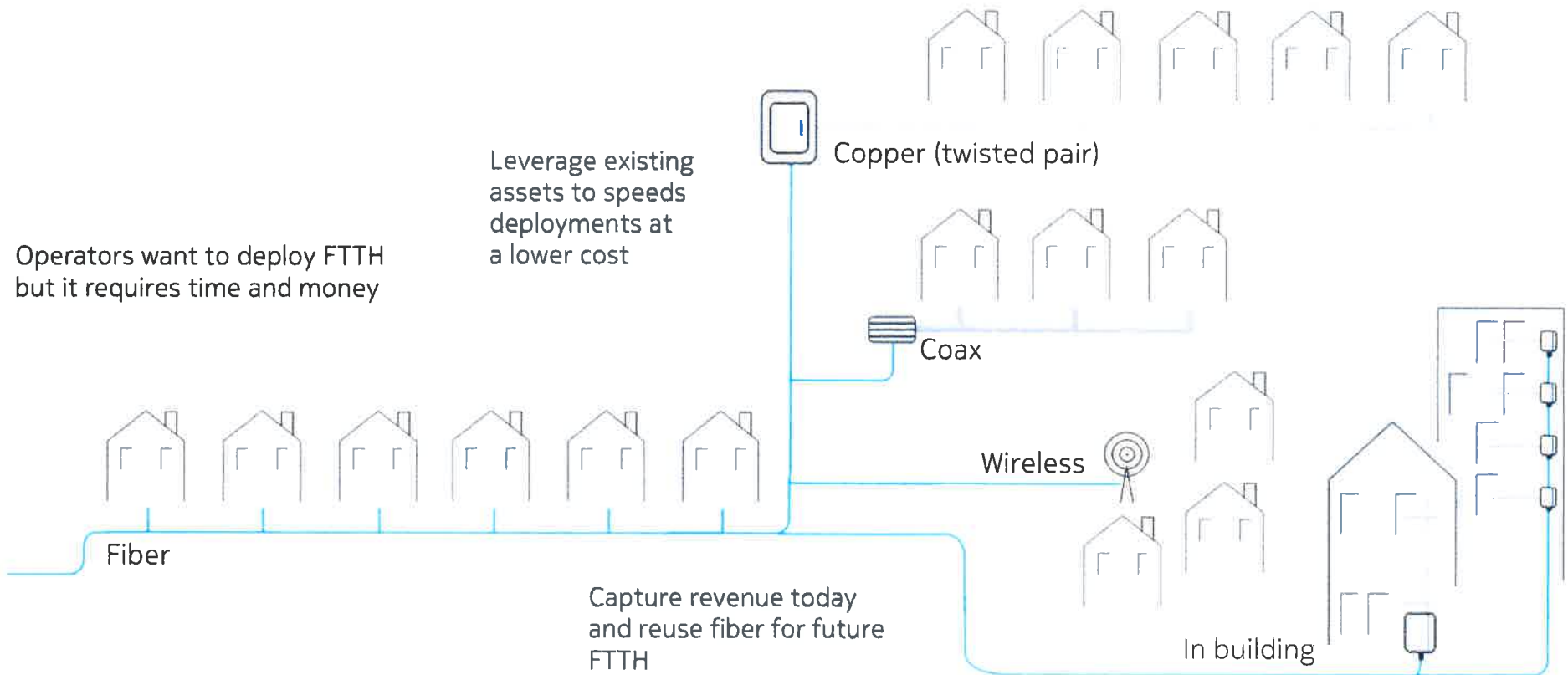## End-to-end GPON solution for grid operations
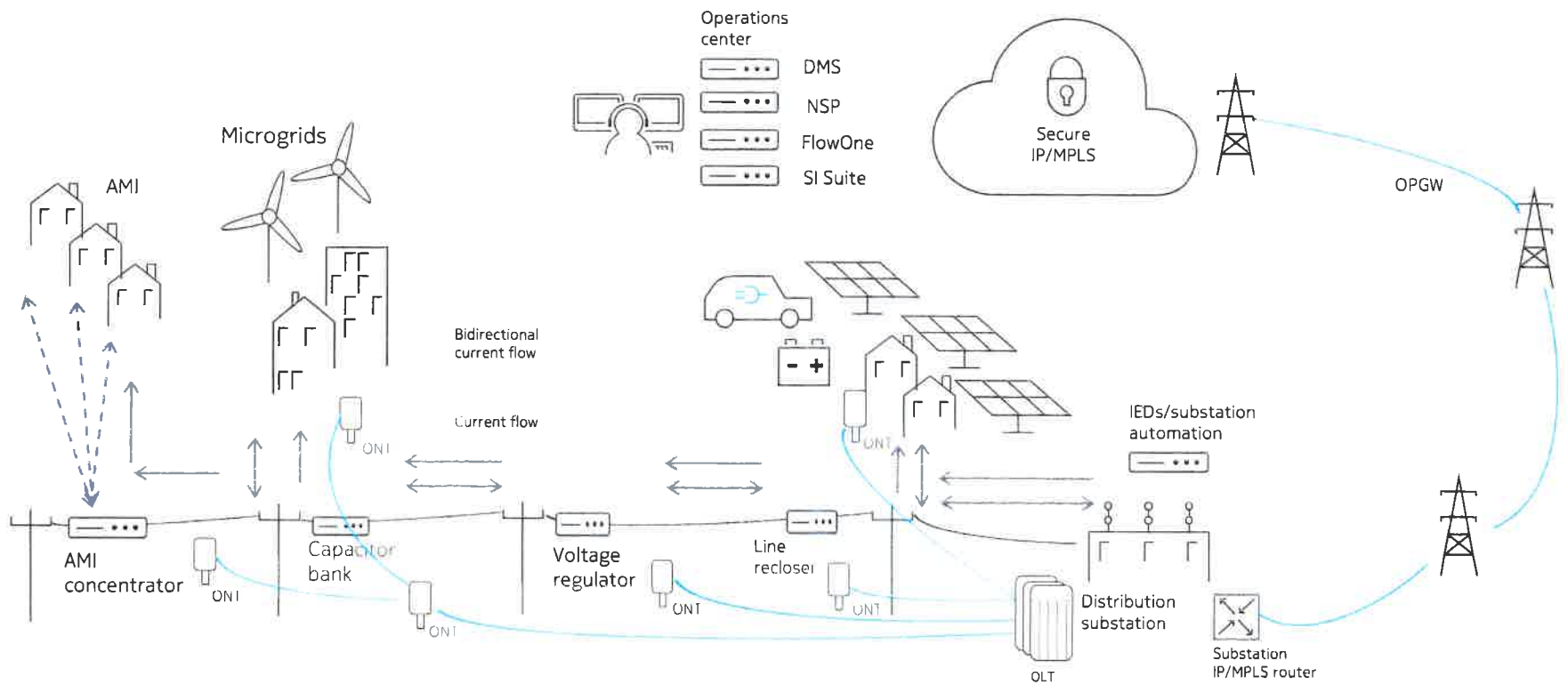
**NOKIA**

Nokia's Power Utility -Use Case Driven- Solutions

Blueprint for NOKIA End to End Network Infrastructure, devices, software & Services

Group Communications | Scene Analytics | Asset Performance Management | Asset Failure Prediction | Network Encryption | Network Service Management | Evolved Packet Core | Identity Access Management | Policy Compliance Management | IOT Device Management | Service Creation & Fulfillment | Smart & Secure Contracts | Bell Labs Consulting

MC PTx | LTE CPE

Drone

DC switching | LTE RAN | Renewable sensor | LTE UE | Commercial Smart meter | DA sensor | Smart meter | Residential WiFi | Retail IOT sensor

IP/MPLS router | DWDM Optical transport

LTE RAN

IxDSL/PON/POL

ONT

Microwave transport

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For Communities: Nokia offers flexible adoption of technologies
Combine fiber, copper, coax, and wireless for ubiquitous ultra-broadband

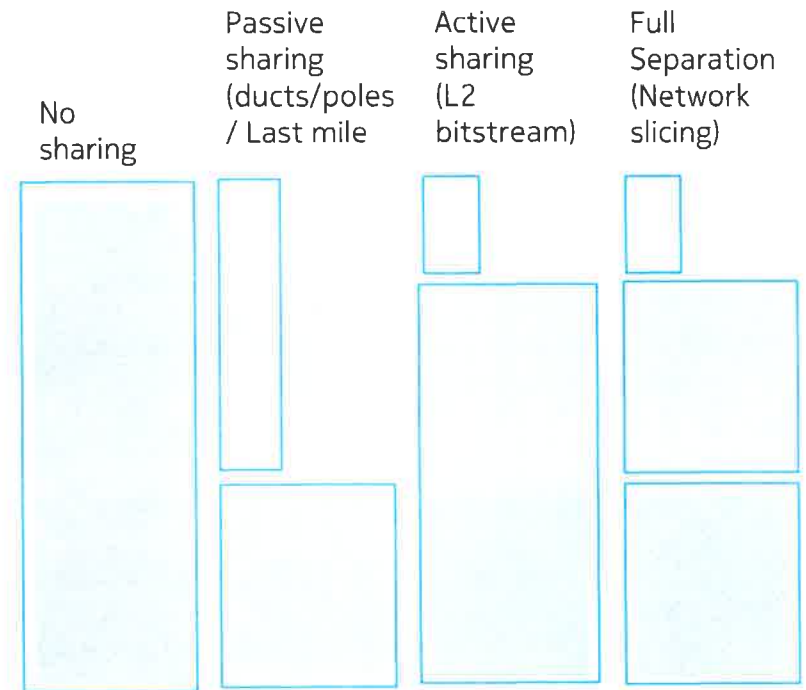Copper (twisted pair)

Leverage existing
assets to speeds
deployments at
a lower cost

Operators want to deploy FTTH
but it requires time and money

Coax

Wireless

Fiber

Capture revenue today
and reuse fiber for future
FTTH

In building

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The Nokia Solution Set(s) support full flexibility for all service delivery models
Depending on the business models (Open Access vs Full Service)
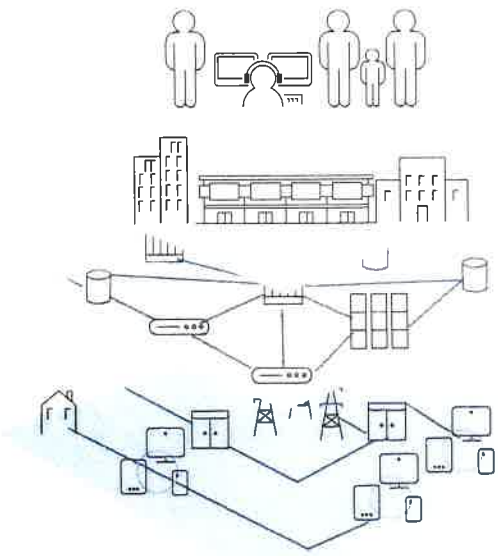
Retail service
Residential, public, business servcies

Active layer
Network equipment, business and operations

Passive infrastructure
Ducts, sewers, poles, dark fiber, wavelength

	No sharing	Passive sharing (ducts/poles / Last mile)	Active sharing (L2 bitstream)	Full Separation (Network slicing)

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What are some of the utility and community operations need

Transmission Operators
• Point-to-point communications
• Very high reliability
• Latency and uptime are critical

Distribution Operators	Municipalities
• Point-to-multipoint communications, to manage growth of:
• Automation ➔ thousands of sensors and controls
• Smart Metering and energy management in user premises
• Electric Vehicle (EV) charging points
• Small scale renewables

p2p   p2p   p2m
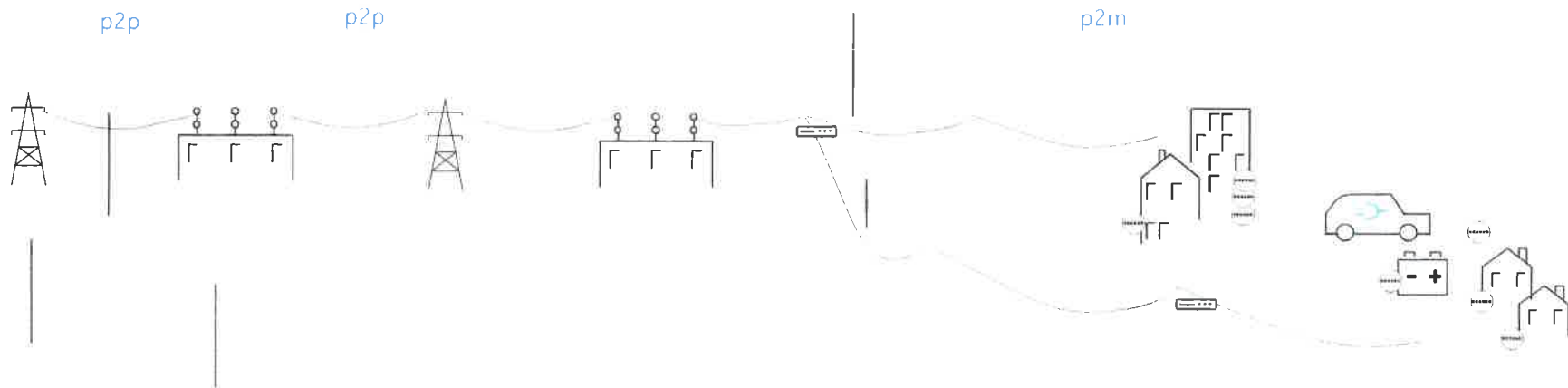
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The Nokia solutions that fit Utilities and also serve their Community of Interest
## Nokia Offers the Full Range of Products to support these solutions
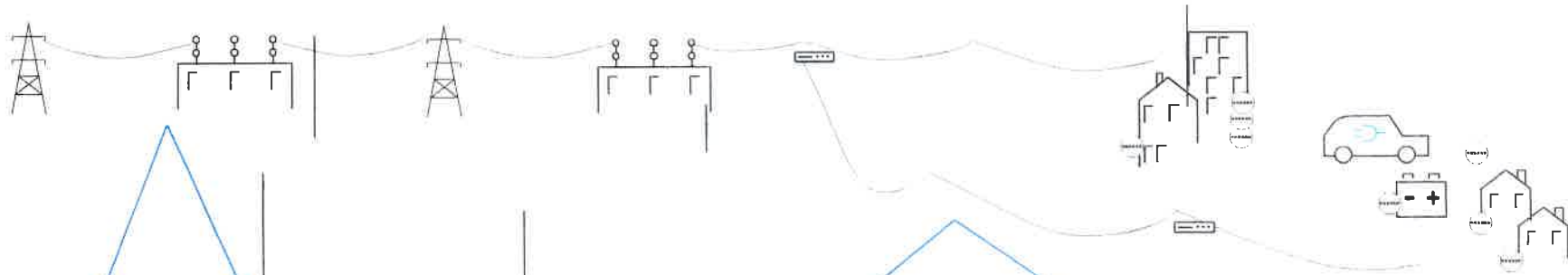
- **Optical/WDM** and **IP/MPLS** for highly reliable, low latency control circuits
- **Private LTE** for mobile workforce
- **Analytics** for xxx
- **Microwave** where fiber is not feasible
- Easy to use **management platforms**

- **XGS-PON** for reliable fiber access to each pole, IED, meter and home
  - System management and control
  - Broadband
- **Fixed Wireless Access** (4G or 5G) for hard-to-connect locations
- **Private LTE** or **p5G** for mobile workforce
- **IP/MPLS** for aggregation and low latency control
- **Microwave** for backhaul

Distribution and municipalities

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Use cases which the Utilities will recognize
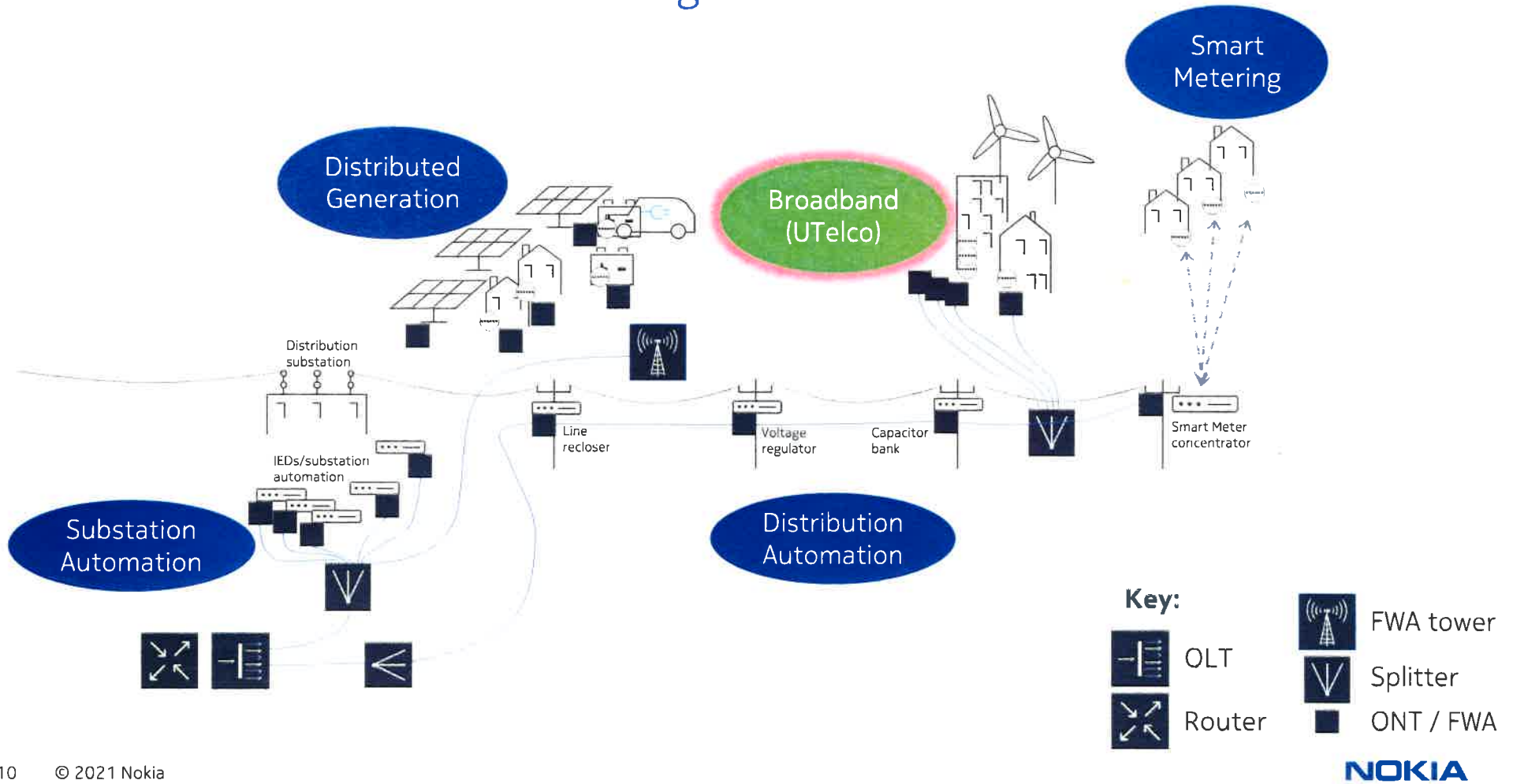
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Nokia Broadband Planning Portfolio Overview for Educating Utilities and Municipalities

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Broadband makes the smart grid and Municipal business case(s) work

Distribution Automation for Utilities within urban areas requires a large Capex investment

The payback is not necessarily recognisable at this small case

- The upper graph is how a small US municipality saw the business case using GPON for smart grid only

Adding broadband can completely transform the case and the Community

- The lower graph is for the same muni and includes broadband using the same infrastructure

Stand alone smart grid cash flow over 20 years

Broadband plus smart grid cash flow over 20 years
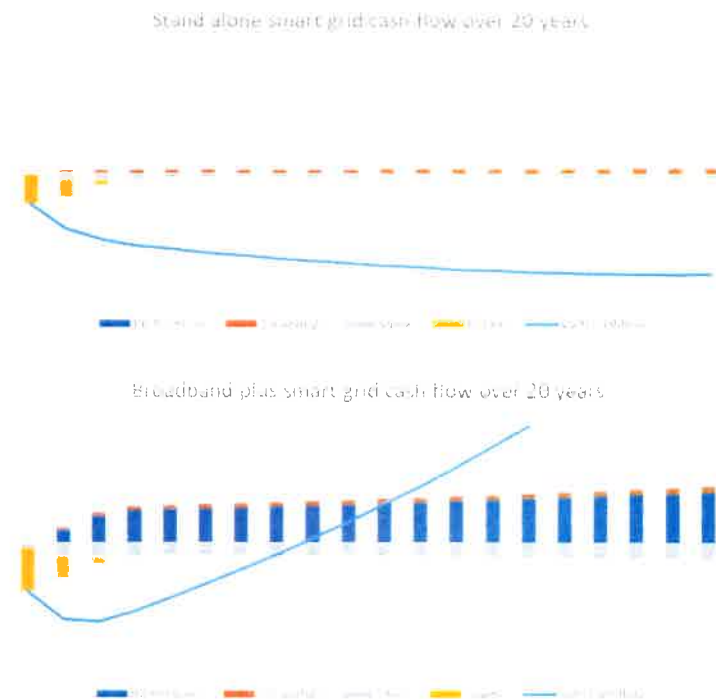
Source: Nokia business case for a small US muni using GPON

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Examples of Nokia's Worldwide and North American experience

Retail service
Residential, public, business services

Active layer
Network equipment & operations

Passive layer
Ducts, poles, dark fiber, wavelength

Vertically Integrated | Passive & Active Wholesale | Active Wholesale

Chattanooga, US

Wheeeeeeeeeeee!
The fastest Internet available
epb Fiber Optics

1st Gigabit city in US

47% Take rate | **2,800** New jobs

300M/300M	at 52€
1G/1G	at 61€
10G/10G	at 269€
Bundles :	
Smart Wi-Fi (1G)	at 70€
Best Value	at 130€

Denmark

norlys

Norlys is conglomeration of Eniig (150k), SE (80k) and Stofa (400k users)

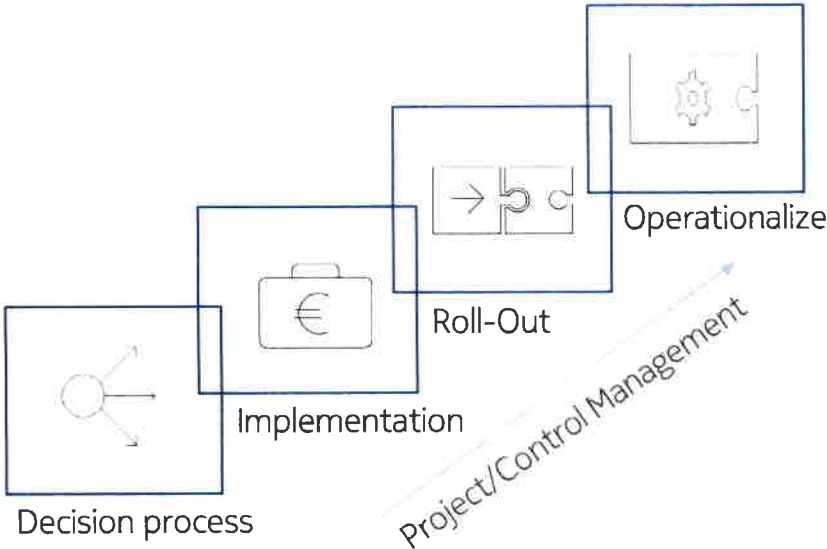|	
20M/20M	at 33€
100M/100M	at 43€
300M/300M	at 50€
1G/1G	at 65€
Bundles :	
Smart Wi-Fi incl. on 300M/1G	

Italy

✓ Wholesale-only operator (passive and active)
✓ Shareholders : 50% Enel (electricity prov) 50% Cassa Depositi
✓ Targeting Fiber-5G convergence

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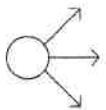# Nokia utility references

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Nokia Utility Broadband Services

Decision process

Implementation
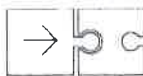
Roll-Out

Operationalize

Project/Control Management

Broadband Introduction Services to Educate and Assist

- Optimized ROI through decision process support and business modeling

- RF planning support

- Design and integration into existing customer network and operations

- Automated WPON home units activation

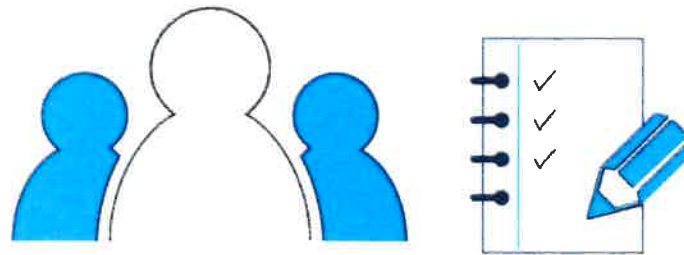- Maximum ROI, fastest time-to-market, improved quality of experience

Select the right strategy

Define solution rrequirements, design and integration

Test & Validate solution

Implement large scale deployment

Operationalize the solutions

1.5x
Faster to market

>95%
Best evolution-path accuracy

3x
Less roll-out errors

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End to End Customer Journey (B2B2C)

Learn
- Respond to campaigns
- Multi channel learning journey
- Browse offerings

Purchase
- Recommendations
- Availability & compatibility
- Offer configuration
- Checkout

Get
- Self serve - buy
- Confirm order
- Contract sign
- Setup install
- Activation
- Order tracking

Use
- Community
- Usage analytics
- Service notifications
- Upsell, cross-sell, & renewals

Pay
- Billing inquiry
- Payment history
- Payment method updates

Support
- Proactive Resolution
- Identity Management
- Knowledgebase
- Provide feedback

Change
- Move home
- Subscription changes
- Upsell & add-ons

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