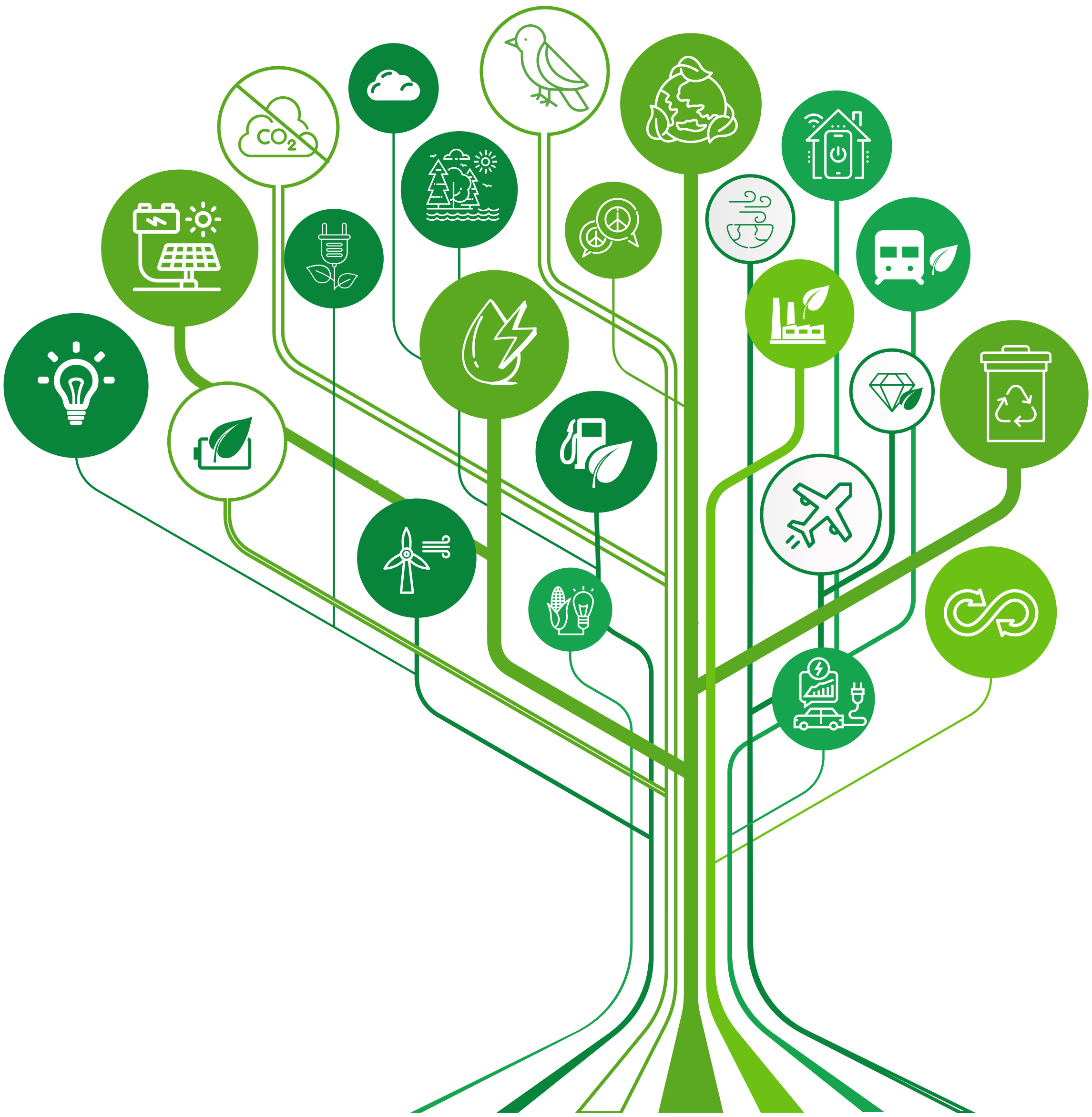
Next G Alliance Green G:

The Path Toward Sustainable 6G

Green G



NEXTG ALLIANCE

an ATIS initiative

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FOREWORD

As a leading technology and solutions development organization, the Alliance for Telecommunications Industry Solutions (ATIS) brings together the top global ICT companies to advance the industry's business priorities. ATIS' 150 member companies are currently working to address network reliability, 5G, robocall mitigation, smart cities, artificial intelligence (AI)-enabled networks, distributed ledger/blockchain technology, cybersecurity, IoT, emergency services, quality of service, billing support, operations and much more. These priorities follow a fast-track development lifecycle from design and innovation through standards, specifications, requirements, business use cases, software toolkits, open-source solutions, and interoperability testing.

ATIS is accredited by the American National Standards Institute (ANSI). ATIS is the North American Organizational Partner for the 3rd Generation Partnership Project (3GPP), a founding Partner of the oneM2M global initiative, a member of the International Telecommunication Union (ITU), as well as a member of the Inter-American Telecommunication Commission (CITEL). For more information, visit www.atis.org. Follow ATIS on Twitter and on LinkedIn.

The ATIS 'Next G Alliance' is an initiative to advance North American wireless technology leadership over the next decade through private-sector-led efforts. With a strong emphasis on technology commercialization, the work will encompass the full lifecycle of research and development, manufacturing, standardization and market readiness.

ABSTRACT

The challenges of global climate change and the need to reduce our carbon footprint makes it vital that the next generation 6G networks reflect the most energy efficient available technologies, reducing our dependence on non-renewable sources and using as much as possible renewable and ambient sources of energy.

Energy consumption is not the only aspect to consider for achieving these goals and conserving our planet. Beyond energy consumption and emissions, the ICT sector's overall environmental impact also must be considered, including water consumption, raw material sourcing, and waste handling.

The objective of this report, is to provides detailed insights of the current initiatives employed across the ICT to address climate change and environmental sustainability. Furthermore, the report identifies areas for improvement, describing a range of potential solutions that could be incorporated within next generation networks to further reduce energy consumption and to be more sustainable. The report concluded on a call to action, highlighting how North America is well positioned through these key areas to drive 6G innovation in energy and environmental conservation technologies globally.

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INTRODUCTION

The Next G Alliance is a bold new initiative to advance next generation (Next G) mobile technology leadership over the 5G evolutionary path and 6G early development, ensuring North American leadership in mobile technology across key sectors will strengthen and promote the region's economic interests globally.

1.1 SUSTAINABILITY: A BIG CHALLENGE

Scientific reports have raised global awareness around climate change in the past five years and convinced the U.S., Canada, and most other worldwide governments to commit to keeping global temperature increases to well below 2°C above pre-industrial levels. In 2018,[1] scientists clarified global warming must not exceed 1.5°C to avoid the catastrophic impacts of climate change. To achieve this, greenhouse gas (GHG) emissions need to have peaked and be reduced by half every decade and drop to net-zero emissions by 2050. The most recent report, published in August 2021,[2] states that we have already reached +1.2°C, so the imperatives for action are urgent!

> **GOOD TO KNOW**
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> **Carbon neutral** means that a company's carbon emissions are reduced as much as possible and then balanced by offsets.
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> **Zero carbon** means that no carbon was emitted in the first place.
>
> **Carbon negative** means that a company removes more carbon than it emits.
>
> **Net-zero emissions** means that there are net-zero emissions of all greenhouse gases, not just carbon.

In this situation, the Information and Communications Technology (ICT) sector must make sure to do its part. For this reason, the ICT industry has developed a trajectory for the sector's decarbonization following a 1.5°C aligned ambition.[3] The majority of the ICT sector footprint is related to the use of energy, so reducing energy consumption and decarbonizing the energy supply are the most important steps for the sector to reduce its emissions. However, energy consumption and carbon emissions are not the only aspects to consider for achieving these goals and protecting the planet. It is important to account for the ICT sector's overall environmental impact, including water consumption, raw material sourcing, and waste handling. This can be achieved by transitioning to a circular economy: an economic system that tackles global challenges such as climate change, biodiversity loss, waste and pollution comprehensively.

It is also recognized that ICT, including 5G and any next generation of wireless networks, has an important role to play as it can be crucial in enabling many sectors in reducing their contributions to global carbon emissions.

Creating a more sustainable Next G is a huge challenge, but also a huge opportunity. Almost a quarter of Fortune 500 companies have pledged to become carbon neutral by 2030.[4] The number continues to grow rapidly, with one-fifth of the Fortune 100 signing a United Nations pledge to eliminate their carbon emissions by 2050. With the inevitable transition to sustainable practices already well underway, global leadership in sustainable Next G has the potential to positively impact the entire North American economy.

1.1.1 Footprint of the ICT Industry

The ICT industry has a crucial role to play in reducing GHG emissions. Telecommunications specifically consumes 2-3% of the global electricity supply.[5] [6] The broader ICT industry currently consumes 5-9%, but with the rapid growth in digitization this may rise up to 20% by 2030.[7] Projected increases in energy consumption are driven in large part by the growing world population and society's demand for connectivity and high-speed data. Another demand on ICT infrastructure is the Internet of Things (IoT). By 2030, the number of IoT devices could surpass 125 billion, which is larger than the expected human population.[8]

In 2020, the ICT industry set a Science-Based Pathway,[9] to reach net-zero GHG emissions by 2050. This industry-wide commitment to tackle global climate change is in line with the end goal of a joint trajectory to decarbonize the ICT industry. Twenty-nine operator groups, representing 30% of global mobile connections, are already committed, including TELUS, AT&T, T-Mobile USA, and Verizon. The Science-Based Target sets emission reduction trajectories for each ICT Sub-Sector (mobile, fixed, and data center operators). For example, Mobile Network Operators (MNOs) adopting these targets are required to reduce emissions by at least 45% between 2020 and 2030. Most of these reductions are expected to come from adoption of renewable power sources and deploying network energy efficiency measures.

GOOD TO KNOW

Direct emissions come from energy consumption like on-site combustion or vehicle fleet fuel combustion.

Indirect emissions are caused by activities or assets not directly owned by the company. Examples include electricity purchased by the company, business travel, footprint of purchased assets, and investments. This category often represents most of an organization's total emissions.[10] [11]

1.2 ENVIRONMENTAL SUSTAINABILITY IS MORE THAN EMISSIONS

1.2.1 Material and Circular Economy

Electronic waste is a huge global problem. A 2020 global study estimates that 54 million metric tons of electronic waste (e-waste) were generated in 2019, with approximately 80% of that heading to the landfiill.[12] As e-waste disintegrates, harmful toxins and chemicals released into the air, water and land can cause huge damage to both human health and the planet.

Enormous amounts of telecom devices become e-waste in a short time. Mobile phones, SIM cards, wires, batteries, and other equipment are often in service for just a few years. Many device components, such as plastic in printed circuit boards (PCBs), can take hundreds of years to break down. Other components often contain heavy metals including lead, mercury, and cadmium, which, if handled incorrectly, can pollute the environment. Additionally, these heavy metals are difficult to source. Up to 60 elements from the periodic table can be found in complex electronics like smartphones.[13] Sending old devices to the landfill means that for every new device, new raw materials need to be extracted, many of which are finite and gradually depleting.[14] [15]

A circular economy[16] is a regenerative system in which resource input, waste emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling.[17] Only 8.6% of the global economy is circular as of today, and only about 17-18% of all e-waste is formally captured, according to the World Business Council for Sustainable Development (WBCSD),[18] one of the founding partners and the current secretariat of Circular Electronics Partnership (CEP).

1.2.2 Land and Water

Energy production,[19] manufacturing[20] and data center cooling[21] all consume large amounts of water. Water quality and overuse are growing problems around the world. By 2025, two-thirds of the world population could be under stress conditions caused by water scarcity.[22] Climate change will expand the geographic extent of water-stressed areas and increase production variability and price volatility. Investments in water management and water conservation processes must be made urgently.

Next G technologies can be used to improve the way water is consumed, such as with more efficient liquid water cooling[23] or monitoring water consumption. Metrics like the Green Grid's water usage effectiveness (WUE) can be used to track progress in water savings[24] and prevent water shortages that have immediate impacts like hunger and thirst, or lead to long-term negative consequences for land, like desertification.

The ICT industry also has both direct and indirect impacts on land. The process of mining for the rare materials needed to manufacture electronics can have significant impacts.[25] Land degradation is occurring in almost all world regions and already affects about 30% of the global land area.[26]

1.3 NEXT G ALLIANCE: GREEN G DRIVING SUSTAINABILITY ACROSS THE ICT INDUSTRY

In response to these challenges, industry players have joined together to form the Green G Working Group within the Next G Alliance. This group seeks to position North America as the global leader in environmental sustainability of future generations of wireless technology or "Green G." The Green G Working Group's mission is to reduce Next G technologies' energy consumption and environmental impact on the planet.

The objectives of the Green G Working Group are to:

- Position North America as the global leader for 6G.
- Drive reduction of carbon emissions of Next G telecom infrastructure and technologies.
- Promote environmentally friendly materials in supply chain components for Next G.
- Recommend sustainable use of water, energy, and materials.
- Explore how the telecom industry can enable other industries to reduce their environmental footprint.
- Influence standards and the communication industry globally to be in line with environmentally friendly policies.
- Create an evolution path toward environmentally friendly Next G networks.
- Describe the benefits of Next G for the environment.

To further the Green G Working Group mission, this document focuses on describing the sustainability status quo of today's mobile networks, as well as discussing ongoing and potential future steps to create an evolution path toward environmentally friendly Next G networks. The working group also explores how the telecom industry can enable other industries to reduce their environmental footprint and identify where there are gaps in knowledge or progress and opportunities for research.

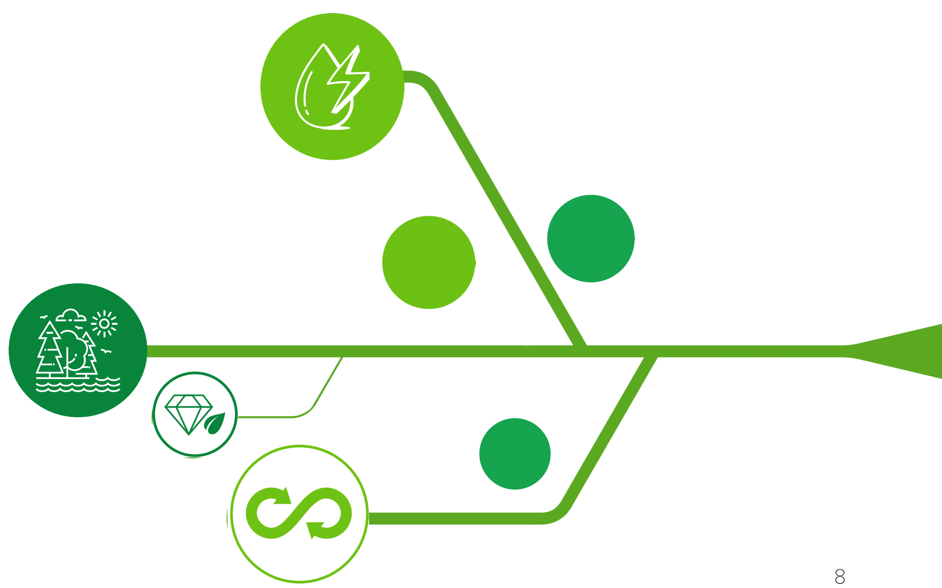
1.3.1 Summary of Findings

This white paper identifies key areas where the ICT sector — including the mobile infrastructure, radio access technology, data center industry and device manufacturers — have made significant improvements over the past decade in reducing the overall energy consumption per compute and network traffic. However, the digital economy and new applications require ever increasing computational resources, connectivity, and bandwidth, resulting in higher network traffic loads. Consequently, the overall energy consumption continues to increase. The ICT industry must remain vigilant and continue to improve.

The Green G Working Group recommends that industry players accelerate their commitment to sustainability in a way that anticipates and factors in future effects. It is believed that this industry is capable of this transformation. As more companies commit to adopting corporate and social responsibility (CSR) strategies that address environmental and social issues, many companies have a sustainability program in place and are committed to reducing their energy consumption and impact on the environment.

In addition to transitioning to the use of green energy and improving energy efficiency to reduce GHG emissions, the ICT industry has an opportunity to participate more fully in the circular economy. Improvements to manufacturing, supply chain management, and recycling practices are important opportunities for improvement.

No single organization alone will achieve a significant impact on climate change. However, the collective impact of Next Generation mobile networks can enable millions of businesses globally to reduce their energy and environmental impact, which will have a profound effect on climate change. Enterprise customers using 6G infrastructure will be able to leverage the industry's sustainability efforts to reduce their own environmental impact. Further, the working group recognizes that the ICT sector, with the use of 5G and subsequent generations, will be crucial in enabling other novel sectors, such as agriculture and transportation, to reduce their GHG emissions.



2

STRUCTURE OF A TYPICAL MOBILE NETWORK

Figure 1 illustrates a typical mobile network, which can be broken down into four main parts: (1) end-user devices like smartphones and IoT devices, (2) the Radio Access Network (RAN), (3) the core network, and (4) the data center network/cloud.

1. End-user devices are often battery powered and therefore have a strong incentive to be power-efficient. These devices still can impart a significant carbon footprint, due to battery and electronic sourcing and manufacturing processes.
2. The RAN resides between the user devices and the core network and contains the cell tower/base station. This is the most power-hungry part of the network, due largely to the power amplifiers required for wireless communication.
3. The core network handles essential centralized functions such as connectivity and mobility management, authentication and authorization, subscriber data management and policy management, among others. Core network functionality can operate either on specialized hardware or standard data center networking hardware. The trend is toward complete virtualization, with the core running on typical data center servers
4. The cloud takes care of all other information-transfer needs, such as transmitting data between core networks and accessing user data in the cloud for mobile applications.

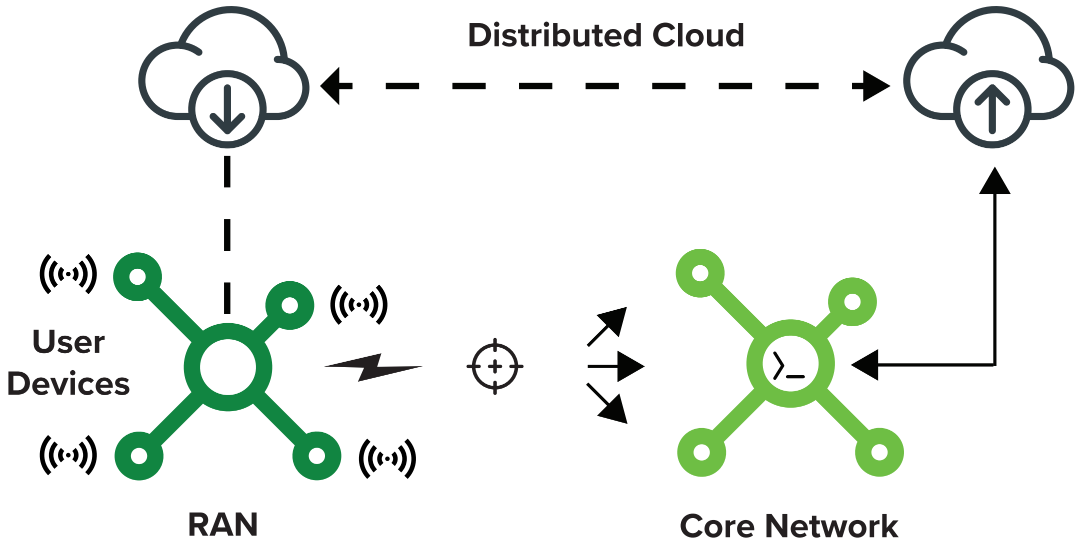


Figure 1 – Typical end-to-end architecture of a Next Generation mobile network

2.1 NETWORK POWER CONSUMPTION

Figure 2 illustrates the distribution of power consumption across the components of both 4G and 5G mobile networks. The figure clearly illustrates that the RAN consumes the most power. Although RAN power consumption is reduced in 5G, it is still over 50% of the total 5G network infrastructure consumption.

Another trend worth noting is the rise in data center power consumption in 5G. With many of the core network services moving to the cloud in 5G, we see a reduction in the energy consumption of core network elements from 4G to 5G and an increase in data center energy consumption as these core services migrate in 5G into data centers.

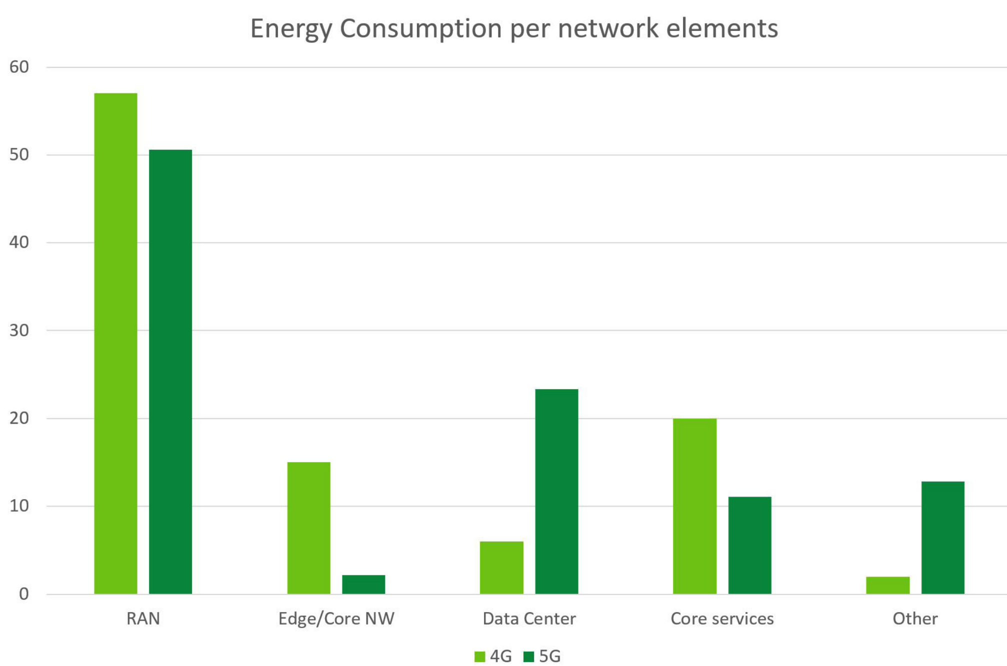


Figure 2 – Breakdown of power consumption in a 4G/5G mobile network [4G[27]][5G[28]]

Despite improvements in energy efficiency, the RAN continues to consume more power than any other part of the network. This is due largely to new technology like mmWave transceivers and MIMO antennas, all of which require more power. Fortunately, these technological advances allow us to communicate more data using less power (watts per bit).[29] While this increased efficiency is good, we are also expecting significant increases in traffic: as much as a 27% compound annual growth rate in North America between 2020 and 2026.[30] The world is becoming more connected, and the data needs of each user also grows each year. These traffic increases mean that the ICT industry is projected to consume more power in the future, despite the recent advances in energy efficiency.

Timely network modernization is very important for minimizing power consumption in the immediate future. Some estimates show that modernizing from 4G to 5G RAN hardware could save as much as 90% of the energy needed per bit.[31] It is important to be vigilant to maintain these advances, however, to compensate for growing traffic demands.[32]

2.2 CHANGES IN MOBILE NETWORK STRUCTURE

With 5G networks, many network elements can be virtualized through software components that are deployed in data centers. Carriers are shifting from customized hardware solutions to software-enabled implementations on general-purpose hardware. More and more network functions are moving to the data center and cloud. Software-defined networks enable more rapid development of new features because the barriers to deployment are significantly lower. Advances in hardware will continue to be an important aspect of future mobile networks, but it can be expected that many new network features can be deployed without hardware updates.

Given that future networks will be significantly more agile, it is important to make energy consumption a first-class metric when designing 6G and beyond. Despite the new metrics defined by 3GPP and ETSI (e.g., energy consumption and efficiency), metrics still need to be implemented. The problem is that almost all publicly available global measurements of mobile network power consumption are not being updated.[33] [34] [35] [36] [37] In the short term, these measurements need to be collected on the latest 5G networks because accurate data on power consumption to inform sustainability goals is needed.

However, this cyclic approach is not practical for the future paradigm of rapidly changeable networks. The industry needs to invest in R&D to ensure that Next G is designed with robust and granular power and energy monitoring so that real-time energy consumption data is available. This data will enable the industry to verify that power-saving features are working as expected, and to ensure new features do not unintentionally increase power consumption. Furthermore, this granular data can be used to design novel optimization algorithms. Fortunately, North America has historically been a leader in the software-defined networking and virtualization spaces.[38] [39] That leadership should continue and leverage those areas to make sustainable design changes that will benefit the whole world.

Given the increasing importance of datacenters in modern and Next Generation mobile networks, we will discuss the sustainability of mobile networks in two broad parts: the network and data center, and devices and hardware manufacturing.

3

SUSTAINABILITY OF THE NETWORK AND DATA CENTER

This section analyzes the RAN, core, and cloud components of a mobile network.

3.1 RAN ENERGY CONSUMPTION

Energy consumption in mobile networks is dominated by the RAN. A significant change between 4G LTE radio and 5G NR is that the latter has an ultra-lean design that minimizes always-on transmissions to enhance network energy efficiency and ensure forward compatibility. In contrast to the setup in LTE, the reference signals in NR are transmitted only when necessary.

There are several factors affecting 5G RAN energy consumption:

- Idle mode transmission is designed with very long-time gaps (up to 20 ms for standalone operation and up to 160 ms for non-standalone operation), enabling significantly deeper and longer sleep modes than the 0.2 ms in LTE.
- Multi-carriers and Massive MIMO in radio units, with wider carrier and more antennas, will lead to an increase in the compute requirements, making energy-lean processor design more crucial than ever.
- Pooling baseband-processing resources, when possible, can also lead to more efficient use of processing resources.

Prior to 5G, each base station base band unit (BBU) handled baseband processing locally, thereby consuming a lot of power in total. This is changing with 5G onward with the consolidation of baseband processing across wideband front ends. However, the BBU is still a minor contributor to total RAN power consumption when compared to the radio units.

Advancement in energy efficiency in 6G is possible by using different techniques, such as improved separation between "idle mode" and "active mode" functions. Other techniques include further modularization within the system to introduce dynamic and efficient shut-down of functionalities that are not in use and where no part of such functions is required to remain active for purposes such as signaling. This will result in a high degree of proportionality between instantaneous energy consumption and instantaneous traffic load, thereby keeping fixed energy consumption to a bare minimum and subsequently aiding immensely in areas with strong traffic variations.

Due to the RAN's power consumption, implementing energy-saving strategies for this part of the network is a high priority. While general compute solutions can be used for 5G access, energy savings can be achieved by using system-on-a-chip (SoC) designs. It allows for building smaller and simpler systems embedded in a single chip resulting in increased efficiency.

Solar panels and small-scale wind turbines, such as vertical spiral wind turbines, can also be installed within the premises of the cellular tower. While these may not be able to supply all of the power needed to support communications, the harvested energy can be stored in batteries to support other facility needs.

There is a trend in the mobile industry to disaggregate RAN hardware and software into functional components suitable for deployment on general-purpose IT hardware.[40] [41] This has resulted in efforts, such as within the O-RAN Alliance, toward developing open interfaces for RAN functions. These mainly correspond with implementation of central unit and digital unit hardware, and associated mechanisms for the introduction of third-party solutions for various radio resource control functionality, including near-real-time control. The industry must adapt to the impact of such changes in architecture to account for two things. One is the maturity of the industry in reducing energy footprint over time. The second is the tension between fragmented functionality and sustainability requirements by means of rigorous attention to energy performance when integrating disaggregated functions and ensuring interoperability. There are many industry players and organizations looking at the energy efficiencies made possible by Open RAN solutions.

5G adds a new radio resource control (RRC) state called "RRC Inactive." When a user device does not have an active event, the radio is transitioned to the RRC Inactive state, but the context for device connection remains. The next time the device needs to transition to an active state, it is transitioned without going through the energy-intensive process of reestablishing context. Adjusting protocols to take increased advantage of this new state will lead to UE battery savings and some additional RAN energy savings.

Additional aspects that have an impact on energy consumption in the RAN include pooled processing of Centralized Unit (CU) – Distributed Unit (DU), placing user plane functions closer to users and making protocol improvements with the potential and extent of energy savings depending on deployment scenarios. For example, 80% of sites carry 20% of all traffic (see Figure 3). Centralized baseband processing allows one to pool resources to match the fluctuating demand by dynamically adjusting the number of DUs to serve an offered load while making sure UE service coverage is not impacted. Also, the close co-design of hardware and software can play a crucial role in facilitating the creation of high-performing and energy-efficient products for a wide range of deployment scenarios.[42] Continuing to invest in these and other strategies will be essential for keeping the power consumption of the RAN under control.

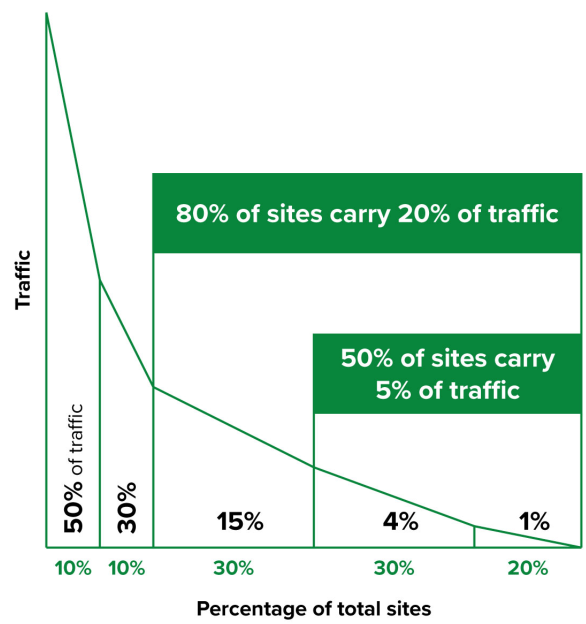


Figure 3 – Aggregated network traffic profile[43]

Besides the RAN itself, data center strategy can also impact power saving. By running as much software as possible in the cloud, virtual networks such as Open RAN can take advantage of the economies of scale inherent to large data centers. Cloud data centers allow more effective concentration of cooling, lighting and electricity, reducing power consumption compared to local compute operations.[44] Total computations performed in data centers have increased by 550% since 2010, while total power consumption increased by only 6% over the same period.[45] As the semiconductor technologies used in data center servers continue to evolve in terms of power consumption efficiency improvements, telecom operators are benefiting from the corresponding savings in operational expenditures.[46] When virtualized RAN architectures are employed for 5G, DU, and CU functions will be deployed in Virtual Machine (VM) such as Virtual Network Functions (VNF) or Container Network Functions (CNF). Furthermore, virtualization of other network functions will require monitoring features in data centers to keep track of servers' and VMs' power consumption, corresponding CPU and memory levels.

3.2 CORE NETWORK ENERGY CONSUMPTION

5G standards adopted virtualization and cloud-native designs that provide the flexibility to run core Network Functions (NFs) as a set of microservices on different combinations of hardware, hypervisors, and operating systems, with VNF and CNF. The container technology typically encapsulates NFs microservices into independent and autonomous containers, CNFs, to achieve the maximum flexibility to run the CNFs on any on-premises hardware platform and in the cloud independently of the vendor.

Having so many choices to support CNFs or VNFs across bare metal, on premises and in the private/public cloud raises challenges regarding energy consumption. Being able to determine the resource allocation for xNFs across various platforms, while at the same time preserving the balance between computational power and energy consumption, can be challenging.

Design for energy efficiency is a concept that, until now, has been applied mainly to hardware, leaving out the impact of software.[47] This means real platforms to measure the impact of software on energy consumption have not been created.

There are several efforts being undertaken to address this in both proprietary and open-source software ecosystems. Eco-design, a methodology to build sustainable software and studies, is in progress to optimize AI algorithm energy efficiency.[48] Other initiatives measure the power consumption at the platform and cloud (private/public CaaS) level. Two examples of projects working on this are:

- Redfish, a REST API used for platform management and standardized by the Distributed Management Task Force, Inc.[49]
- Scaphandre, an open-source metrology agent that can be deployed on a CaaS platform (Kubernetes) to collect power metrics related to the overall cluster and the individual CNFs running on it.[50]

Evaluating and understanding the impact of software on the environment is a new area that is attracting several of the most important software vendors. A number of them have joined forces to start the Green Software Foundation to work on this.[51]

> **GOOD TO KNOW**
>
> Training a machine learning (ML) or artificial intelligence (AI) model can consume significant amounts of power. Before using AI/ML to seek power savings, consider whether the hardware involved with training can be powered renewably, and how much power is expected to be saved in the long term versus power consumed in the training process.[52 53]

The efforts referenced above are important work, but Next Generation networks will need to build on that work to create an ecosystem capable of providing detailed, end-to-end, real-time data about network power consumption in terms of both hardware and software.

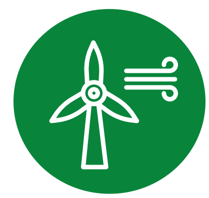
Detailed information about the xNFs' energy resource consumption, jointly with a ML approach, could be used to explore a model that considers a theoretically infinite set of traffic models, their respective power consumption (e.g., expressed in Watts) and predict a target energy-consumption or energy-efficiency rating. The same approach could be used to identify the most recurring clusters of power consumption along several dimensions (e.g., CPU, disk, network traffic, and memory) and on different hardware and software setups (e.g., private/public cloud, any on-premises).

3.3 DATA CENTER ENVIRONMENT FOOTPRINT

Because so much of the functionality of mobile networks are moving into the data center, it is important to consider the environmental impact of data center operations. There are several components to the environmental footprint of a data center, including energy usage and water consumption.

According to the International Energy Agency, as of 2019, datacenters consume approximately 200 terawatt-hours (TWh) of electricity, or nearly 1% of global electricity demand, contributing to 0.3% of all global CO_2 emissions.[54] Another study showed that telecom and the IT industries together accounted for 29.4% of the global market for green and efficient modular data centers.[55]

3.3.1 Renewable Energy



Transitioning to a renewable energy source is an important step in decarbonization of data centers. Adopting renewable energy is an effective component of a strategic energy management plan. Today there are several market-based solutions available for procuring renewable energy, including physical power purchase agreements, green tariffs, virtual power purchase agreement contracts and self-generation either on-site or off-site, as well as Renewable Energy Credits (RECs).[56]

3.3.2 Green Backup

Data centers have backup generators to keep systems running when primary power supplies fail. These typically use diesel fuel, so moving workloads to data centers fueled by more sustainable backup solutions will lower energy emissions.

Depending on the source and process used to produce hydrogen, hydrogen fuel cells can be a sustainable energy solution for data centers. These fuel cells use an electrochemical process to cleanly and efficiently capture energy and supply it back to the data centers.[57] Hydrogen fuel cells produce a short-term backup power under peak loads that would reduce the demand on the grid without emitting carbon. The fuel cells can also generate electricity two times more efficiently than combustion engines.[58]

If transitioning to hydrogen fuel cells in the near future is not an option, natural gas offers 28.6% lower CO_2 emissions, not considering the efficiency of the engines, than traditional or synthetic diesel.[59] Transitioning from diesel to natural gas is a stop-gap solution that offers lower lifetime carbon emissions and does not require any alterations to current generators.

3.3.3 Grid-Interactive Batteries

Grid-interactive Battery Energy Storage Systems (BESS) and Uninterruptable Power Supply (UPS) batteries can make a big difference in reducing emissions while also giving back to the grid. These batteries can be charged with renewable power and then "export power to the utility grid…. using surplus energy for use in times of low generation."[60] These mechanisms can be automated with Demand Response Modules (DRM) and optimized with AI based energy prediction.

Optimal battery utilization can lower energy demand on the grid under peak load. Unlike lead acid batteries, grid-interactive BESS and UPS batteries store energy at up to 90% efficiency. To use stored power, an algorithm regulates frequency between batteries and the grid by determining microbursts of electricity in either direction based on need in any given moment. Returning power to or taking it off the grid also serves as a potential source of monetary income for data centers, enabling them to sell excess renewable energy stores.[61] While grid-interactive batteries are promising, the environmental impact of battery hardware also must be considered.

3.3.4 Cooling and Water Consumption

Data centers consume water across two main categories: indirectly through electricity generation (traditionally thermoelectric power) and directly through cooling. Properly cooling data centers are essential to ensuring that servers and network equipment do not overheat. Most data center equipment uses air-based cooling, where powerful fans circulate cool air across the interior of the equipment. In general, for this to work, the ambient air temperature must be chilled. Both air conditioning and evaporative cooling of buildings the size of data centers may require considerable water usage. The typical data center uses 3-5 million gallons of water a day – the same amount an entire city of 30,000-50,000 people would consume.[62]

Many data centers are located in arid climates, due to inexpensive land, lower electricity costs, financial incentives and potential abundant supply of renewables like wind and solar. However, the large water needs of these data centers can strain local water supplies. As a result, local governments may be reluctant to permit new data centers. There are a few developing and underutilized techniques to try to reduce the electricity and water load needed to cool data centers.

A number of approaches to reduce water usage for data center cooling leverage geothermal temperature regulation[63] to reduce the load on other cooling systems or even leveraging geothermal heat pumps as an additional source of electricity.

Project Natick[64] implements immersion cooling, in which the whole building's air is chilled. In this approach, the equipment is submerged in the ocean because saltwater boils at a lower temperature than fresh water, thus regulating the temperature. Liquid immersion cooling is predicted to lower server energy in the future by a minimum of 5-15% while also using less water than chilled-air cooling.

The Hamina data center in Finland has used seawater for cooling since it opened in 2011.[65] Using existing pipes from when the facility was a paper mill, the cold seawater is pumped into heat exchangers within the data center. The seawater is kept separate from the freshwater, which circulates within the heat exchangers. When expelled, the hot water is mixed with cold seawater before being returned to the sea.

3.4 AUTONOMOUS SYSTEMS

Autonomous system capabilities can be leveraged to enhance energy utilization efficiency through optimized and lightweight AI/ML models with infrequent training demands, such as variants of Deep Reinforcement Learning (DRL). Energy consumption in the network and devices could be reduced through an intelligent allocation and placement[66] of networking, computing, and storage resources and by managing the on/off states of these resources to closely follow demand while simultaneously sustaining the desired behavior and performance. For example, by intelligently transitioning network elements or devices that are inactive or dormant for appropriately estimated durations, the corresponding power (e.g., transmit, networking, computing, or storage) may be reduced or turned off while elastically altering latency or jitter, without any corresponding service experience impact.

By adding radio and infrastructure components as an application in the cloud, network data from multiple sources can be aggregated in a common database and analyzed using AI/ML. This would advance the state of the art of efficient, distributed, self-organizing network algorithms (DSON) that can be empowered using AI/ML. Empirical data would allow diverse power-efficient algorithms to be developed via insights and wide-area optimization routines that will ultimately result in OPEX savings.

3.5 EDGE COMPUTING

Connected living combined with IoT has a huge potential to reduce carbon emissions by enabling new ways of operating, living, and working that are more efficient and sustainable. However, connecting user and IoT devices creates huge electricity demands due primarily to the transmission and storage of data in cloud data centers. While data center efficiency and the use of green energy, as outlined in the sections above, will reduce the CO_2 emissions, it does not address the problems directly associated with centralized cloud data centers and the energy associated with data transport to the cloud.

IoT devices were estimated to produce around 2.8 ZB of data in 2020, globally.[67] Only a small portion of that data is stored and used, yet 90% of generated data is transferred to the cloud.[68] Transferring 1 GB of data to the cloud costs between 3 and 7 kWh.[69] Assuming an average of 5 kWh, this means a 0.14 ZB multiplied by 5 kWh, resulting in a total energy expenditure of 635 kWh. Following the same calculations, IoT-generated data transferred to the cloud would be responsible for 8 billion metric tons of CO_2 in 2025. This calculation highlights the need for a more efficient way to process IoT data through edge computing.

Edge computing essentially moves the processing power from the cloud to a point closer to the end user or device. In doing so, edge computing can reduce the energy consumption in networks by reducing the total amount of data traversing the network. By running applications at the edge, data can be processed and stored near the devices rather than relying on data centers that are hundreds of miles away. This could lead to a significant reduction in energy consumption related to network transport while also benefiting from low latency that edge provides.

However, an increase of edge computing devices leads to additional energy consumption. There are multiple ways to address the projected increase of energy consumptions in edge data centers. One is to minimize infrastructure overprovisioning by actively monitoring multi-site energy utilization and deploying resource-optimized infrastructure. Secondly, because edge data centers require relatively small amounts of energy compared to large, centralized data centers, it is more realistic to fully power those edge data centers with sustainable, onsite energy resources and have them become part of a smart grid.

Hence, to assess the effect on total energy consumption, further detailed studies would be necessary. One benefit of adopting edge computing is that additional energy may be reduced by savings associated with data transport, which is another factor as discussed in the previous paragraph.

4

SUSTAINABILITY OF DEVICES AND HARDWARE MANUFACTURING

This section examines devices and their characteristics, assesses the environmental impacts from the production process, raw materials used, the emissions and waste produced in manufacturing and distribution, energy consumed by end-devices during operation, and how recyclable components and materials are at end-of-life.

Life Cycle Assessment (LCA) has been proven to be an adequate methodology to evaluate the environmental impact of products from material sourcing to end-of-life in different disciplines. To use LCAs for decision making, it is important to understand the variability and uncertainty associated with a model-based assessment methodology like the LCA as opposed to measurement methodologies used for performance monitoring.

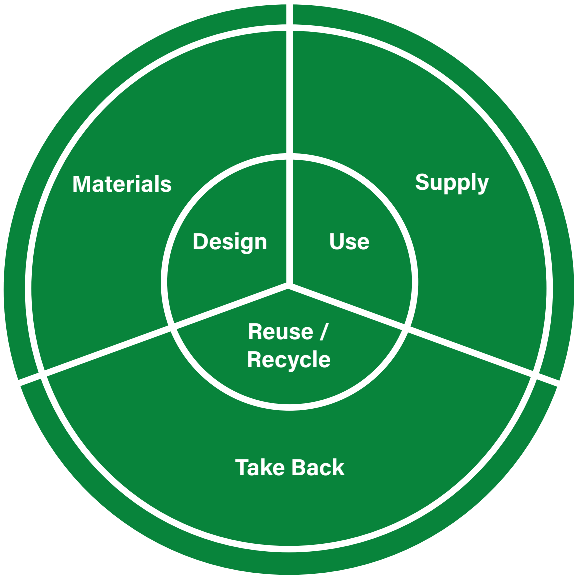


Figure 4: Stages in a product lifecycle[70]

Assessment of the entire lifecycle (cradle to grave) of a mobile phone indicates that production is the biggest contributor to climate change and primary energy consumption impacts.[71] The use stage of mobile phones contributes to 11% of total climate change impact, which varies based on the usage scenario and the charger used.[72]

4.1 MATERIALS

Between 2007 and 2018, 7 billion smartphones have been manufactured and 968 TWh have been used in their production. According to a Greenpeace report,[73] production heavily relies on fossil fuels and produces GHG emissions. The bulk of smartphone emissions arise out of the production chain as mentioned by ITU L.1410.[74] The researchers said that while phones consume little energy to operate, 85% of their emissions impact comes from production. The smartphone components that require the most amount of energy to produce are the chip and the motherboard because they are made up of precious metals mined at a premium environmental impact.[75]

According to that same report, there are more than 60 different elements included in a smartphone. Each of these elements contributes to a whole host of environmental and socio-economic effects coming from the places in which they are mined. For example, in order to obtain these precious metals and produce a single smartphone, 34 kg of ore needs to be mined, using 100 liters of water and 20.5 g of cyanide.

To put this into context, the analyst firm IDC found that 1.4 billion smartphones were shipped globally in 2018. That means in 2018, 34 billion kg of ore would have had to have been mined, using 100 billion liters of water and 20.5 million kg of cyanide, to produce these devices.[76]

Minerals	Symbol	Examples
Gold	Au	Printed Circuit Board (PCB). Contacts SIM Card and Battery
Lithium	Li	Battery
Aluminum	Al	Case, Components, Shielding
Cobalt	Co	Rechargeable Battery, Circuits, and Electrical Components
Copper	Cu	Printed Circuit Board (PCB)
Nickel	Ni	Capacitors, Battery
Silver	Ag	Printed Circuit Board (PCB)
Zinc	Zn	Circuit Board
Iron	Fe	Screws
Palladium	Pd	Contacts between components
Tantalun	Ta	Capacitor
Tin	Sn	Solder
Gallium	Ga	LED
Indium	In	Display
Tellurium	Te	Tinting Glass
Manganese	Mn	Rechargeable Battery
Tungsten	W	Vibrator
Natural Graphite	C	Battery, Antennas

Table 1: Key minerals used in mobile devices.

Over time, the demand for smartphone components has increased. This has led to an increase in demand for rare raw materials and earth elements. Table 1 outlines some of the common minerals needed to produce a phone. There is no doubt that mining precious materials also displaces huge amounts of rock in the process. Typically to remove 100g of needed materials, 34 kg of rock must be mined.[77] Considering the millions of phones made each year, the amount of damage being caused is significant.

In addition to the minerals detailed in Table 1, there are other compounds used in device manufacturing that contribute to the carbon footprint. For example, thermoplastic polyolefin is used in antenna and device substrate, encasements, and packaging.[78] Strategies to reduce the global carbon footprint of plastics include aggressive application of renewable energy, recycling and demand-management strategies. In concept, this has the potential to keep 2050 emissions comparable to 2015 levels.[79]

Embodied carbon from the fabrication and the recycling of electronic devices represents a substantial portion of the total footprint of the devices. For portable devices, the emissions due to material extraction, manufacturing and distribution exceed the energy the device consumed during lifetime operation.[80] Integrated circuit (IC) fabrication represents at least a fourth of the total footprint of the devices.[81] Some part of semiconductor manufacturing is resource intensive in energy, water, chemicals, and raw materials and generates different classes of emissions, including GHG.[82]

Generation after generation, the performance improves, but the chip production necessitates steadily a larger amount of energy. The evolution toward more connected devices and (sub-)THz carrier frequencies with higher bandwidths, will increase the demand for producing devices with a large amount of embodied energy. Therefore, the reduction of GHG emission during chip production is key.

Action has been taken within the semiconductor manufacturing industry to reduce emissions and environmental impact through strategies such as increased usage of renewable electricity, abatement of fluorinated gases, process and equipment optimization and energy and water conservation. Besides pure device performance, the environmental impact of RF technologies such as Si CMOS, InP HBT and technologies based on other compound semiconductors must be carefully planned for the development of future broadband radios. However, future networks enabled by more advanced semiconductor technology will support new applications with the potential to enable end users to dramatically reduce their GHG footprints.

In the short term, several effective means can be adopted to lower embodied emissions. For example, the carbon footprint of polypropylene plastic (2.00 kg CO_2/kg) is much less than the footprint of polycarbonate plastic (9.45 kg CO_2/kg). Furthermore, using recycled materials instead of new materials will lower the carbon emissions by about 30%.[83] More effective means of re-claiming rare materials are needed, as well. In many cases, it is cheaper and easier to produce new plastics than to recycle existing ones.[84] Current recycling systems actually degrade the plastic during the recycling process, so each plastic can be recycled only a limited number of times. To increase recycling and reprocessing percentages, improvements are needed in recycling technology and infrastructure, as well as consumer incentives.

Longer term, one topic that warrants investigation is using bio-based plastics instead of petroleum-based plastics. Bio-based plastics produce significantly fewer GHG emissions than traditional plastics over their lifetime.[85] The use of bioplastics in electronics is an area of active research.

The use of solvents is another undesirable aspect of the manufacturing processes. During conventional PCB production, multiple processes involving solvent removal, surface cleaning, drying, and waste treatment produce a large amount of carbon emissions. In 2020, the PCBs of all electronic devices generated approximately 23 million tons of carbon emissions globally, and the communications-related applications account for 35% of the total. Transitioning to new, solvent-free PCB manufacturing processes, such as using UV-curable resin, will be an effective solution for lowering emissions in electronics manufacturing.

4.2 OPERATIONAL EFFICIENCIES

While the manufacture stage of a mobile device is the largest portion of its climate impact during its lifetime (cradle to grave), the operation use stage of the device still contributes around 11% of its climate impact footprint. The exact percentage is dependent on the usage scenario and the charger used.[86] Fortunately, the air interface is more efficient than previous generations of mobile technology. A mobile device spends most of its time in an idle or inactive state, relieved from data monitoring by staying in a low-power mode state known as "deep sleep." Only when data arrives does the device enter a connected mode for data transmission. There are additional mobile device energy saving modes available, as well.

Current devices have implemented a device power model that captures the relative powers associated with different active operations in relation to the lowest power: deep-sleep mode. Clearly, reducing the fraction of time for the device to perform unnecessary downlink signal channel monitoring and enabling the device to be in a sleep state instead offers a high potential for energy conservation.

In addition to energy conservation, methods of energy harvesting could be adopted and incorporated in devices and base stations. In electromagnetic energy harvesting systems, the electromagnetic waves propagating in free space may be received by harvesting antennas and converted to electronic energy that is used to charge batteries and other devices. Other sources used in energy harvesting include light, thermal, and vibration.

The same methods can be used on mobile devices by integrating small photovoltaic (PV) panels and micro kinetic elements (even piezoelectric generators) to reduce the frequency of recharging. While the amount of the energy harvested on each device may be minute, the overall energy generation can be significant once the total number of devices is factored in. For battery powered IoT devices, the aforementioned energy harvesting methods can help reduce the need to replace the batteries.

4.3 IMPROVEMENTS IN IoT, BATTERY, AND REGENERATIVE TECHNOLOGIES

Since 4G, there has been a discernable increase in the use of cellular networks to serve massive IoT applications. Next G networks are expected to continue this trend across industry use cases like smart homes, smart cities, mining, and exploration. Many massive IoT applications involve the use of low-energy sensors to monitor and measure physical quantities often associated with sustainability and energy efficiency goals. In many cases, replacing the batteries of IoT devices entails significant electronic waste and costly manual operations, which are typically two orders of magnitude higher than the device cost itself.[87] Thus, battery lifetime is an important factor that should be considered in the use of massive IoT.

The prediction of the future cellular systems powering a trillion IoT devices[88] would require replacing 274 million batteries every day, even with the assumption of 10-year average battery life. Clearly, this is infeasible, and leads to significant operational expenditures, increased carbon footprint, and electronic waste. Furthermore, as shown by Figure 5, past technology trends show that battery technology has dramatically lagged in comparison to other technologies. There has been less than a 10x improvement in battery energy density from 1990 to 2025 compared to multiple orders of magnitude increase in storage density, computing power and peak wireless data rates. This trend is expected to continue in the future.

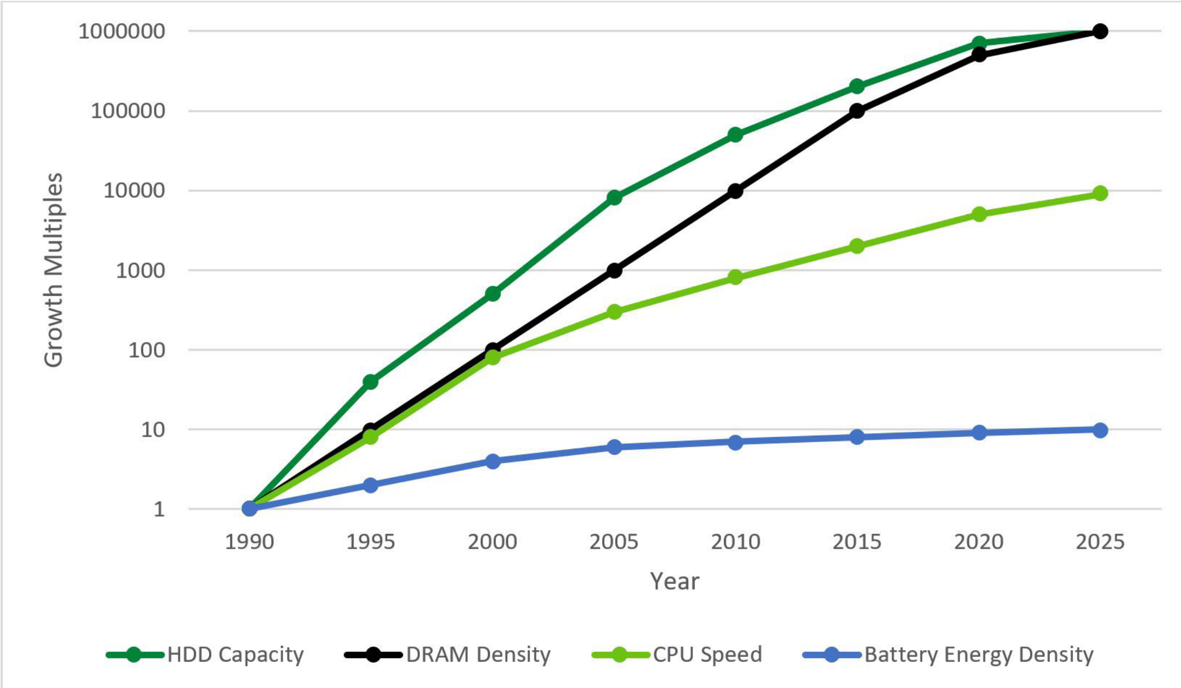


Fig. 5: Battery Technology Lags the Progress of other Technologies[89]

It is also worth noting that it takes up to three orders of magnitude energy to create a battery with a unit of energy. Thus, relying on battery technology improvements is not foreseen to offer the envisioned energy efficiency gains. Instead, techniques such as ultra-low-power and energy harvesting have been proposed as alternative sources for powering connected devices.

The process of conversion of ambient energy into electrical energy is known as energy harvesting.[90] Over the years, several techniques have been developed to harvest a number of different sources. Pairing energy harvesting with a true ultra-low-power interface may alleviate the device reachability and latency-vs.-battery lifetime trade-off. Ultra-low-power receivers would be capable of operating with a very low power consumption budget (e.g., 1 microwatt), ideally paired with a wake-up signal from RAN. This could enable "almost zero-energy" radio operations for cellular-connected IoT. Such a system would eliminate the need to draw battery power for downlink signal detection and processing, resulting in 100x to 1,000x times less power consumption and alleviating the need for battery replacement.

5

SUSTAINABLE AND CIRCULAR DESIGN CHOICES

A circular economy is a sustainability model designed to reduce resources utilized, as well as waste and emission production. It creates a model that balances material needs with the impact on the planet. The current economic model is linear and based on a take-make-waste/dispose model. It creates a considerable amount of waste and pollution in favor of speed and affordability. The current global economy has gone down 9.1% since 2019 levels and is only 8.6% circular as of 2021.[91] While the numbers are low, the market for more sustainable practices continues to grow.

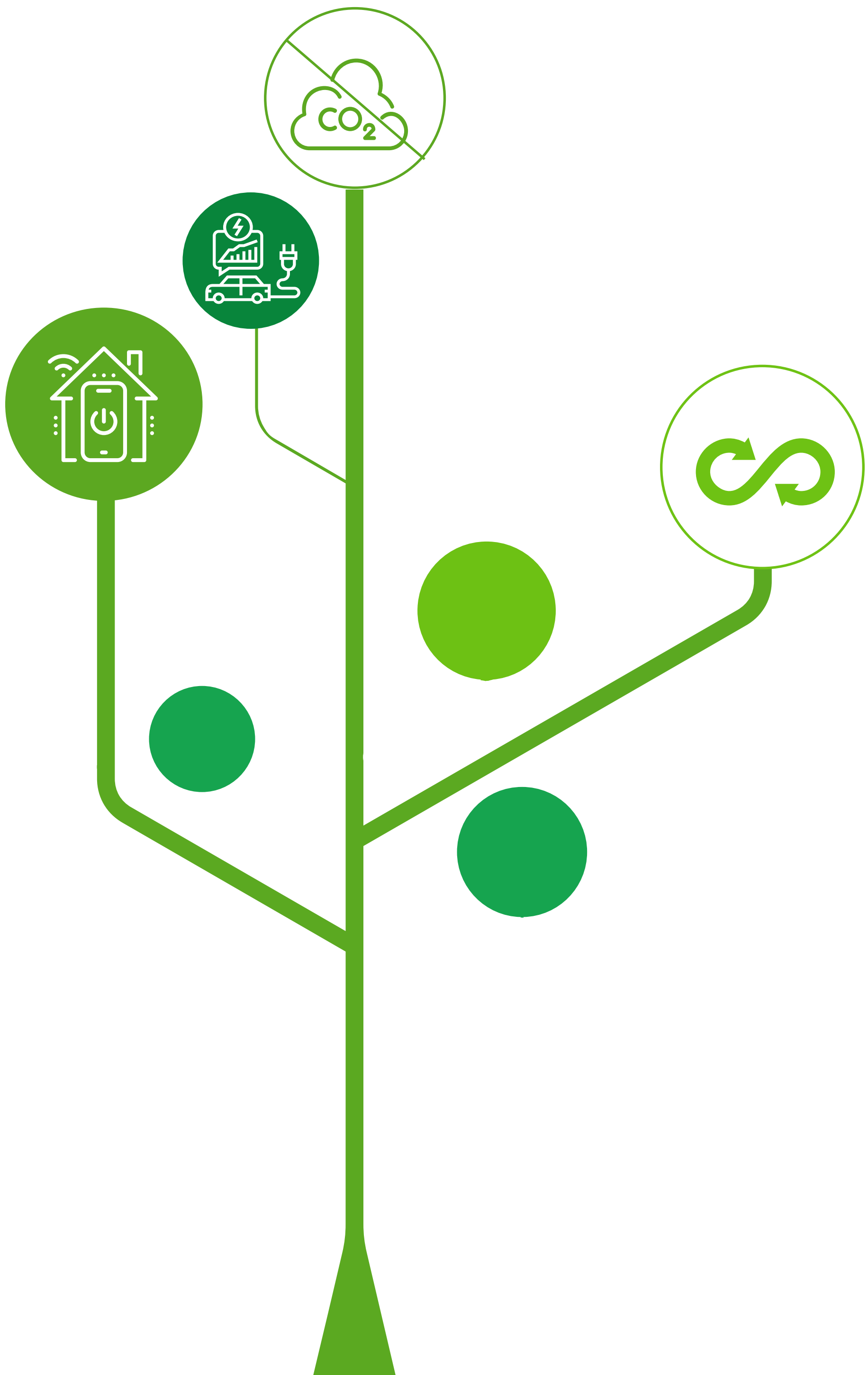
Proponents of a circular economy believe that it is possible to achieve high levels of sustainability while still having a profitable business and not having to reduce the number of products and services available. This concept is based on three principles:

1. **Designing low/no-waste products:**
    - Re-evaluate the materials used in electronics to maximize use of recycled material and recyclability. Short-term costs will be offset by gains in material reclamation. Studies suggest that up to 80% of a product's circularity may already be determined at its design stage.[92]
2. **Using products as long as possible:**
    - Make electronic devices easier to be refurbished and repaired. Recover component parts and re-use them to manufacture new devices.
3. **Preserving or enhancing renewable resources:**
    - Rapidly renewable resources, like bioplastics or green energy, can eliminate the use of non-renewable resources like petroleum plastics and diesel.

A McKinsey study of the European economy[93] found that a circular economy could increase GDP by 7%, meaning as much as US$2.1 trillion in the long run due to savings from material costs and new job opportunities and innovation. The Ellen MacArthur Foundation[94] estimates that circular economy activities could contribute as much as US$700 million in annual material cost savings to consumer goods production, along with a 48% reduction in carbon dioxide emissions by 2030.

Though challenging, investing in a circular economy can yield long-term benefits. Companies with a greater commitment to environmental, social and governance (ESG) benchmarking and reporting regimes continue to prove their ability to weather periods of uncertainty in the market better than their peers.[95] The global green technology and sustainability market is projected to grow from US$11.43 billion in 2021 to US$41.62 billion in 2028.[96] In parallel, consumers step up their effort to identify brands that reduce environmental impact (68% of U.S. consumers).[97]

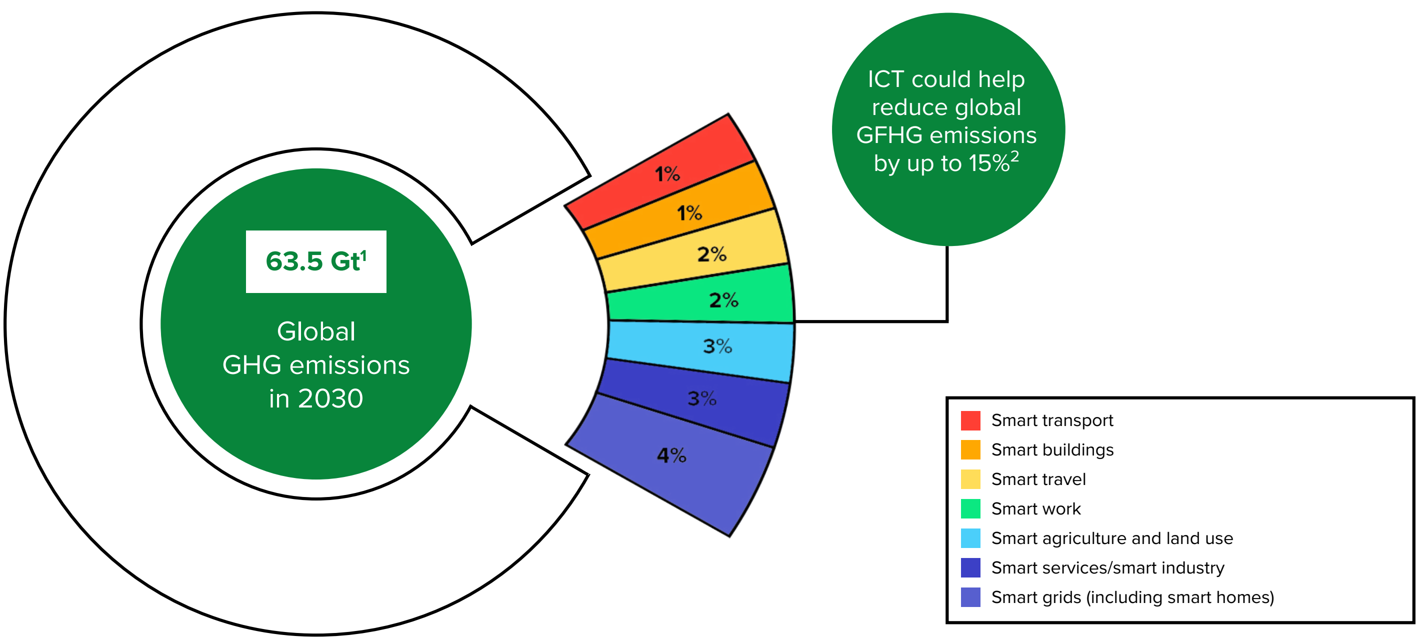
Market struggles caused by the COVID-19 pandemic have caused political pushes across the U.S. to return manufacturing, especially electronics manufacturing, to the U.S.[98] Rebooting an industry can come with benefits. Unlike currently dominant regions such as China and Taiwan, the U.S. does not have incumbent manufacturing plants that need to be expensively retrofitted. By combining these trends, North America has the opportunity to become a leader in sustainable manufacturing.



6

NEXT GENERATION MOBILE NETWORKS AS A SUSAINABILITY ENABLER

According to the Exponential Climate Action Roadmap, existing digital technologies can help reduce global carbon emissions by up to 15% by 2030.[99] This corresponds to more than the current carbon footprints of the EU and the U.S. combined.[100] With the ubiquitous availability of Fourth Industrial Revolution Technologies like Next G, IoT and AI, the pace of decarbonization can be accelerated. The roadmap report identified the digital sector as an "exponential technology." The ICT industry is currently responsible for approximately 1.8% to 3.9% of global GHG emissions[101] but has an outsized influence in enabling the decarbonization of key sectors in the global economy. It is important to keep emissions under control as the ICT industry continues to grow digital services that have potential to increase their footprint tenfold, to reduce energy and materials across the economy, and directly enable a third of the emissions reductions needed by 2030.



[1] Malmodin, J. and Bergmark, P. (2015), Exploring the effect of ICT solutions on GHG emissions in 2030, Proceedings for ICT for Sustainability Conference

[2] In a high reduction scenario based on the broad application of ICT in other sectors to drive efficiency and transformation. The sum of the individual sectors is around 16 percent, whilst double counting effects have been removed for the aggregated total of around 15 percent.

Fig 6: ICT an enabler to reduce GHG[102]

The increased heterogeneity of modern networks has also led to a growing ecosystem of IoT/edge devices. These devices tend to consume little power and can often survive harsh conditions. This enables the deployment of sensor networks, which allow for real-time monitoring of resource consumption. For example, soil moisture sensors allow the agriculture industry to reduce water consumption,[103] and vehicle fleet tracking technology allows delivery companies to track their trucks' emissions properties. In addition to preventative methods, IoT devices can allow for better monitoring of changes that climate change has already wrought, saving lives and property. Researchers at University of California Santa Cruz have examined using IoT to prevent forest fires,[104] which have grown more and more devastating each year in the North American West and Midwest.

The integration of Next G into products and processes could allow the creation of a greener economy (e.g., by using features such as ultra-low latency and extreme reliability). Key findings include:[105]

- **Reduction of GHG Emissions**: By 2025, mobile networs are expected to enable the reduction of 374 million metric tons of GHG emissions in the U.S. Overall, this represents an annual decrease of approximately 6%. Significantly impacted industries include transportation, manufacturing, energy, and agriculture.
- **Optimized Household Water Management**: Smart water systems can optimize household water management by 410 billion gallons in the U.S. This annual savings equates to water usage in more than 4 million homes.
- **Decreased Pesticide Use**: Networked drones for remote sensing and spray application can lead to a 50% decrease in the amount of pesticide use.
- **Optimized Energy Consumption**: C-V2X-enabled lane and traffic management systems can lead to up to 20% in fuel savings. Smart grids will reduce gas and electricity consumption by 12%. Automated train operation will reduce energy consumption by 20%.
- **Creating Green Jobs**: In the U.S., the deployment of Next G technologies will create as many as 300,000 new green jobs by 2030. The increasing adoption of industrial IoT solutions will create these new green job opportunities. For these solutions and their data to be handled properly, a reskilled workforce will be in demand.

For example, as Figure 6 shows, most smart work solutions such as videoconferencing and telepresence solutions like AR/VR can help reduce carbon emissions associated with business travel. The pandemic has become a digital tipping point. Nearly 60% of office workers foresee a permanent increase in online meetings with customers, suppliers, and colleagues – and need tools that better support remote interaction.[106] To understand the potential impact of decarbonization using ICT enabled smart work solutions, for the carbon emissions of a person making a transatlantic return flight, a smartphone could be used for over 50 years.[107] It is expected that the new generation of connectivity and intelligent technologies in 6G will further advance ICT technologies and further facilitate the shift towards global sustainable growth by means of smarter ways of operation, more immersive communications, advanced monitoring and analysis, and more granular control and management.

7

RECOMMENDATIONS

To establish North America as a leader in sustainable Next Generation (Next G) technologies, the Green G Working Group recommends a two-pronged approach that includes company operations, value chain, product and technology development, and a design to enable decarbonization of other sectors using ICT products and services.

COMPANY OPERATIONS, VALUE CHAIN, AND PRODUCT/TECHNOLOGY DEVELOPMENT:

a) Though challenging, every single company (including ICT) must transition to renewables as much as possible and become carbon neutral by 2050 or sooner.

b) Since ICT is an industry that other industries are built upon, and because of the high growth rate, companies should aim higher and become carbon neutral by 2040 or sooner.

- Innovation in green data centers, virtualization, network management techniques, and IoT energy consumption are all big focus areas for energy conservation, transitioning to renewables, and possible self-powered devices.
- Optimization across the radio and core network architecture, with new protocols and AI-based networks and service automation that minimize any unused resources, provide just-in-time network connectivity to meet the capacity needs of what is actually required.
- Design 6G hardware, software and the e2e system to treat energy as a first-class metric. Design future networks to provide accurate, high-fidelity, and real-time/near-real-time data on energy consumption.
    - This is essential for rapid prototyping, energy efficiency innovation, and catching errors.

c) Invest in sustainable supply chains and begin a transition to a circular economy.

- For cellular devices, the manufacturing process footprint exceeds that of the device footprint during its lifetime.
- Commit to reducing emissions across the company value chain in line with climate science and work with suppliers and business partners to halve emissions before 2030.
- Support supply chain partners by providing resources for implementing a robust climate strategy.[108]
- North America, and especially the U.S., has a renewed interest in bringing back domestic electronics manufacturing.
    - This is a great opportunity to re-design manufacturing processes from scratch to be more sustainable.
- Re-design devices to use more recycled, recyclable, and sustainable components.

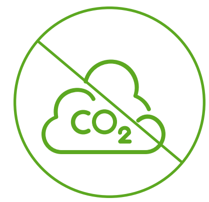
- Work with governments and partners to improve e-waste recycling to recover materials, especially rare materials.

DESIGN NEXT G TECHNOLOGIES TO ENABLE DECARBONIZATION OF OTHER SECTORS USING ICT PRODUCTS AND SERVICES.

a) Focus on research and innovation that leverages existing ICT (including 5G networks) to develop concrete applications that enable and magnify the impact of climate mitigation solutions.

b) Focus on research and innovation of Next G technologies in the following areas:

- Sensor networks (e.g., smart ag, fleet and building management) – IoT, low power, and inherently backscatter compatible 6G.
- Telecommuting.
- Smart grids and grid-interactive data centers.
- Micro grids, where devices can share and trade low levels of energy to prevent the need for batteries.
- Logistics (e.g., e-vehicle delivery to replace diesel).
- Zero-energy devices – a new opportunity in 6G.



The working group notes that the recommended research agenda is not exhaustive, but merely a starting point. Further, it is noted that these recommendations are very much in line with other ICT sustainability initiatives.[109]

To help achieve these aims, the working group recommends that the ICT industry support and engage in the development of sustainability-related international standards for adoption. It is also recommended that the industry implements accountability measures.

8

CONCLUSIONS

The latest report from U.S., Canadian, and international scientists, issued on August 9, 2021, is being heralded as a *code red* for the planet. Key findings of the report indicate the need for rapid decarbonization of global economy to avoid climate catastrophe.[110]

The ICT sector, including the data center industry, has made significant improvements over the last decade in reducing the overall energy consumption per compute and network traffic. However, the digital economy and new applications require ever increasing computational resources, connectivity and bandwidth, resulting in higher network traffic loads. Consequently, the overall energy consumption continues to increase. To achieve zero impact on total energy consumption, the ICT sector must accelerate its commitment to sustainability in line with the U.N. Sustainable Development goals (SDG) in a way that anticipates and factors in future effects.[111] [112] [113]

It is recognized that the ICT sector, with the use of Next G networks, will be crucial in enabling other sectors, such as agriculture and transportation, to reduce their GHG emissions.[114]

IT IS POSSIBLE TO BREAK THE ENERGY CURVE BY REDUCING MOBILE NETWORK ENERGY CONSUMPTION AND STILL MEETING TRAFFIC DEMAND.

This can be achieved by addressing all parts of the network holistically. If the next generation of mobile technologies are designed and deployed in the same way as previous generations, mobile network energy consumption would increase dramatically in proportion with the increase in mobile traffic. Therefore, the ICT industry needs to rethink how it designs, builds, operates, and manage networks by adopting smarter, more strategic and sustainable methodologies. Improvements such as hardware modernization, software-controlled power management and power-saving modes, and the introduction of AI-enabled energy efficiency measures, are all part of the solution.[115] In addition, the ICT sector also must accelerate the use of renewable and sustainable resources to further lower GHG emissions.

The global mobile sector is a leader in the race to eliminate carbon emissions. More than a third of mobile operators by revenue have met rigorous criteria set by the U.N.'s Race to Zero campaign and committed to net-zero emissions by 2050 at the latest. This includes 36% of mobile operators by revenue and 31% by connections. In addition, the wider industry is committed to this goal, including mobile network equipment and device manufacturers.[116]

In addition to transitioning to the use of green energy and improving energy efficiency to reduce GHG emissions, the ICT industry has an opportunity to participate more fully in the circular economy.

A way to participate may include performing Life Cycle Assessment (LCA) to measure and prioritize the mitigation of components of ICT that have the greatest impact on the environment (e.g., air, water, and land).

Other options include:

- Optimizing design to reduce environmental impacts.
- Using manufacturing alternatives (both process and materials) that reduce environmen-tal impacts and maximize energy and water efficiency.
- Reducing the use of rare, limited, or non-renewable natural resources and considering alternatives.
- Exploring options to reuse or recycle waste and water.
- Incentivizing device recycling and other responsible disposal methods.

CALL TO ACTION

- As 6G is being designed and deployed, it is critical for ICT companies — including mobile networks, fixed networks and data center operators (cloud-based and edge deployments) — to establish near and mid-term science-based targets for reduction of GHG emissions in accordance with internationally agreed sector-specific trajectory and guidance.[117] The ICT industry must further commit to achieving net-zero emissions targets for company operations as soon as possible. A number of companies have committed to 2040 or earlier.[118] [119]
- Aggressive sustainability objectives (e.g., limiting CO_2 emissions, reducing energy consumption, conserving water, and applying circular economy) must be set with commitment from the entire industry.
- Strategies for decarbonization of the ICT sector must include investing in and utilizing renewable energy, including sustainable onsite backup power generation, and improving energy performance of mobile network, data centers, and mobile devices. Furthermore, there must be a commitment to reducing carbon emissions associated with manufacturing of ICT products.[120]
- Deployment of Next G technologies is projected to occur after the 2030 target of 50% GHG reduction necessary to avoid the catastrophic impacts of climate change, so it is urgent to develop and deploy sustainable solutions with current ICT solutions. In parallel with research and innovation of Next G technologies, the ICT industry is urged to investigate avenues for leveraging currently available ICT solutions (including energy-efficientnetwork features) and partner with sectors and organizations developing and implementing climate mitigation solutions to achieve global sustainability goals.
- Companies within the ICT industry are urged to fully align with the above priorities within company visions, missions, business strategies and operations to meet expectations from investors, policy makers and other stakeholders.
- Legislators are urged to implement incentives and tax credits to actively support the ICT industry in advancing the recommendations outlined in this paper to create a truly sustainable Next G.

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APPENDIX: DEFINITIONS, ACRONOYMS & ABBREVIATIONS

For a list of common communications terms and definitions, visit the ATIS Telecom Glossary at https://glossary.atis.org

NEXTG ALLIANCE
an ATIS initiative

Building the Foundation for North American Leadership in 6G and Beyond

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