The Path to Net Zero for ICT Requires Technology Innovation

27 June 2021

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Informa Tech research, commissioned by Huawei

Technology and nature must coexist harmoniously

Global economic growth needs green energy for a sustainable future

Global economic growth has increased greenhouse gas (GHG) levels in the atmosphere, notably CO_2, because of a heavy reliance on fossil fuels such as oil and coal. To keep climate change within controllable limits, a key global challenge is to reduce GHG emissions without negatively impacting economic growth. To achieve this, governments and industry leaders must take immediate countermeasures, such as reducing fossil fuel usage and switching to renewable sources of energy, such as solar, wind, and tidal. Failure to do so risks an environmental disaster.

Carbon emission reduction goals will be at the forefront of discussions at the United Nations Climate Conference later this year. Like the last such conference in 2015, we expect governments to set new targets for countries and industries to reduce the amount of CO_2 they emit. Discussions around these targets are likely to focus on specific commitments for countries, industries, and companies to achieve carbon neutrality – something many have already committed to.

Governments set CO_2 reduction targets

To promote carbon emission reduction in industrial sectors, at the governmental level, carbon tax policies are being implemented to encourage the transition to greener energy sources by imposing a cost on CO_2 emissions that companies emit. Some countries are moving to emissions-based trading systems, which set a limit on the total level of GHG emissions an industry can emit. Companies with low emissions can sell their surplus emission allowances to other companies that emit more than their allowance permits.

According to the World Bank, 40 countries have already implemented carbon tax regimes. In Europe, Denmark, Finland, Germany, Ireland, Italy, the Netherlands, Norway, Slovenia, Sweden, Switzerland, and the UK each have carbon tax regimes, while some parts of the US and Canada have also implemented a form of carbon tax.

There are also early signs that governments are looking at potential policy approaches to reduce CO_2 emissions, specifically by network operators. In December 2020, the French regulator, ARCEP, launched a proposal to incorporate environmental factors in its telecom network performance indicators in 2021. At the pan-European level, the Radio Spectrum Policy Group is debating what concrete actions, related to spectrum management, it should recommend combatting climate change. Moves such as these indicate that network-related emissions are moving onto governments' radars. We expect telecom operators will increasingly be required to publish emissions-related data and will be further encouraged to reduce their emissions through sector-specific regulation.

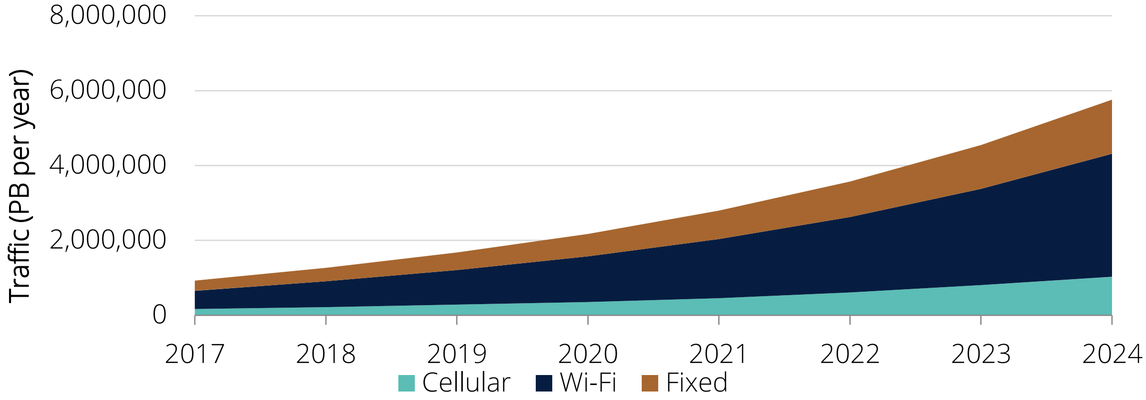
What does this mean for the ICT sector? While many leaders are putting in place measures to reduce their CO_2 emissions, some in the ICT industry have yet to formulate a plan. Leaders are not only being good corporate citizens, they are also seizing the opportunity to reduce the amount they spend on electricity. Energy efficiency is not only good for the planet, it can also be good for the bottom line.

Digital market expansion drives ICT sector's energy needs

As well as carbon emission guidelines from governments, all those in the ICT industry are facing another type of pressure from their markets: an explosion in the demand for digital services. In the past decade in particular, digitalization has increased as business and consumer activity moves online more and more. Looking at the consumer market alone, the growth in data traffic is being fueled by the booming demand for digital content and services. People want to access these services more frequently and for longer periods of time each day. According to Informa Tech data (see Figure 1), global consumer data traffic from cellular and fixed broadband networks will grow at a 29% compound annual growth rate (CAGR) from 2018 to 2024. This will reach 5.8 million petabytes (PB) of data in 2024 – the equivalent of every person on the planet uploading over 6,700 photos per day – up from around 1.3 million PB in 2018. Within cellular, total traffic is expected to grow by a factor of nearly five times over the same period.

Communications have moved beyond simply connecting people. Today, "always on" access to an expanding range of digital services is seen as a basic need. As enterprises and industry digitize more processes and consume more digital services, they will see a similar surge in data traffic that will place significant demands on ICT infrastructure.

Figure 1: Global data traffic from cellular and consumer fixed broadband networks, 2017–24



Source: Informa Tech's Network Traffic Forecast: 2019–24

The ICT industry therefore faces a challenge to meet increased demand for data and digital services while meeting its obligation to curb carbon emissions. Guidelines from the ITU and partners in 2020 stated that the ICT industry should reduce its emissions by 45% by 2030 to comply with the 2015 Paris Agreement. These guidelines are incorporated into the ITU Standard L.1470 ("*GHG emissions trajectories for the ICT sector compatible with the UNFCCC Paris Agreement*"), which cover fixed, mobile, and data center operators.

Green strategies for the ICT industry's sustainable development

As demand for ICT services increases, more electrical energy will be required to meet it. However, consuming more electrical energy generated from fossil fuels will increase carbon emissions. This contradiction is prompting the ICT industry to set green strategies to ensure its sustainable development.

Thanks to strong technical progress, the ICT industry has an increasingly sophisticated range of options to meet its growing needs. Using green energy (e.g., solar photovoltaic) is arguably the biggest opportunity for ICT players to reduce their greenhouse gas emissions. In addition, the industry is shifting focus from reducing absolute energy consumption to enhancing energy utilization efficiency – that is, to optimize energy usage so that every bit of energy could be used precisely to support the current digital service demand, thereby reducing CO^2 emissions while potentially lowering operating expenses.

Recent responses within the ICT industry clearly highlight the growing trend of adopting green strategies. Informa Tech's Environmental, Social, and Governance (ESG) Service Provider Index, which tracks relevant announcements from the largest 15 service providers by revenue, finds that telecom operators are already becoming increasingly active in each of these areas. The research identified that green energy accounts for the highest number of individual measures, equivalent to 25% of the total ESG initiatives we tracked. Indeed, all 15 service providers covered in the research announced at least one green energy initiative over the research period with commitments targeted mainly at sourcing energy from renewable sources and eliminating carbon emissions within a specified time, often going beyond government-set targets. We expect that more ICT companies will adopt green energy strategies to support sustainable growth and ensure they comply with increasingly strict government regulation.

ICT carbon reduction strategies to achieve green targets

The roadmap targets a low carbon telecom industry

Leaders in the telecom industry have realized the upcoming contradiction and played early and active roles in finding countermeasures. In 2000, telecom operators including BT, Deutsche Telekom, and Orange were founding members of the United Nations Global Compact, an accord to encourage businesses worldwide to adopt sustainable and socially responsible policies. In 2016, the mobile sector became the first industry vertical to commit to the UN's Sustainable Development Goals, which promote climate action and responsible consumption. Major telecom operators provide excellent disclosure of their CO_2e emissions through initiatives such as the Carbon Disclosure Project (CDP).

Leading operators, including Vodafone, BT, Orange, Deutsche Telekom, Telefónica, Verizon, and KDDI, have pledged a date by which they will reduce their carbon emissions to net zero, while many operator climate commitments also include sourcing energy from carbon-neutral suppliers. Some service providers, such as China Mobile, are building their own renewable energy power facilities, while many, including AT&T, Deutsche Telekom, Orange, Verizon, and Vodafone, have struck long-term renewable power purchase agreements with green energy providers. Data centers are becoming more sustainable through advanced cooling techniques that reduce the amount of energy they need to run.

Driven by the advanced cases in the industry and actual need for a green and sustainable future, more and more operators are now voluntarily setting goals to reach carbon neutrality or net-zero carbon emissions, as shown in Table 1. To reach these goals many operators are following pathways outlined by the Science Based Targets Initiative (SBTi), a partnership between CDP, the United Nations Global Compact, World Resources Institute (a non-profit research organization), and the World Wide Fund for Nature (a charity).

Table 1: Carbon-neutral target announcements by telecom operators

Operator	Announcement
AT&T	AT&T aims to be carbon neutral in its global operations by 2035.
BT	BT reaffirmed its commitment to be net zero by 2045.
Deutsche Telekom	Deutsche Telekom aims to target group-wide network power from 100% renewables by 2021. Deutsche Telekom aims to reduce CO_2 emissions per customer by 25% by 2030 compared to 2017, and to reduce CO_2 emissions of the company by 90% by 2030.
KDDI	Aims for net-zero CO_2 emissions by 2050.
NTT DoCoMo	DoCoMo aims to increase its usage of renewable energy to 30% of total energy use by 2030.
Orange	Orange aims to be carbon neutral by 2040. 50% of its energy will come from renewables by 2025.
Telefónica	Telefónica will reach its target of net-zero emissions in its four main markets by 2030 and for the entire group by 2050.
Verizon	Verizon plans for 50% of its total electricity usage from renewables by 2025 and plans to become carbon neutral by 2035.
Vodafone	By 2030, Vodafone will eliminate all carbon emissions from its own activities and from the energy it purchases and directly uses. Vodafone also pledged that by 2030 it will halve carbon emissions from joint ventures, all supply-chain purchases, the use of products it has sold, and business travel. By 2040, Vodafone will have eliminated emissions completely. Vodafone's European network will be powered by 100% renewables by July 2021.

Source: Informa Tech

Energy reduction initiatives of telecom operators

Following the general carbon reduction trends in the ICT industry, telecom operators have started taking initiatives to reduce carbon emissions from their network facilities. Table 2 gives various examples of energy reduction initiatives drawn from the environmental, social, and corporate governance reports of telecom operators. As an indication of the relative importance of the categories shown, Telefónica says that of the savings it has achieved through energy efficiency projects, 69% relate to network transformation, 6% to cooling, 4% to power-saving features, 2% to power, 1% to lighting, and the remaining 19% to other categories. As can be seen, most of the examples we show in the table relate to decommissioning obsolete equipment, which fits with the network transformation topic. Sleep/standby mode is the main example of power-saving features that operators are employing. Renewable energy generation does not improve energy efficiency but can help operators meet their goals of carbon reduction.

Table 2: Telecom energy reduction initiatives

Category	Examples
Network transformation	AT&T reduces unused capacity, unnecessary energy expense, and real estate, by replacing energy-hungry network equipment with energy-efficient hardware that runs virtualized network functions.
	China Telecom says it has continued to optimize network infrastructure and resources, eliminating inefficient, old equipment. The company implemented new technologies of energy saving and emission reduction for facilities and equipment such as internet data centers and air conditioners.
	Deutsche Telekom says it is updating network infrastructure, for example, by migrating to IP technology and removing equipment that is no longer needed. Deutsche Telekom is using energy-efficient technology not just for networks, but also for lighting, monitoring, and – most importantly – cooling.
	NTT says it has reduced electricity usage by focusing on consolidating telecom equipment and replacing equipment with more energy-efficient versions.
	Telefónica is replacing copper with fiber optic for fixed-line access, renovating its air-conditioning and power equipment, and shutting down legacy networks. Telefónica claims FTTH is 85% more energy efficient than the copper network and targets 100% of retail customers on fiber before 2025.
	Verizon has reduced carbon intensity by moving to more energy-efficient technologies, installing energy-efficient systems, and employing energy management best practices at its facilities.
Cooling	America Movil is using outdoor air-cooling to reduce the need for air conditioning. In Peru the company has increased the working temperature from 23°C to 27°C to reduce the need for air conditioning.
	China Mobile has applied liquid cooling technology to base stations in Jiangsu province, leading to a 35% energy saving compared with air-based cooling.
	Telefónica is using outside air to cool equipment instead of air conditioning where possible.
Sleep/standby mode	AT&T allows a subset of a cell site's capacity to temporarily go into sleep mode. 5G technology will yield further enhancements to this capability.
	Orange says it has been activating "standby" mode on networks and using AI to optimize the deployment and operation of infrastructure.
Replacing AC with up to 400 VDC (HVDC)	NTT is working to enhance air conditioning and power supply facilities by introducing optimization systems and by using high-voltage direct current instead of alternating current (AC).
Network sharing	Orange says it has reduced overall electricity usage by telecom operators in its markets by sharing infrastructure such as power and cooling systems.
Renewable energy generation	KDDI is implementing "tribrid" base stations that supply three kinds of electric power depending on time and weather: ordinary grid power, power generated by solar panels, and off-peak power stored in batteries.
	Telefónica is reducing the energy consumption of some cell sites by adding solar panels. These supply the base station during daylight and store any surplus energy in batteries for use at night. Once the battery is exhausted, the cell is supplied by the electric grid or a diesel generator.

Source: Informa Tech based on company ESG reports

Navigating to carbon reduction targets

Measuring the current greenness of ICT

Although operators in the ICT industry have raised similar goals toward a greener future, the actual conditions to realize it could be highly different. For example, wireless and fixed networks and data centers vary widely based on the region, the local climate, and other company-specific factors. Therefore, the approaches to carbon reduction goals will differ greatly between CSPs.

Given the complexity and diversity, a comparable measure across operators of the greenness of their networks is desirable. By measuring the greenness of an ICT facility, it is also possible to make the decarbonization effort comparable between regions. Below we discuss different approaches from standards bodies and individual operators to measure the "green" performance of ICT network infrastructure.

ETSI ES 203 228: Mobile network data energy efficiency

The European Telecommunications Standards Institute (ETSI) is a nonprofit telecommunications standardization organization approved by the European Commission. In 2015, ETSI drafted its first document that deals with the definition of metrics and methods to measure energy efficiency performance of mobile radio access networks.

ETSI has defined a key metric – mobile network data energy efficiency ($EE_{MN,DV}$) – expressed in bits/joules. As shown below, this is the ratio between the performance indicator (DV_{MN}: defined as the data volume delivered by the equipment of the mobile network during the time frame T of the energy consumption assessment) and the energy consumption (EC_{MN}: defined as the sum of the energy consumption of equipment included in the mobile network) over a certain time period:

$$EE_{MN,DV} = \frac{DV_{MN}}{EC_{MN}}$$

In ETSI's standard, the minimum duration of measurement is one week, while monthly and yearly measurements are also recommended.

TIM: Network carbon intensity

Since 2017, TIM (formerly known as Telecom Italia) has been measuring the "carbon intensity" of its business by using an indicator that establishes a relationship between the service offered to its customers and the company's direct and indirect operational CO_2 emissions (referred to as scope 1 and scope 2 emissions by the SBTi).

TIM's decarbonization efforts have resulted in a continuous decline in its carbon intensity. According to the company, network carbon intensity fell from 10.6 kg CO_2/terabit in 2017 to 7.05 kg CO_2/terabit in 2019—slightly below the target for that year of 7.54 kg CO_2/terabit. The company targets a level of 4.26 kg CO_2/terabit by 2025.

Deutsche Telekom: Carbon intensity ESG KPI

Deutsche Telecom has been reporting its carbon intensity KPI since 2016. This measures the mass of CO_2 equivalent emitted relative to the transmitted data volume of the network. The KPI considers total CO_2 equivalent emissions for all energy sources—fuel, gas, district heating, and electricity. The definition is comparable to the SBTi scope 2 coverage. The data volume includes all transmitted IP data volumes (including VoIP, internet, and IPTV).

From the ESG KPI measurement in 2020. The entire Deutsche Telekom group emitted 2,466 million kg of equivalent CO_2 and provided 105.9 million terabytes of IP data service volume. The overall annual ESG KPI therefore is 23 kg CO_2/terabit.

Defining network carbon intensity

In a variety of vertical industries, companies tend to use absolute metrics to assess their progress on decarbonization. Absolute emission reduction goals are also favored by environmentalists to measure the overall carbon impact a company has on the environment. This approach may work for many of the verticals whose business volume only vary moderately; however, for the overall ICT industry, absolute carbon emission may not be the best metric to assess its progress on decarbonization, as the usage of mobile networks, fixed networks, and data centers has expanded rapidly around the world in the past decade as society has become more digitalized. As such, decarbonization efforts in the ICT industry may not be fully appreciated if we only look at the absolute reduction. Instead, we believe it is fairer for ICT infrastructure operators to look at their decarbonization progress relative to the amount of data they process.

To create a link between carbon emissions and data traffic, the relationship between carbon emission and primary and secondary energy consumption needs to be understood. Different from direct emissions described in scope 1, the carbon emissions generated by ICT infrastructure devices have certain particularities:

- Most of the energy consumed comes from local grid electricity. A small proportion of energy comes from backup diesel generators
- The services provided by ICT infrastructure to the society relate to the storage, transport, and processing of data. Due to the rapid expansion of network coverage and generation upgrades, the data flow handled by each network device has been increased significantly over the years.

The current carbon indicators used by leading operators are mostly expressed as the ratio between carbon emission (or energy consumption) and the amount of data carried (or the number of customers). Absolute carbon reduction targets are also used. However, the degree to which operators use green energy is not considered. As such, we propose an index that meets the following requirements:

- It should include the carbon emissions related to the electricity consumption of all ICT devices
- To minimize the daily, weekly, and seasonal variations in ICT demand the index measurement should cover a long period of time
- It should include the total amount of digital services provided during this period, measured in bytes of data
- It should reflect the positive impact of using sustainable energy and high-energy efficiency equipment.

We call this index Network Carbon Intensity (NCI) and define it as follows:

"The ratio of the carbon quantity emitted by all equipment due to electricity consumption of a systematized network facility within a long period of normal operation (preferably one year) to the total amount of data volume handled by the facility in the same period."

$$Network\ Carbon\ Intensity\ (kg\ CO_2e/terabyte) = \frac{Total\ Carbon\ Emission}{Total\ Data\ Volume}$$

To distinguish green energy (wind, hydro, solar, etc.) from traditional energy in terms of carbon intensity, the numerator of the above formula can be extended as follows:

$$Network\ Carbon\ Intensity = \frac{I_{carbonperkwh} \cdot (1 - \Phi_{green\ ratio})}{\eta_{energy\ efficiency}}$$

Where:

$I_{carbonperkwh}$: The mass of carbon emitted per kWh of electricity generated by the grid and auxiliary power generator using traditional energy (kg CO_2 e/kWh)
$\Phi_{green\ ratio}$: The proportion of renewable energy in the electricity consumed by the network (%)
$\eta_{energy\ efficiency}$: The ratio between the total amount of data services of a network and its total consumed electrical energy in the same period.

The $I_{carbonperkwh}$ of each fossil fuel used in electrical power generation can be sourced from the International Energy Association (IEA) or local energy authorities. Assuming the electricity consumption of a certain network is sourced from "n" types of fuels' combustion (including traditional power plant and self-generation), the overall $I_{carbonperkwh}$ of this network can be calculated through the formula below:

$$I_{carbonperkwh} = \sum_{i=1}^{n} I_{fueltype\_i} \cdot \Delta_i$$

Where:

$I_{fueltype\_i}$: The mass of carbon emitted per kWh of electricity generated from combustion of a certain type of fuel.
Δ_i: The percentage of the fuel used in electricity generation (by electricity output).

The overall $I_{carbonperkwh}$ in ICT is estimated to have been 0.63 kg CO_2 e/kWh in 2015, including supply chain and grid losses. To achieve the ITU's trajectory for the ICT industry, the carbon intensity must reduce to 0.35 kg CO_2 e/kWh in 2025 (a 44% reduction) and 0.20 kg CO_2 e/kWh in 2030 (a further 43% reduction) with a goal of net zero by 2050.

As to $\eta_{energy\ efficiency}$, this is the ratio between the data traffic of a network and its total energy consumption. It is expressed as:

$$\eta_{energy\ efficiency} = \frac{D_{totalnetwork}}{E_{totalnetwork}}$$

Where:

$D_{totalnetwork}$: The total amount of data that the network serves in a fixed period

$E_{totalnetwork}$: The total electrical energy from grid or auxiliary generators consumed by the network system in the same period.

The calculation of NCI value is mainly applicable to the green decarbonization performance of network facilities. Given the huge gap in functions between different types of network facilities, and varying availability of sustainable energy, it is not suitable for a horizontal comparison between different types of network facilities; nor is it suitable for comparisons between similar network facilities in different regions. However, it is suitable for comparison between the same type of network facilities across different operators in similar geographical or grid environments. It is also a suitable benchmark to track over time for a particular operator.

The green network assessment approaches of Deutsche Telekom and TIM are quite similar to the definition of NCI. The NCI value for the entire Deutsche Telekom network should be equal to its carbon intensity ESG KPI, which is about 23kg CO_2/terabyte. As for TIM, as its network carbon intensity calculation takes both scope 1 and scope 2 into account, the outcome of its calculation will be higher than the NCI approach. Assuming half of the company's annual direct/indirect CO_2 emissions are generated by network facilities, then, based on its reported target value 7.54 Kg CO_2/terabit set for 2019, its NCI value in 2019 should be around 30.16 kg CO_2/terabyte.

When it comes to a more micro and specific level of energy utilization assessment, such as certain fixed and wireless networks, or data center cases, there are existing and mature measures to make a targeted evaluation.

For example, in wireless applications, $EE_{MN,DV}$ defined by ETSI as mentioned above, is used to present data-energy efficiency. The index is defined as the ratio between total data volume and total device energy consumption in a wireless network. It represents the data-generation efficiency of a wireless network. The higher the value, the higher energy-data conversion rate the network has.

In addition, there is also a similar index defined by ITU called Site Energy Efficiency (SEE) in wireless applications, defined as the ratio between energy consumption from site devices and the total energy consumption of the whole site. This index displays what percentage of total energy consumption of one site is utilized by core functions.

In data center cases, to describe the energy utilization efficiency, Power Usage Effectiveness (PUE) is commonly used. This index is the ratio of total energy consumption to its IT energy consumption. It can intuitively present the energy utilization performance of the data center facility.

Compared with these conventional and specific indexes for energy utilization, the Network Carbon Intensity index is more applicable to a macro level of network greenness assessment. It not only encourages the reduction of auxiliary electricity consumption, but also the use of green energy sources and improving energy utilization efficiency.

Technology enablers for a greener telecom industry

To improve the NCI, operators should:

- Reduce the carbon intensity of their energy by using renewable electricity.
- Reduce their energy consumption by adopting more efficient technologies and management techniques.

Below we discuss these two broad approaches in more detail.

The switch to renewable electricity

Telecom operators are reducing the carbon intensity of their energy supply by embracing renewable energy. Given that electricity is the main energy source for telecom operators, moving to renewable sources such as wind, solar, or tidal is key. Below are some key approaches to higher renewable energy source adaptation of ICT infrastructure:

- Case 1: Purchasing electricity from renewable generators—purchasing power from grids that produce electricity from renewable sources such as solar and wind. For example, Verizon plans for 50% of its total electricity usage from renewables by 2025 and plans to become carbon neutral by 2035
- Case 2: Generating renewable energy at the cell site – Building own decentralized renewable energy installations to supply some cell sites, such as solar panels together with energy storage devices. Typically, these are small-scale deployments designed as an alternative to diesel generators as an energy supply backup in case of grid electricity outages.

Case 1: Purchasing electricity from renewable generators

The companies listed in Table 3 are all members of RE100, a global initiative bringing together the businesses from around the world that are committed to using 100% renewable electricity. RE100 is led by the Climate Group, a nonprofit organization, in partnership with the Carbon Disclosure Project. While challenges remain in sourcing renewable electricity in some countries, collaboration with members of the RE100 initiative is helping to bring improvements in supply.

European operators such as BT, KPN, and Proximus set out their targets to reach 100% renewable electricity in the run-up to the Paris Agreement signed by members of the United Nations Framework Convention on Climate Change in 2016. Since then, more operators have made commitments to use only renewable energy with some already achieving this, notably Deutsche Telekom, KPN, Proximus, and Swisscom.

Table 3: Telecom members of RE100

Company	Comment
BT	BT announced in November 2020 that its network, offices, and shops worldwide are now powered with 100% renewable electricity. The company said it will run its global operations on renewable electricity where markets allow and will purchase the remainder from neighboring markets until local solutions can be found. BT's transition to renewable electricity has been delivered by supporting the development of local renewable energy markets, with 16% of its electricity supplied through corporate Power Purchase Agreements (PPAs) and the remainder from high-quality green tariffs or, in a small number of markets, renewable certificates.
Deutsche Telekom	Since the beginning of 2021, Deutsche Telekom has been sourcing its electricity throughout the group exclusively from renewable energies. The company aims to achieve net zero for in-house emissions by 2025 at the latest. The emissions involved from the production stage to operation by the customer are also to be reduced to net zero by 2040—10 years earlier than originally planned.
KPN	All of KPN's electricity has come from renewable sources of energy since 2013. KPN only uses wind energy and electricity from biomass that does not compete with food production.
Proximus	Since 2019, all electricity consumed by Proximus has come from renewable sources.
SK Telecom	SK Holdings (which owns SK Telecom) is aiming to power its operations with 100% renewable electricity by 2030. In its Green New Deal, the Korean government has promised to provide sourcing options for companies looking to buy renewables and join RE100.
Swisscom	By purchasing certificates of origin, Swisscom already uses 100% renewable energy today. In the coming years, Swisscom wants to further increase the proportion of solar power it generates and reduce its use of fossil fuels.
T-Mobile US	T-Mobile US says it is on track to power its business and network with 100% renewable energy by the end of 2021. It is the only US carrier so far to sign the global RE100 pledge.
Telefónica	Telefónica aims to reach 100% renewable energy across its business by 2030. Currently, it is around 88% renewable with key markets Europe and Brazil already at 100%.
Virgin Media	Company aims to source 100% of its electricity from renewable sources by the end of 2025.
Vodafone Group	At the group level, Vodafone has committed to purchase 100% of the electricity it uses from renewable sources by 2025 (up from 35% in the fiscal year ending March 2020). Vodafone's European network will be powered by 100% renewable electricity no later than July 2021, creating a Green Gigabit Net for customers across 11 markets that will grow sustainably using only power from wind, solar, or hydro sources. Around four-fifths of the energy used by Vodafone's networks will be from renewable sources obtained directly from national electricity grids via PPA and green tariffs. The remaining fifth, supplied by Vodafone's landlords on buildings and other infrastructure, will be covered instead by credible Renewable Energy Certificates. Where feasible, Vodafone will also invest in self-generation on site, mostly via solar panels.

Source: Company announcements

The list above is by no means exclusive. Telecom operators that have announced targets of 100% renewable energy but have not yet joined RE100 include Telia and Turkcell. Orange and Verizon have committed to source or generate renewable energy equivalent to 50% of their total electricity consumption by 2025.

Case 2: Generating renewable energy at the cell site

To keep their mobile networks running during temporary disruptions to the electricity supply, telecom operators have traditionally relied on diesel-powered generators, particularly in developing economies where blackouts are common. While this ensures the reliability of service, the burning of diesel to generate electricity increases operators' carbon emissions. The diesel fuel itself also attracts theft, which undermines its usefulness as a backup and leads to additional expense replenishing fuel tanks. As an alternative, many operators are deploying photovoltaic (PV) solar panels at their sites. During the day, these panels generate electricity that is stored in high-capacity lithium batteries. When needed, the electricity can be drawn from the batteries to keep the cell site equipment running.

Operators that deploy PV solar generation equipment and battery storage on their cell sites can reduce their electricity bills by only consuming grid electricity during off-peak hours when prices are low. If electricity prices are high during the day, the solar PV energy can actually be used to feed the grid using a smart meter. The operator can therefore generate revenue from the electricity it produces during the day and use this to buy back electricity cheaply during the night. This electricity can be stored in the cell site battery for use during the day. By charging the battery using cheap electricity at night and discharging the battery during the day (when electricity is more expensive) the operator can make an arbitrage profit, which allows it to pay for the battery costs in less than three years, according to Huawei.

In some cases, the solar PV energy can become the main energy source for the site with grid electricity only being used at night. The solar panels can also be positioned at the site to provide shade for the shelter where the base station is housed. This has the added benefit of reducing the need for air conditioning of the shelter and associated electronics.

Operator A case study

Operator A managed to reduce its grid electricity consumption by around 50% at some sites thanks to the use of solar power. By using equipment that could be deployed outdoors instead of in an air-conditioned shelter, and by improving the efficiency of its AC-DC rectifiers, the company was able to reduce energy consumption of these sites by around 20%. By deploying solar panels, the company was able to further reduce its grid electricity consumption by another 40% leading to the overall reduction of 50%.

Improving energy efficiency of ICT infrastructure

There are many ways to improve the energy efficiency of ICT infrastructure. For example, the base station equipment that operators deploy in their networks will typically have been designed with power efficiency in mind. This includes the use of modern integrated circuit designs that produce less wasteful heat. Base stations might also use more power-efficient semiconductor materials in integrated circuits instead of the more traditional silicon.

Below we discuss some key approaches to improving the energy efficiency of ICT infrastructure:

- Case 1: Simplifying mobile cell site equipment—avoiding the need for air-conditioned shelters by mounting equipment in smaller cabinets or directly on the radio tower
- Case 2: Switching from copper access networks to optical fiber—this boosts data rates and reduces the amount of electricity consumed
- Case 3: Modularized data center construction—this saves time, cost and GHG emissions

- Case 4: Natural cooling of data centers—this reduces the amount of electricity required for thermal management.

Case 1: Cell site simplification reduces space and energy requirements

Operators worldwide face many challenges when deploying next-generation networks. Given the existence of multiple prior generations of radio access technology on their sites, many operators simply do not have enough space to accommodate the additional infrastructure for 5G. In some cases, the extra weight of the equipment may exceed the load-bearing capacity of the tower. Renting additional sites to mount new towers takes time and is expensive.

Fortunately, by improving device energy efficiency, the form factors and weights of the remote radio unit, baseband unit, power supply, and battery can be shrunk further while maintaining the performance, so that these elements can all be easily deployed on existing sites. Different modules can be combined and installed in less and smaller cabinets, or directly on a pole, tower, wall, or roof. Compared with traditional base stations, cabinet and blade sites greatly reduce the area occupied but not at the expense of performance. In addition, these installation methods could also use natural air cooling instead of air conditioning and thereby help to reduce the power consumption of the network.

Blade site solutions can simplify antenna configurations by integrating passive sub-3 GHz antennas and active massive MIMOs into a single-blade baseband unit. Similarly, the power supply and battery can be incorporated into a blade. All the 5G elements can be deployed directly on the tower without any need for equipment to be installed in a cabinet or shelter. Due to their lightweight nature, the blades can also be deployed on poles (as opposed to traditional towers) such as street lighting poles. As such, the network can be easily densified with small cells.

To reduce the number of sites an operator must supply with electricity, information technology (IT) and communication technology (CT) sites should be integrated where possible. The power supply and backup battery can thus be shared across IT and CT infrastructure, leading to cost and energy savings.

Cell sites are evolving from large, air-conditioned equipment rooms into smaller and less power-hungry deployments. For example, a shelter might be replaced with a waterproof and dust-proof outdoor cabinet. With miniaturization of the electronics, base station components can even be mounted on the pole, further reducing the footprint of a mobile cell site. This can save rental expense, which, together with the lower energy requirements, leads to an improved total cost of ownership (TCO) for the telecom operator.

Case 2: Improving energy efficiency of optical networks

Optical networks deliver extremely high data rates. They also enable energy savings. In contrast with traditional copper fixed access networks, optical fiber-based access networks require very little power. This is also true in the transport domain. Studies[1] suggest that a move to all-optical transport networks can reduce power consumption by over 40%. Staying in the optical domain and avoiding conversion into electrical format operators can make significant energy savings in their core networks. All-optical equipment has the added benefit of being smaller and requires less air conditioning than traditional electrical optical switches, which further reduces the power requirements.

An all-optical cross-connect WDM switch can occupy just 10% of the cabinet space of traditional WDM products. For the same amount of switching capacity the power consumption can be reduced by as much

[1] IEEE, Volume 32, Issue 8, "All Optical Switching Networks with Energy-Efficient Technologies from Components Level to Network Level," https://ieeexplore.ieee.org/document/6849473 (Accessed 23 June 2021)

as 60%. These savings are achieved using an all-optical backplane, which avoids the need for intra-site fiber connections. In addition, all-optical switching enables one-degree cross-connections on a single board.

All-optical user case study

Company B has deployed all-optical cross-connects, OXC, achieving significant reduction in power consumption at each node, according to the company. Only one cabinet was required to house the OXC versus six cabinets for the legacy technology. The cumulative energy savings added up to hundreds of MWh over the course of a year across all nodes.

Case 3: Green data center construction – modularization reduces carbon emission while saving cost and time

Many applications and new industries have emerged with the enhancement of communication networks. This is set to accelerate as we enter the 5G era, leading to more and more network traffic peaks and forcing operators to expand the capacity and computing power of their data centers.

Constructing new data center facilities traditionally took around 20 months from initial site clearance to final testing. However, the modularization of data center facilities creates new possibilities for fast construction and with a lower carbon footprint. Standardized modules made with light steel structures can partially replace traditional construction methods that rely heavily on steel and concrete. Construction times can be reduced to as little as six to nine months. Highly modularized data centers also enable unified management and standardized processes, which can improve energy efficiency during operations.

Airport C data center case study

Taking Airport C data center as an example, as a world-class international passenger and logistics trans-shipment center, this airport is facing increasing operational pressure. To meet the rapidly growing passenger and logistics needs, the airport needs a new data center to host its own private cloud environment. It wants to build this as quickly as possible while meeting its energy efficiency objectives.

In response to this demand, Huawei provided Airport C with a fully prefabricated modular data center solution: a new Tier III-certified data center composed of container-sized prefabricated modules. The completion and delivery of this data center saved about 13 months, which is far shorter than the construction period of a similar-scale traditional data center, effectively reducing construction costs and the carbon emissions associated with traditional construction methods.

Case 4: Natural cooling of data centers

Data centers are a major consumer of electrical power and consume 2–3% of the total electrical power in a country. With the rapid evolution of key components such as CPU and storage, advances in chip technology and processes are leading to more processors entering the market with greater performance but high-power requirements. Currently, the power consumption of CPUs for data centers ranges from 165W to 275W, but we expect this to increase to above 400W in the future. Furthermore, the number of servers in each cabinet is also increasing. The average power density per rack has increased from 2–4kW 10 years ago to 7–10kW today, and we expect this to rise to 50kW in the future.

In addition to the energy consumption of the IT infrastructure, we must also consider the energy used for thermal management (cooling), power distribution, lighting, and other systems. In traditional data centers, thermal management consumes about 25–30% of the total power consumption.

In data centers with low-density cabinets and computing power, it is possible to deploy low-power air-cooling solutions using natural cooling sources as an alternative to air-conditioning units. Cool air can be drawn into the building through filters or used to chill the water that is used to cool the air inside the data center.

Natural cooling reduces the amount of electricity required for thermal management. Consequently, many web-scale players that operate large data centers have opened facilities in cold climates.

Data Center D case study

Taking Cloud Service Data Center D as an example of a natural air-cooled data center.

The special local geographical conditions make the place rich in cold air resources. The average temperature is generally between 0℃ and 18℃, significantly lower than in surrounding areas. In Data Center D a traditional cooling system is complemented by a natural cold air-cooling system. When the outdoor wet bulb temperature is lower than 10℃ and cooling tower water temperature is lower than 15℃, the air conditioning system stops working and the system enters a completely natural cooling mode. As such, for about 10 months throughout the year negligible power is used for cooling and the power utilization efficiency (PUE) falls by 8% when air conditioning is required.

Energy saving through intelligent energy management

In an ICT network facility where renewable energy sources are employed and device efficiency is quite improved, it is not yet enough to become an ideal low-carbon green facility. It is necessary to apply precise energy management to the whole facility, so that every bit of energy could be used precisely to support the current power demand. There are a variety of techniques that operators can adopt to improve the energy efficiency of their networks through more intelligent management.

For example, most operators will offer 4G and 5G services through multiple carriers over multiple frequency bands. To meet the high capacity demands in crowded areas (e.g., a subway station), all the available frequency bands are fully utilized during peak traffic hours. However, when the mobile traffic demand is lower (e.g., inside the subway station at night), a single carrier may be sufficient, enabling other carriers to be turned off temporarily. This avoids unnecessary power consumption for both radios and basebands. With intelligent network management, the network can be changed dynamically to match fluctuating demand levels while using the minimum amount of energy.

Another example involves coordinated energy saving among networks of different radio access technologies (RATs) operating on multiple bands. By identifying users that are covered by more than one RAT at a point in time, they can be switched to lower power bands when total traffic is low. This enables the high-power bands to be switched off to save energy. By monitoring the energy-saving performance and the impact on network KPIs in real time, energy-saving parameter configurations can be iteratively optimized.

Apart from the above-mentioned solutions, the following technical solutions are also good examples of intelligent energy management:

- In many site cases where grid power is mainly used, facing the mismatched situation of power and data business peaks is inevitable, which is: in the day, data businesses are at peak, but the electricity price from the grid is more expensive; at night, the situation is the other way around. To balance workload and power while saving cost, intelligent power systems based on advanced energy storage solutions such as lithium batteries are quite important. Through intelligent energy coordination, lithium batteries act as a buffer pool to solve the mismatching peaks of power and business needs. It is expected to play a bigger role when solar power solutions are employed on site also.
- In order to make real-time energy consumption of a facility visible to owners and the Operation and Maintenance (O&M) team, a visible dashboard that displays current workload, energy consumption, and forecast would be a very useful method in combination with AI-driven energy coordination.

Case 1: Granular measurement of energy usage

An important tool to improve energy efficiency is to increase an operator's visibility into the energy usage of the network. Many network elements do not keep close track of their energy consumption. Those that do record energy usage may not report this in a frequent and automated way. Operators need to be able to measure the amount of electricity being consumed by the various subsystems within a cell site (base station, cooling, power rectifiers, etc.). Within the base station the operator should be able to measure the power consumption of its components, including baseband units, power amplifiers, and transceivers. These measurements can be correlated with RAN performance management counters to ensure the right trade-off between energy efficiency and QoS is maintained.

Passive elements (battery, diesel generator, rectifier, HVAC, solar, etc.) supporting the RAN are often overlooked, even though they might represent over half of the overall site power consumption. Operators should deploy sensors and controllers to be able to make passive equipment visible, measurable, and controllable.

Smart sensors should be deployed to track battery levels, active hours, fuel levels of diesel generators, inside and outside temperatures, and air conditioning activity. Accurate energy monitoring can help to identify faults that are causing too much power to be consumed and reveal energy-saving opportunities such as lights left on inside an enclosure or temperature settings being set unnecessarily low. Monitoring the temperature and humidity inside an enclosure can improve the energy efficiency of the heating, ventilation, and air conditioning (HVAC) system by switching it off when it is not required.

Case 2: AI-driven energy saving in mobile network and data centers

Mobile network systems increasingly use AI to optimize network-level load balancing, such as sleep modes and air conditioning usage. AI enables network engineers to forecast data traffic based on time of day, weather, nearby events, etc., and set appropriate sleep periods for power amplifiers, transceivers, and baseband components.

AI can boost the energy savings from active radio cells through utilization of machine learning algorithms and automations. Shutting down low-traffic cells is a standard energy-saving practice. Setting fixed windows (for example, only putting a cell into sleep mode from 1 am to 5 am each day) removes flexibility and doesn't consider service demand. By using machine learning to predict network traffic, these windows can be increased dynamically to increase energy savings without impacting network performance and subscriber experience.

The prediction algorithm can identify which RAN cells can be shut down individually during the day, based on historical trend analysis. The algorithm might also actuate the shutting of cells based on these predictions. However, if the AI operates independently in a closed loop, it is important to deploy a real-time monitoring algorithm to detect any negative impact on customer experience.

Operator E case study

Operator E implemented AI-enabled network-level energy optimization technology, which analyzes site traffic demand to improve overall energy efficiency. This approach allows networks to customize power-saving strategies, by putting configuration and traffic needs on different bands and modes at the base station level. With these strategies, mobile users can be switched to lower bands when total traffic remains low, enabling high bands to be switched off, realizing significant power saving.

Accurate co-coverage identification enables coordinated energy saving among networks of different RATs operating on multiple bands. Mobile users can be switched to lower power bands when total traffic is low so that high power bands can be switched off to realize deep power saving. Based on the real-time monitoring of energy-saving performance and impact on network KPIs, energy saving parameter configurations are iteratively optimized. Base stations using the solution consumed 10% to 15% less electricity per year.

The project was initially conceived during the beginning stages of the energy crisis in local area, where the security of supply was perceived as the biggest need. During the trial phase, over one day of operation, energy saved while maintaining stable network performance equates to around a few million US dollars of annual electricity savings per cell site.

AI also has a big role to play in optimizing energy use in data centers. Here, AI can reduce data center energy use through better management of resource scheduling and the energy required to keep centers cool. In data centers where several cooling methods are employed, an AI-embedded energy management system could recognize real-time workload and heat dissipation requirements, and coordinate cooling resources accordingly. Advanced algorithms ensure the energy management system can be effectively trained and the energy efficiency of the whole data center facility be maximized as well.

Operator F case study

Operator F improved its data center energy consumption through AI-based analysis. The demand for massive amounts of data enabled by 5G poses greater challenges to data centers than ever before. Within the data center the air conditioning system is the chief consumer of electricity. As data center loads constantly change, cooling systems need to constantly adjust to avoid unnecessary energy consumption. A regional branch of Operator F introduced technology that integrates big data and AI, enabling data centers to learn to save power and automatically optimize their power efficiency. The company improved its data center PUE by around 10%. Instead of manually configuring the cooling systems Operator F was able to automatically collect data about temperatures and workloads and make automated configuration changes to the cooling systems.

Conclusions: A greener ICT industry for a greener world

A growing number of governments and companies are establishing goals to become “net neutral” or “net zero.” Parts of the ICT industry have responded to these goals and set their own, more ambitious targets as they strive to be good corporate citizens and play their part in minimizing the adverse impact of their operations on the environment. The expanding ecosystem and range of technologies that optimize energy consumption also gives companies a wide range of possible approaches to reduce their CO_2 emissions and become more energy efficient.

While there are sound ethical justifications for reducing CO_2 emissions and becoming more energy efficient, there are equally sound business and financial reasons. These include lower Opex through reduced energy-related costs, being able to meet other companies’ supplier selection criteria, as well as improved corporate image.

While governments tighten their policies to encourage companies to reduce their CO_2 emissions, ICT companies can not only respond to these but can set the pace for other sectors to follow. If ICT companies leverage their technology expertise and demonstrate industry-leading approaches to their own energy efficiency and CO_2 reductions, they may be able to help other companies to do the same. In the process, they can create new business opportunities that will be in increasing demand as more green energy regulation comes into force.

IoT can play a key role in this by helping companies to perform remote operations and maintenance. Connected sensors can collect and analyze real-time data to help avoid failures, reduce downtime, and track the health and energy use of machines. Connected sensors reduce environmental impact by avoiding the need for human operatives to visit sites.

Ongoing digitization is also causing applications and processes to move from company premises to the cloud. Like the growth in IoT adoption, the move to the cloud will also place more demand on networks and related ICT equipment. These will have to be met with technologies that optimize power use to ensure that the increase in data traffic does not cause a comparable increase in energy use.

Governments have responded to the climate emergency by committing to timeframes to become carbon neutral. In turn, these countries are placing pressure on their domestic industries to reduce their CO_2 emissions. One approach is to introduce carbon taxes that give companies an economic incentive to become greener. Another approach could be to legislate that equipment such as that used in the ICT industry must be energy efficient and meet agreed emissions levels both in its manufacture and use. Governments can also help industry define standard measurements for key environmental impact KPIs, enabling like-for-like comparisons between companies.

Parts of the ICT industry have already made significant strides in reducing CO_2 emissions, and many companies have committed to dates to become carbon neutral. As the demand for ICT services continues to accelerate, reducing the energy requirements of ICT equipment becomes increasingly important to sustainable economic development. As ICT players deploy more energy-saving equipment and use more green energy to power their own infrastructure, they will develop expertise that they can use to help other industries. Areas with clear potential to reduce their GHG emissions by using the latest ICT technologies include agriculture, logistics, mining, and manufacturing. **With advanced technologies, companies in the ICT industry can play a unique and positive role to enable other industrial sectors to accelerate their transformation process toward a higher level of digitalization and lower carbon emissions.** Doing so will enable ICT companies to play a key role in enabling global, sustainable economic growth.

Appendix

Methodology

This report is based on existing published research by Informa Tech, as well as insights gained from the authors' ongoing research into the communication service provider and technology industry.

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