5G Connectivity

A Key Enabling Technology to meet America's Climate Change Goals

accenture

Commissioned by CTIA

Contents

Executive Summary

Recently rejoining the Paris Agreement in 2021, the United States set national targets to reduce net greenhouse gas emissions by 50-52% in 2030 and reach net-zero by 2050.[1]

This study illustrates the key role 5G telecommunications networks will play in the journey of the US to meeting its sustainability commitments. Until now, analyses primarily investigated previous-generation technology (4G LTE and below), upstream network efficiencies from 5G, or impacts outside of the United States. In this paper, we present a view of the impact 5G technology can have downstream in the US. We define downstream effects as those pertaining to technologies enabled or augmented by 5G technology (e.g., Internet of Things sensors) or from behavior changes stemming from increased 5G connection speeds. In this analysis, we conclude that 5G is poised to be the greenest generation of network technology yet.

Key Finding: 5G Abatement Potential

Technology-based solutions will play an important role in reducing carbon emissions as economies continue to grow and change. 5G networks will play a big part in helping industries reduce their emissions. Across industries, 5G networks will enable more downstream use cases because they are able to support more devices, which will create a multiplier effect when the network is used at scale. These networks can contribute to material reductions in the carbon footprint of the US and be the basis of newly imagined opportunities for sustainability.

In the United States, use cases on 5G networks are expected to enable the abatement of 330.8 million metric tons of carbon dioxide equivalents (MMtCO_2e) across five industry verticals by 2025, which is an approximated 20% contribution towards US emission reduction targets at this time. This is the same effect as taking 71.9 million cars off the roads for one year or eliminating the annual emissions from 83 coal-fired power plants.[2] Nearly 70% of this abatement will come from some of the biggest emitters today: 1) transportation & cities – 86.5 MMtCO_2e, 2) manufacturing – 67.4 MMtCO_2e and 3) energy & buildings sectors 67.9 MMtCO_2e, according to our estimates. Agriculture with 27.8 MMtCO_2e potential abatement, and working, living & health with 81.1 MMtCO_2e make up the balance.

330.8 MMtCO_2e
of 5G-Enabled Carbon Abatement by 2025

20%
Contribution toward U.S. 2030 Emission Reduction Target in 2025

Transportation & Cities	86.5 MMtCO_2e
Manufacturing	67.4 MMtCO_2e
Energy & Buildings	67.9 MMtCO_2e
Agriculture	27.8 MMtCO_2e
Working, Living & Health	81.1 MMtCO_2e

Unlocking Downstream 5G Use Cases

In this analysis, we investigate cross-industry 5G use cases that will help rethink and reshape sustainability for communities and economies. For example, in transportation and cities, 5G use cases will allow us to rethink the ecosystem of sustainable transportation. On the road, 5G can help drivers spend less time idling their cars in traffic because vehicle systems will be able to communicate with one another. When you get to your destination, drivers will have real-time data about available parking spots instead of having to drive in circles around a parking lot looking for a space. Use cases in this industry category can abate an estimated 86.5 $MMtCO_2e$ annually in the US by 2025, the equivalent of removing 19 million passenger vehicles off the road for a year.[3]

In manufacturing, 5G will help augment or speed up key processes, through remote inspections of assembly lines, predictive maintenance, and better inventory management. With 5G-enabled smart manufacturing, this industry can abate up to 67.4 $MMtCO_2e$ annually in the US by 2025, the equivalent amount of emissions generated from 17 coal-fired power plants in a year.[4]

With smart grids and buildings, 5G use cases will enable operators to improve efficiencies, by balancing the supply and demand of power generation. When energy companies add low-power sensors to their networks for monitoring, they will need less manual intervention when problems arise. These sensors, powered by 5G, will improve the collection and processing of performance data in power networks. With smart grids and smart buildings, an estimated 67.9 $MMtCO_2e$ of emissions can be abated cumulatively in the United States by 2025, equivalent to CO_2 emissions from electricity generated to power 12 million homes in a year.[5]

> 5G networks are a gamechanger for industries that have historically been emissions-intensive

Paths to Success

In the US, the mobile industry and 5G networks will play an important role in addressing climate change, as network carriers continue to densify and enhance 5G networks over the coming years across the country. These developments in more sustainable communications technology must be met with action from leaders across industry verticals to place sustainability at the core of their operating models and track their progress against their sustainability targets. They will need to foster new partnerships for 5G use cases within their ecosystems.

SECTION 01

The Climate Imperative

Mounting data and recent events have demonstrated that addressing climate change is a global imperative. The urgency is recognized at a national level. The US has set aggressive goals to reduce greenhouse gas emissions by 50-52% (from 2005 levels) by 2030 and to achieve net zero emissions by 2050.[6]

Addressing the climate reality

As climate change became part of political and business discussions decade after decade, leaders warned of the perilous future that climate change would bring, but few listened and even fewer acted. Now, that perilous future has arrived: Climate change is a problem that societies and economies around the world must solve collectively, or life as we know it will be radically different. People who live on coastlines will be displaced due to rising ocean levels, and agriculture and food production will be adversely affected by changing temperatures and humidity. Inaction is no longer an option. If the world does not stop the growth of greenhouse gas (GHG) emissions, we will all pay severe human, environmental, and economic costs.

The Intergovernmental Panel on Climate Change (IPCC) has assessed that the rise in mean global temperatures must be limited to less than 1.5˚C above pre-industrial levels to mitigate the most devastating impacts of climate change.[7] However, many climate experts believe too little has been done, and too late. Even if new emissions reduction targets announced by governments at the 2021 United Nations (UN) Climate Change Conference (COP26) are met in full and on time, the International Energy Agency (IEA) predicts that the mean global temperature would still rise by 1.8˚C by 2100.[8]

The difference between a 1.5˚C and 2.0˚C rise in the mean global temperature is significant: With a 2.0˚C rise, the projected reductions in global crop yields would double, the projected loss of plant species and decline in marine fisheries would likewise double. We would furthermore see a 29% greater decline in coral reefs, more than twice the amount of people would be exposed to severe heat, and we would see 10 times as many ice-free summers in the Arctic.[9]

We must do more, and it needs to be done quickly.

> We need to shift our mindsets: Sustainability is an important source of enduring competitive advantage. The communications industry has a large role to play in building sustainable and resilient infrastructure. Investing in 5G solutions will enable cities to better connect their infrastructure, devices, and people.

Jimmy Etheredge
CEO, Accenture North America

US Climate Objectives

In February 2021, the US rejoined the Paris climate accord, pledging to work with other signatories to limit the increase in global mean temperature to "well below 2.0˚C" above pre-industrial levels.[10] The US is currently one of the highest per-capita emitters of greenhouse gasses, emitting more than 6.5 billion metric tons of carbon dioxide equivalents ($MtCO_2e$), or 19.6 metric tons per capita, in 2019, according to the US Environmental Protection Agency (EPA). In April 2021, President Biden announced a new target for the US to achieve a 50-52% reduction from 2005 levels in economy-wide net greenhouse gas pollution by 2030.[11] This amounts to a reduction target of 3,067 - 3,190 $MMtCO_2e$ per year.

The White House further committed to achieving a 100% carbon pollution-free power sector by 2035 and a net zero emissions economy by no later than 2050.[12]

> This is the decade we must make decisions that will avoid the worst consequences of the climate crisis.

US President Joe Biden
at the White House Virtual Climate Summit (April 2021)[13]

These pledges are part of the White House's clean energy priorities under the Infrastructure Investment and Jobs Act. The version of the act passed by the US Senate in July 2021 includes $7.5 billion to build a national network of electric vehicle chargers, $73 billion for power infrastructure and clean energy transmission, and $65 billion for broadband development.[14] The Biden administration aims to reduce GHG emission reductions by one gigaton by 2030, with much of those reductions coming from advances in efficient energy and communication infrastructure. While initiatives within the Biden agenda will keep the US on track for its 2030 reduction targets, consumers and industry will still need to do their part to realize the GHG emission reduction targets.

COVID-19 and Climate Change

While the human, societal, and economic effects of COVID-19 have been well-documented, the long-run environmental effects of the pandemic may prove just as significant. Concerns about germ spread have led to a significant increase in single-use plastic-based items like gloves, disposable shopping bags, takeaway cartons, and utensils – the manufacturing of which leads to increased energy demand and in turn increased GHG emissions.[15]

At the same time, the pandemic also accelerated many lifestyle trends toward remote work and digital communications. As people around the world went into lockdown, offices closed, and commutes abruptly stopped or were significantly reduced. By the end of 2020, telemedicine urgent care visits had risen 490% globally, online transactions grew 75% globally, and 57% of US workers were working remotely.[16] In short, the COVID-19 pandemic underscored how crucial connectivity is for our modern infrastructure.

With this rise in remote working, consumer use of fixed broadband grew steadily during the pandemic, increasing by an average of 2.5 hours per day, and mobile usage increased by 1 hour per day. 5G can sustainably help meet the increased demand for data and can help bridge the digital divide in the US through means such as fixed wireless access (FWA). We look at more benefits of FWA later in the paper (see Working, Living, and Health).

The COVID-19 pandemic underscored how connectivity has become a crucial component of modern infrastructure.

+490% Telemedicine urgent care visits rose by 490% globally by end of 2020[16]

+75% Online transactions grew by 75% globally by end of 2020[16]

57% of US workers were working remotely by end of 2020[16]

SECTION 02

Introduction to 5G

5G builds upon existing network infrastructure to handle increased demand for data in an interconnected society. It is transforming industries and is changing the way businesses and consumers use mobile technologies, providing substantial processing and efficiency benefits that previous generations of mobile technology did not.

5G mobile communications networks are the foundational platforms that enable other emerging technologies to communicate. Technology providers across industries, from chipset makers to infrastructure and device developers, are bringing new capabilities to life on these networks. Compared to 4G networks, 5G can deliver up to 100 times higher bandwidth, greatly improved reliability, ultra-low latency, and connections for a much higher density of devices.

2G led to ubiquitous mobile phones, 3G helped put the internet in consumers' hands, and 4G provided increased bandwidth over 3G so that video streaming, navigation, and rich email over wireless networks became the norm. 5G will not only surpass 4G performance in terms of bandwidth but can efficiently support a greater number of connected devices. This will enable greater connectivity in the form of machine-to-machine (M2M) communication, bringing together the dimensions of speed, latency, and reliability across a managed network to support new use cases across all industries. 5G is the glue that enables the easy connection and interworking of a wide array of connectivity technologies. Network providers have already rolled out 5G networks across the country and will continue to densify and enhance these networks over the coming years.

The benefits of 5G will be felt across every corner of the United States. Accenture previous analysis indicates that with Smart City technology alone, 5G is expected to boost US GDP by $500 billion and create up to 3 million jobs by 2025.[17]

5G can deliver up to 100 times higher bandwidth, compared to 4G networks

5G Supporting Green Jobs

Green jobs is an all-encompassing term – it includes roles in traditional, sustainability-oriented jobs such as engineers installing wind farms and also includes jobs that support technology-based use cases in carbon abatement, like software engineers developing bike sharing programs. As firms across industry verticals look to embed 5G use cases and carbon abatement into their day-to-day practices, they will need the right human capital to deliver on it. Deployment of 5G enabled technologies are expected to create up to 300,000 net new green jobs in the US between 2021-2025.[18] This presents new opportunities for existing employees to ramp-up their relevant skills and interests in new roles but also for new employees to join the workforce.

300,000
net new green jobs

How 5G Drives Technical Efficiency Gains

5G can reduce carbon emissions through a more efficient use of energy per bit of data transmitted. We call this an "upstream" effect because of technical efficiency gains realized by the network itself. In addition to the upstream effect, widespread 5G adoption will bring a positive effect "downstream," or changes that result from behavior changes stemming from technologies enabled by 5G's higher speed or device throughput. We discuss the downstream effects in more depth in the Art of the Possible section of this analysis. There are five aspects within the upstream effects that help explain the energy-reduction possibilities of 5G on a per-bit basis.

Beamforming

allows antennas to focus the wireless signal to where the devices are located, reducing energy spent on broadcasting a signal in locations where no devices are currently in use

Massive Multiple-Input, Multiple-Output (mMIMO)

reliably increases the quality, throughput, and capacity of the radio link to use the same amount of energy to transmit more data

Millimeter Wave Spectrum (mmWave)

helps increase the amount of data that can be transmitted within a given signal, decreasing energy consumed per bit of data transmitted

Smart-Sleep Mode Technology

enables radio infrastructure to "sleep" when there is no traffic, thereby reducing energy consumption without sacrificing performance or reliability

Virtualized Radio Access Networks (vRAN)

will dynamically program and centralize computing resources such as operating and cooling servers, allowing greater economies of scale and reducing per-bit energy use

Three characteristics of 5G will help offset the increased costs stemming from growing network traffic levels, helping 5G to be the greenest generation of wireless networks yet.

01

Superfast Connectivity

5G delivers speeds that can match the experience of using a wired connection. These advancements are important because they allow the network to run more demanding industrial and business applications such as live video monitoring, augmented reality (AR), and virtual reality (VR). These use cases in turn facilitate a more seamless remote work experience.

02

Priority for Critical Services

5G provides more reliable, more secure, near-instant response times between the transmitter and the device. Current 4G networks, with latencies of 45 to 55 ms on average, are not fast enough to support crucial safety and quality specifications for many use cases, such as car-to-car communications for autonomous vehicles. 5G networks prioritize critical traffic, such as machine-to-machine (M2M) communications for health-care services, giving non-critical data like video streaming less priority. Reduced latency means greater potential for remote work and more reliable applications in industry.

03

Massive Connected Device Support

Since 5G can support more connections than older networks, it will better enable the Internet of Things, a network in which large numbers of devices communicate. In 2021, there were an estimated 185 million M2M connections in the US, and this number is expected to grow up to 279 million by 2025. Previous network infrastructure was not designed to support this increased use. 5G networks, on the other hand, are designed to support a diverse variety of IoT connections by providing the necessary bandwidth and latency, enabling the use of IoT in different settings and with different weather.

> The digital infrastructure threading its way through our communities and our businesses needs to be seamless and ubiquitous. Invest in digital infrastructure — make the move to 5G — and not only will all parts of our economy benefit, but our economy may well be reshaped as we finally bridge the digital divide.

Albert Tan
Global Sustainability Lead,
Communications & Media at Accenture

5G's low latency and high device throughput will allow for high-speed wireless connections where wired connections were previously required. This allows for a greater number of devices and sensors to be connected and communicate with each other over wider expanses in near-instant time, leading to safer, more reliable connections for applications from smart manufacturing to smart transportation. An increasingly-digitalized infrastructure powered by 5G will allow for new automated processes and energy saving opportunities previously unseen with prior generations of wireless networks.

How 5G can help reduce emissions downstream

To isolate the contribution of 5G-enabled carbon abatement towards national emission reduction targets, Accenture developed a model that quantifies the avoided or reduced carbon emissions enabled by 5G mobile technology use cases across other industry verticals. The analysis found that by 2025, the 5G-enabled use cases laid out in this report would make possible up to 330.8 MMtCO_2e in annual carbon abatement – equivalent to removing 71.9 million passenger vehicles off the road for a year or carbon sequestered by 633,000 square miles of US forests in a year.[19][20]

This study's model adapts the methodology of the GSMA, the global association of mobile network operators, published in "The Enablement Effect" to calculate the potential of 5G-enabled carbon abatement.[21] Our model assumes a baseline in which 5G networks have been deployed to a considerable degree (surpassing 4G) and further deployment of 5G infrastructure would not result in a material enablement of additional applications. We assume that 5G is easier to scale than its predecessors with the deployment of small cells. For a full list of assumptions and the methodology please refer to the appendix.

We considered five industry verticals in the model due to their current emission levels and ability for 5G to make an impact: transportation and cities, manufacturing, energy and buildings, agriculture, and working, living, and health. In each industry vertical, we only considered the most significant use cases that would be enabled by 5G. For a use case to qualify as crediting 5G for carbon abatement, the use of mobile technology must have resulted in either the avoidance or reduction of travel-related emissions or energy consumption within an industry vertical. We identified 31 use cases that apply.

In 2025, 5G use cases can abate up to...

330.8 MMtCO_2e

... across five industry verticals

- Transportation & Cities
- Manufacturing
- Energy & Buildings
- Agriculture
- Working, Living & Health

The 5G-enabled carbon abatement potential varied between the 31 use cases in the study, and consequently between the industry verticals as well. The total US 5G-enabled carbon abatement is the sum of carbon abatement across the 31 use cases.

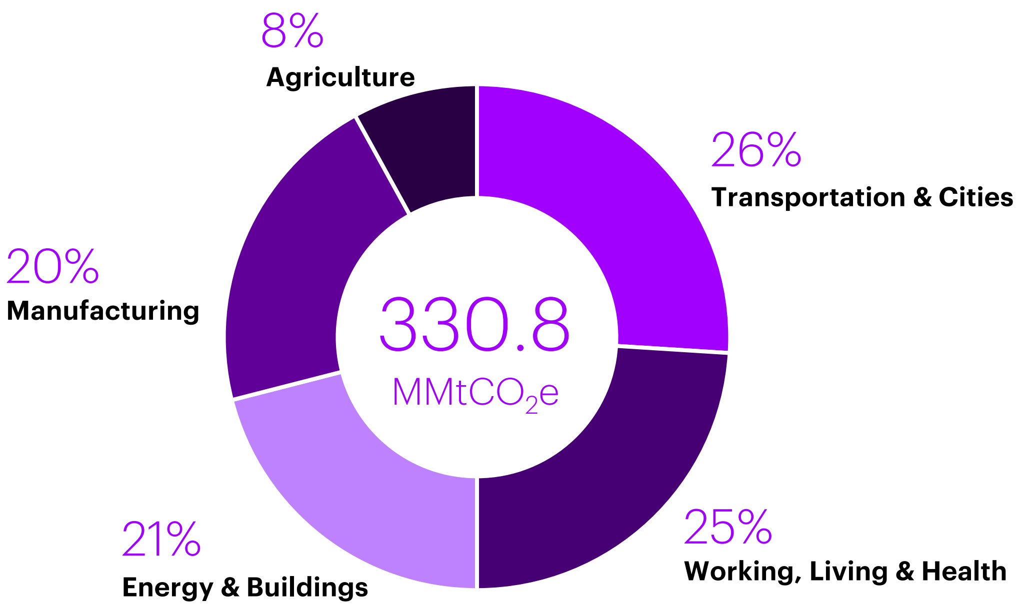
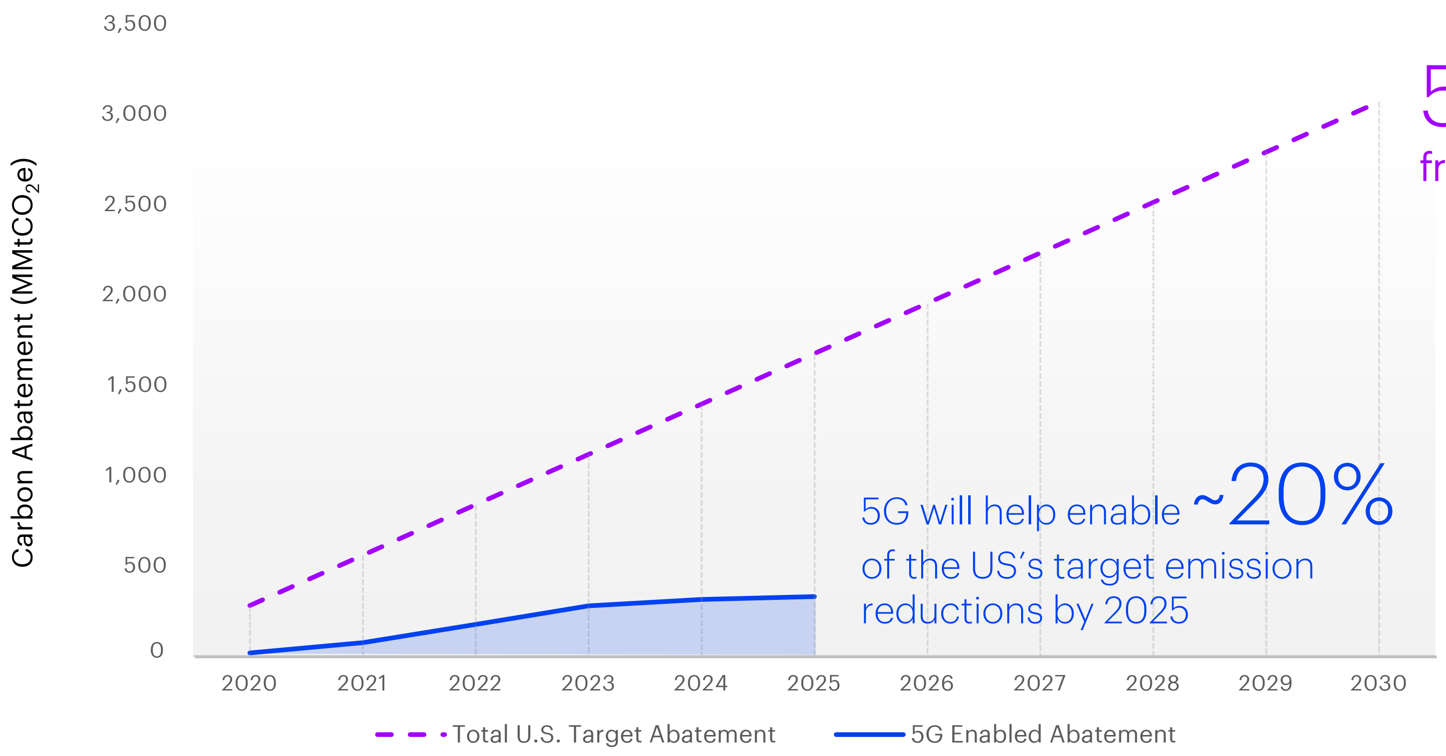


Figure 1
5G-Enabled Abatement Potential by Industry in 2025

> Current global emissions targets will only be achieved through the acceleration of innovative technologies, enabling industries to pivot their organizations towards sustainable operations. Digital technology may be the most powerful, scalable tool the world has to tackle climate change, and 5G is at the forefront of this effort.

Peters Suh
North America Industry Lead,
Communications & Media at Accenture



50-52% target abatement from 2005 emission levels by 2030

While the list of use cases is not exhaustive, it captures a material portion of 5G enabled carbon abatement in the US. By 2030, the United States needs to reduce emissions by 3,067 to 3,190 $MMtCO_2e$ to meet its annual emission reduction target.[22] Assuming a straight-line path to the 2030 emissions reduction target, this would mean the United States needs to abate 1,673 $MMtCO_2e$ in 2025. With the 5G base case abatement totaling up to 330.8 $MMtCO_2e$ in 2025, 5G use cases can contribute approximately 20% toward the estimated U.S. targets in 2025.

Figure 2

Straight-line Path to US 2030 Avoided Emissions Targets

Wireless Industry Pledged Actions

Several US operators have incorporated sustainability as a central tenet in their operations, pledging various forms of carbon footprint reduction. Carriers such as AT&T, Verizon, and T-Mobile have all made pledges of carbon neutrality by 2035 at the latest. They have also identified Scope 1 and 2 emissions as the primary focus of their endeavors.[23 24 25] Scope 1 emissions are direct emissions from facilities owned by an organization, while Scope 2 emissions arise from facilities that provide an organization with heating, cooling, steam, or electricity.[26]

To reduce Scope 2 emissions, telecommunications companies can most easily source energy from renewables rather than fossil fuels. For example, Verizon is a leading corporate buyer of U.S. renewable energy, entering into purchase agreements totaling approximately 2.6 GW of projected renewable energy capacity.[27] AT&T announced renewable energy purchases will surpass 1.5 GW of clean energy capacity.[28] Meanwhile, T-Mobile has committed to buying 100% renewable energy by the end of 2021 as a member of RE100, a global initiative committed to 100% renewable electricity.[29]

> Going greener starts with infrastructure.

Jim Gowen,
Chief Sustainability Officer, Verizon [30]

> T-Mobile [has been] on track to power our business and network with 100% renewable energy by the end of 2021.

Mike Sievert,
Chief Executive Officer, T-Mobile [31]

Equipment manufacturers such as Ericsson, Nokia Corporation, Intel Corporation, and Qualcomm have pledged to reduce their Scope 1 and 2 emissions by as much as 40% in the coming years. Ericsson has deployed artificial intelligence (AI) solutions for traffic prediction to enable mMIMO sleep mode and to support service providers to reduce their site energy consumption by 15%.[32] Nokia has focused on reducing energy consumption for operators with its single RAN solution, enabling 45% lower consumption compared to standard sites for 2G, 3G, and 4G networks. It has also developed a photonic service engine chipset which can increase the capacity of its networks by 65% and reduce their power requirements by 60% by generating wavelengths that are more resilient to noise and other impairments.[33]

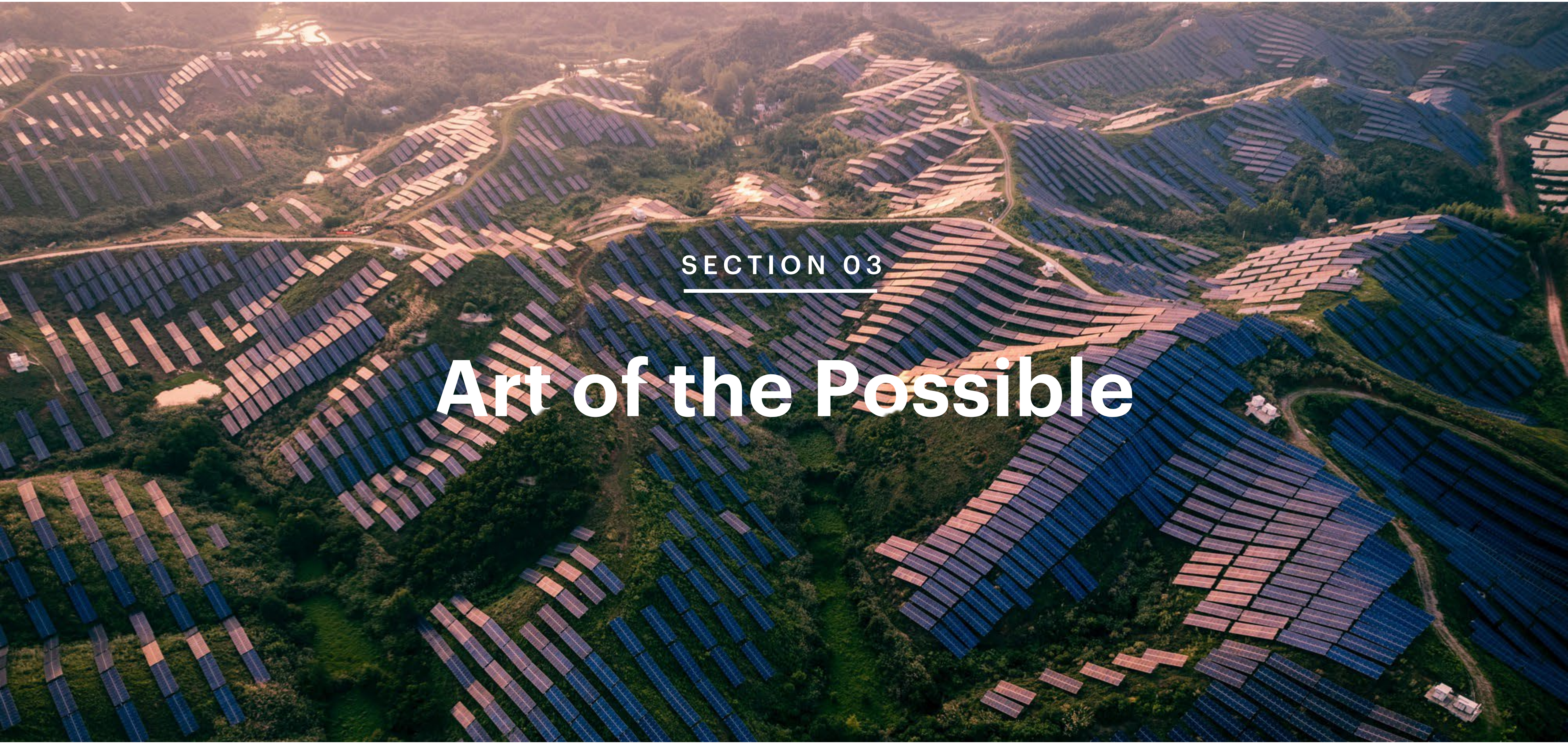
E-Waste Mitigation

Many wireless industry manufacturers and operators have also announced plans to combat e-waste, recognizing the impact that the growth in connected devices may have. U.S network operators such as AT&T, Verizon, and T-Mobile actively reuse and recycle their electronic waste and work with vendors certified for responsible recycling standards.

AT&T follows Restriction of Hazardous Substances (RoHS) Directive and the Waste and Electrical and Electronic Equipment (WEEE) Directive for disposal.[34] Verizon works with e-Stewards or vendors certified in R2 standards for recycling wireless devices and accessories. In 2020, it recycled or reused more than 35.6 million pounds of e-waste.[35] In 2020, T-Mobile collected more than 7.9 million devices such as phones, smartwatches, tablets, hotspots, and IoT items for reuse, resale, and recycling. A Gold member of the Sustainable Materials Management Electronics Challenge, T-Mobile works with R2 standard certified vendors as part of its recycling program.[36]

Equipment manufacturers like Cisco have a product recycling program for end-of-life products with certified, contracted recyclers. Cisco actively engages with customers who can return end-of-life equipment at no cost and encourages employees to responsibly recycle test equipment and lab material through its eBin/Lab Scrap program.[37] Intel's Reverse Logistics Group employed circular strategies to take back electronics from customers leading to <1% of returned product materials ending in landfill and enabling $30M in added value in 2020.[38]

> Ubiquitous connectivity — nationwide broadband, which includes 5G access, for businesses everywhere — has the power to help scale technologies, dramatically accelerating business efforts to reach their climate goals.
>
> **Charlene Lake**
> Chief Sustainability Officer, AT&T [39]



SECTION 03

Art of the Possible

This analysis was performed across five industry verticals in which 5G will have significant downstream carbon abatement potential. We focused most closely on transportation & cities, manufacturing, and energy & buildings, due to their current emission outputs and the potential for 5G to have a material impact on abatement.

While emissions reductions in this analysis are focused on the US, we highlight use case examples from around the world to demonstrate what can be done in the US.

Transportation & Cities	86.5 MMtCO_2e
Manufacturing	67.4 MMtCO_2e
Energy & Buildings	67.9 MMtCO_2e
Agriculture	27.8 MMtCO_2e
Working, Living & Health	81.1 MMtCO_2e

Transportation & Cities

86.5 $MMtCO_2e$

abatement in transportation & cities sector

The Current State of Transportation

In 2019, the transportation industry contributed 29% of greenhouse gas emissions in the US, the highest of any sector.[40] Of these emissions, 58% were due to passenger cars and light trucks, both of which are highly inefficient yet pervasive.

The number of vehicles in the US is projected to increase from 280 million vehicles in 2021 to more than 300 million vehicles by 2030.[41] Without intervention, the transportation sector will continue to produce unsustainable levels of emissions, derailing the nation from meeting its emission reduction goals. With the projected increase in vehicles on US roads, the likelihood of gridlock and idling increases. In the US, the aggregate emissions total from the idling of vehicle creates 30 million tons of greenhouse gas emissions every year, according to the US Department of Energy.[42]

Beyond passenger traffic, shipping & logistics traffic is also a leading contributor of CO_2 emissions in the US. Truck freight accounted for 62.7% of all US shipping in 2018, according to the US Bureau of Transportation Statistics.[43] As ecommerce continues to expand rapidly (particularly in suburban and rural areas), freight traffic is unlikely to decline. Reducing the emissions from delivery vehicles is key, and the transition to cleaner energy sources and energy-saving technologies such as autonomous driving systems and car-to-car communications is even more crucial.

A 5G-Enabled Transportation Ecosystem

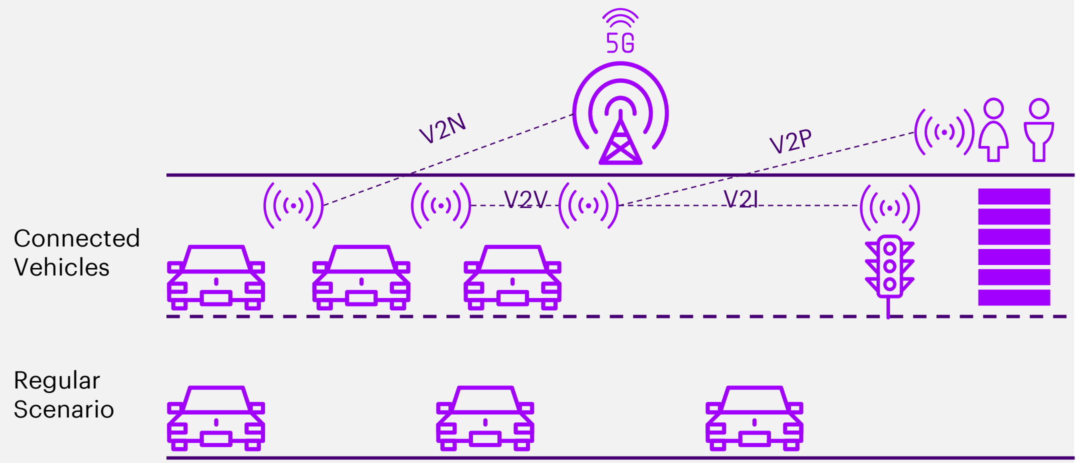
Smart transportation enabled by 5G makes vehicular communication, autonomous driving, tele-operated driving, and intelligent navigation possible through technologies such as mMIMO and small cells deployed on streets and highways.

5G also enables applications in Cooperative Intelligent Transport Systems in which autonomous vehicle systems communicate with each other and cooperate to handle traffic more efficiently. With 5G, these systems can cause a car's brakes to be applied within only 2.5 cm.[44] Such improvements in safety will lead to more widespread adoption of emission-reducing autonomous vehicle systems.

A connected traffic cloud can enable vehicle-to-everything (V2X) communication, where "everything" includes other vehicles, pedestrians, and transportation infrastructure, such as traffic lights and signs. V2X can improve the efficiency of traffic flow and ensure safer travel with the help of sensors on vehicles which capture data about the vehicle, traffic, pedestrians, and the weather.

Communication between traffic lights can optimize wait times at junctions and reduce idling, which can directly translate to lower fuel consumption and carbon emissions. It also helps in maintaining a consistent speed which contributes to improved fuel economy and thereby reduced consumption.[45]

Public transportation, ride-sharing and bike-sharing can reduce transportation emissions significantly, since more than 72% of professionals commute alone to work in the US.[46] 5G can make cloud-based IoT systems possible for the physical infrastructure in such car-sharing applications, improving the user experience and thereby helping the spread of such applications.



V2X – Vehicle to Everything; V2N- Vehicle to Network; V2V- Vehicle to Vehicle; V2I – Vehicle to Infrastructure; V2P- Vehicle to Pedestrian

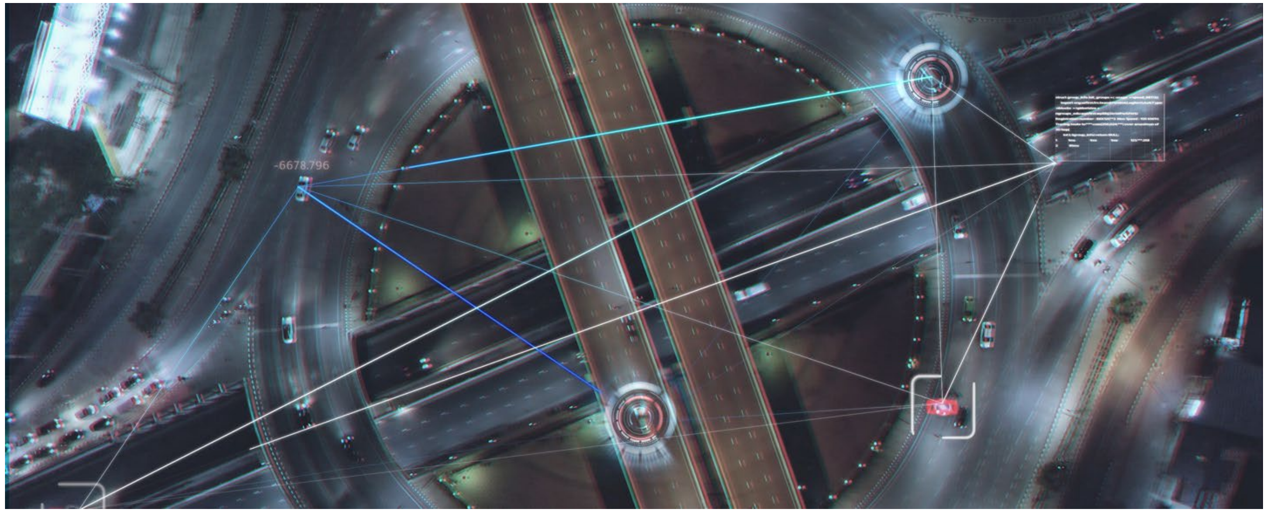
Connected Vehicle Communication

Abatement Impact Estimate

By 2025, it is estimated that the total carbon abatement potential of use cases in this industry can amount up to 86.5 $MMtCO_2e$ for the US, which is 26% of the overall total abatement made possible by 5G. This comes from an array of use cases within the sector, ranging from loading optimization and fleet management for logistics companies, to augmenting usability and reliability of bike sharing programs.

While the applications of 5G are vast within transportation and cities, we will dive deeper on two examples – traffic congestion management and usability of public transit (inclusive of ride sharing). Traffic congestion management by way of navigation apps can lead to a potential abatement of 10.7 $MMtCO_2e$ by 2025 while augmenting the usability of public transport can abate up to 6.3 $MMtCO_2e$.

The number of connected cars (passenger cars with embedded connectivity) is expected to grow annually at 10% between 2020-2025 in the US.[47]



Use Case Spotlight: Traffic Congestion Management

5G can help reduce traffic through applications such as vehicle platooning, smart parking, and augmented navigation.

In vehicle platooning, vehicles are connected to each other and act as a unit so that when the lead vehicle detects an obstacle and brakes, it communicates that to the trailing vehicles, which then brake in unison. This can lead to fewer collisions and more fuel-efficient and lower-emission driving. Vehicle platooning, enabled by vehicle-to-vehicle (V2V) communication, helps reduce air drag by 20-60%, resulting in fuel savings of 25% and CO_2 emissions reductions of up to 16% for trailing vehicles and 8% for the lead vehicle, according to Accenture's research.[48]

New York City has been investing in a network of cameras and sensors at more than 10,000 city intersections as part of a connected vehicle pilot program to manage traffic in real time.[49]

In Europe, the Swedish truck manufacturer Scania has been at the forefront of implementing connected vehicle technology for truck platooning. With support from the network gear maker Ericsson, it has developed systems to enable trucks to join and break off from chains to reduce air drag and fuel consumption, leading to lower emissions. Scania has begun to use 5G to enable truck platooning and optimize routes and schedules, according to Ericsson.[50]

Smart parking, or real-time data about parking spots, helps drivers easily find spots and avoid congestion and idling. These applications are possible with 5G-enabled sensors placed on utility cabinets and lamp posts.

More than 200 million vehicles will be connected to 5G networks by 2025. In 2020, 91% of new passenger car sales in the US were connected vehicles, and by 2025 nearly 100% of new vehicles will be connected to the internet.[51 52]

10.7 $MMtCO_2e$ = Emissions from 1.2 billion gallons of gas consumed annually

The first 5G-connected cars are expected to be on US roads at the beginning of 2022. By 2025, 5G-enabled cars are expected to make up 27% of new vehicles sold.[53]

5G can enable augmented navigation via an intelligent transportation system in which sensors integrated in transportation infrastructure, such as lights and signals, monitor traffic in real time, providing the necessary data for navigation apps to redirect traffic and reduce congestion. These applications seem to be catching on: the US Department of Transportation's Federal Highway Administration recently awarded the University of Michigan $9.95 million to develop smart intersections at 20 locations across the city of Ann Arbor.[54]

In Spain, the Cereixal tunnel has been outfitted with 5G coverage to assist drivers with information on the weather at the exit, construction, congestion due to accidents, obstacles, pedestrians, and other vehicles such as emergency vehicles, slow moving vehicles, and oncoming vehicles. The smart tunnel uses vehicle to everything (V2X) communication, IoT, edge computing, and a 5G network supported by Telefonica in partnership with Nokia, Ineco, Stellantis, the CTAG (Automotive Technology Centre of Galicia), and SICE.[55]

Use Case Spotlight: Smart Public Transportation & Ride-Sharing

To get more people using public transit in the US, it will need to be connected and easier to use. When people use public transit, they are responsible for 55% fewer GHG emissions, compared to driving or ride hailing solo.[56] In 2018 in the US, public transit saved 63 $MMtCO_2e$, when considering that trips are typically shorter and less frequent, according to the Center for Neighborhood Technology.[57]

The opportunity to improve public transit and have it used more widely in the US is huge. 5G can support by enabling minute-by-minute updates on the location of buses and trains, and the number of available seats, thereby increasing passenger trust and utilization. Real-time schedules and updated timetables can help commuters plan their travel in advance, leading to more reliance on public transport. Transit operators can optimize bus inventory and enable dynamic bus routing, reducing idling.

6.3 $MMtCO_2e$ = Emissions from 1.4 million vehicles taken off the road for one year

> 5G means that location is no longer a constraint on presence and human intervention is not a constraint on decisions.
>
> **Andrew Walker**
> Global Industry Lead, Communications & Media at Accenture

5G-enabled autonomous vehicles may boost the adoption of public transit as a means of ride-sharing, as municipalities can make them available for the "last-mile" in a public transport network. These vehicles will be important in large metro areas, where people are more dependent on individual passenger vehicles. Ride-sharing services are poised to make use of advancements in autonomous driving technology. Cruise, a California-based autonomous vehicle startup, was recently licensed by the city of San Francisco to provide its beta users with fully autonomous vehicles for ride-hailing services.[58] 5G will enable more vehicles to connect and communicate with each other and the infrastructure with greater reliability and lower latency.

In Stockholm, the city is testing 5G-connected autonomous electric minibuses for ride-sharing. 5G, with its high data transmission rates and low latency, supports the system by enabling remote monitoring. Telia, a Nordic communications service provider, is involved in the project along with Ericsson and Intel.[59]

Manufacturing

67.4 $MMtCO_2e$
abatement in manufacturing sector

The Current State of Manufacturing

Manufacturing is the third largest contributor to US GHG emissions and accounted for 23% of total emissions in 2019, according to the EPA.[60] Emissions from manufacturing are direct emissions from the operation of facilities for regular business (known as Scope 1 emissions) or indirect emissions from the electricity sourced by manufacturers (known as Scope 2 emissions). Like other sectors, manufacturing can reduce its own Scope 1 emissions by improving energy efficiency and it can reduce Scope 2 emissions by sourcing clean energy.

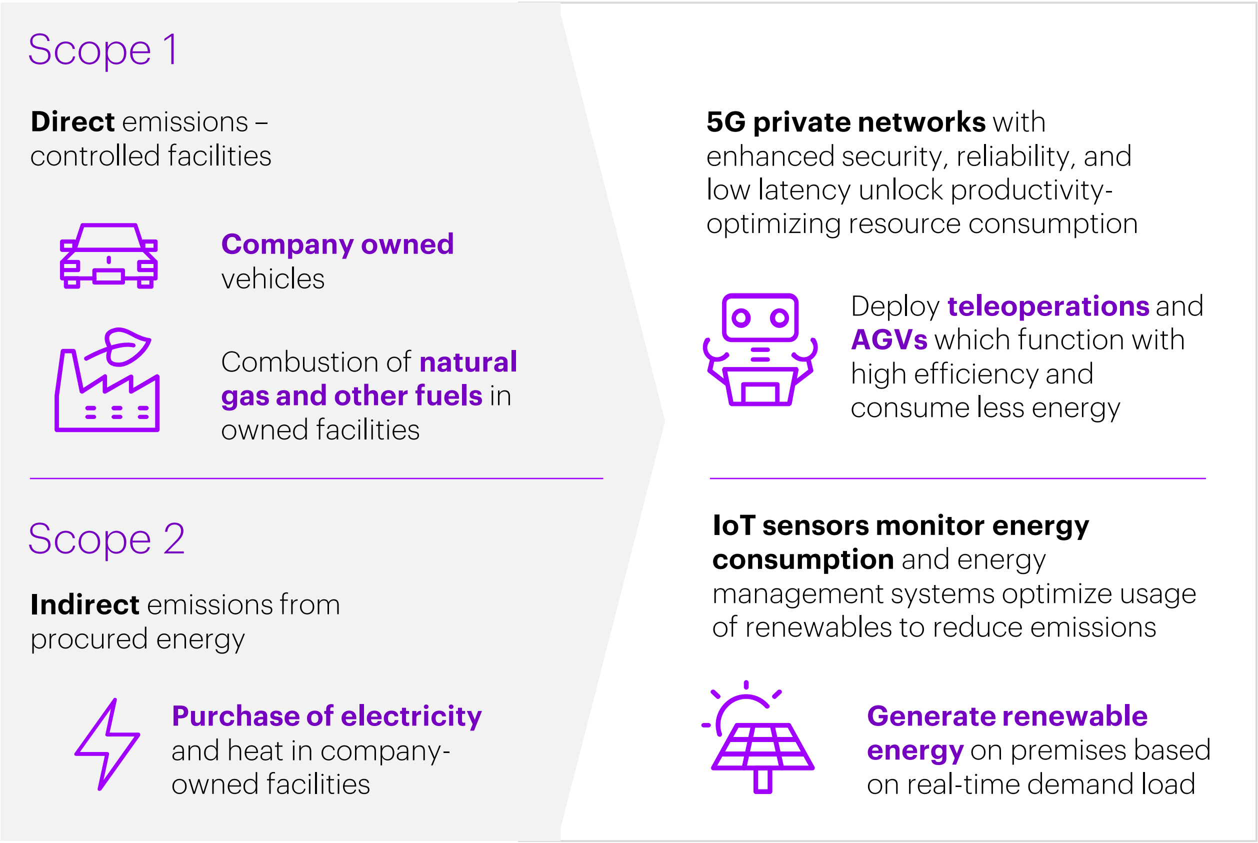


Figure 3

5G Smart Manufacturing For Carbon Abatement

A 5G-Enabled Manufacturing Ecosystem

With its enhanced reliability and security, 5G enables mission-critical manufacturing applications and makes it easy to add and remove machines from an active network.

With production lines, machinery, and warehouses that have enhanced connectivity, companies can lower their operational costs, including the amount spent on energy. For instance, they can use 5G to monitor energy consumption more readily and optimize the timing of when energy is consumed to avoid peak times.

Adoption of 5G in manufacturing is expected to be fastest among those companies that do high-volume and low-margin production and those that are required to report on certain production parameters for regulatory or security reasons. These companies often need to trace the manufacturing of goods, which is made easier with 5G.

Abatement Impact Estimate

Manufacturers with 5G-enabled digital factories can reduce emissions, increase efficiency, and become more productive than others due to real-time monitoring of production processes and predictive maintenance. In addition, through remote operations, they can avoid travel and the associated emissions.

With 5G-enabled manufacturing, by 2025, the inventory management use case has the potential to reduce carbon emissions by 67.4 $MMtCO_2e$ in the United States. Based on model forecasts, by 2025 use cases in this sector can contribute 20% of the total 5G-enabled carbon abatement across all use cases.

The impact of enabling this abatement in the manufacturing sector is the equivalent to the CO_2 emissions from 156 million barrels of oil consumed or the carbon that is sequestered by 83 million acres of U.S forests in one year.[61]

Use Case Spotlight: Asset Monitoring and Predictive Maintenance

In manufacturing, real-time data about machines, or assets, and analytics of that data can improve productivity and thereby energy efficiency. For example, digital twins make it easier to monitor and operate assets remotely and avoid travel. Supervisors can remotely inspect assembly lines with cameras and a simulation of the physical environment. Experts can guide remote teams as they commission equipment in the field. All of this is made easier with 5G.

Predictive maintenance enabled by 5G can also abate emissions by helping companies reduce unplanned downtime, which is costly and leads to more on-site visits from technicians. With the help of 5G connectivity, sensors on equipment can provide real-time data about machine performance and be used to identify potential problems, making it easier to plan and optimize maintenance schedules.

AT&T has demonstrated three smart manufacturing use cases with 5G, edge computing, and IoT-based video surveillance. At one of its demonstration sites, manufacturers can implement solutions to see how they work to identify defective products, based on preset specifications, and to receive real-time notifications about production accuracy.[62]

Use Case Spotlight: Process Augmentation

Process augmentation is used by manufacturers to manage repetitive tasks that are labor-intensive and/or potentially dangerous. 5G can make process augmentation more effective by connecting multiple sensors and monitoring data in real-time, to help avoid lapses in human judgment and to improve operational efficiency.

5G-enabled process augmentation can be used for quality inspections, thereby saving manufacturers time and energy and reducing the risk of product recalls, which result in increased emissions.

Sensors and high-quality cameras, combined with 5G, AI, and edge servers, can enhance the quality inspection process. Telefonica Germany, in association with Ericsson, deployed a private 5G network in 2020 to manage a production line for Mercedes Benz. It created an integrated digital manufacturing ecosystem, linking machines and equipment together with sensors that transmit data via 5G. The system helps reduce emissions through improved production.[63]

Verizon installed 5G Ultra Wideband at Corning's fiber optic cable manufacturing facility in North Carolina to implement factory automation and quality assurance.[64] Taqtile, an AR solution provider cofounded by T-Mobile, partnered with Timberline Communications to perform cell site upgrades and maintenance using AR headsets. The headsets enabled frontline workers to view virtual service checklists and troubleshoot using remote assistance.[65]

> With the installation of a local 5G network, the networking of all production systems and machines in the Mercedes-Benz Cars factories will become even smarter and more efficient in the future. This opens up completely new production opportunities.

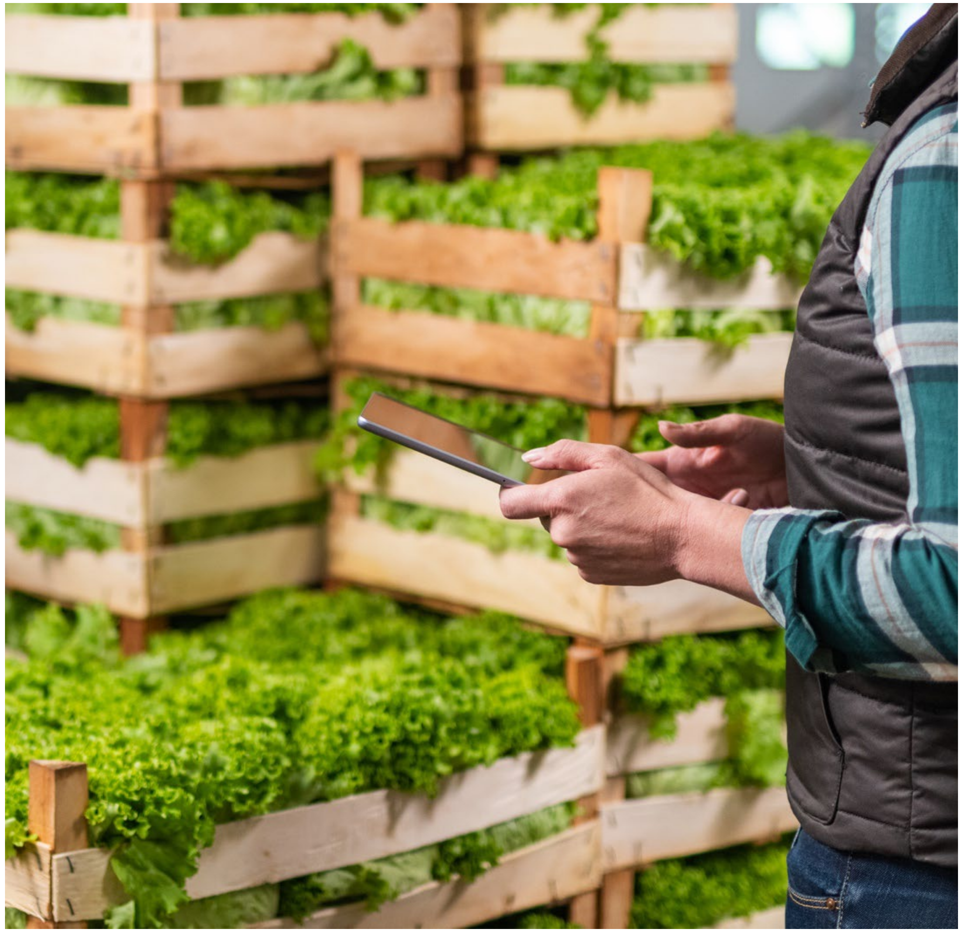
Jörg Burzer
Member of the Divisional Board of Management of Mercedes-Benz Cars, Production and Supply Chain [66]

Use Case Spotlight: Inventory Management

Inventory management optimizes the amount of inventory required for efficient business operations. When a warehouse contains less inventory in an off season, it ultimately leads to less energy needed for lighting and cooling.

Lineage, a food warehousing and distribution company with locations across the US, used 5G sensors in 2020 to collect data about the cooling of its warehouses and improve energy efficiency within them. It reduced yearly energy consumption by 33 M kWh within its first year and with it, the company's Scope 2 emissions.[67]

67.4 $MMtCO_2e$ = Emissions from 156 million barrels of oil consumed



Energy & Buildings

67.9 $MMtCO_2e$

abatement in
energy & buildings sector

The Current State of Energy & Buildings

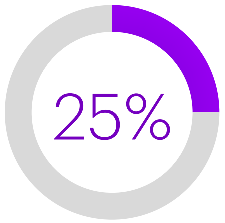
Understanding the efficiency challenges of electricity generation, electricity consumption, and electricity transmission are critical for creating and adopting carbon abatement solutions related to energy and buildings. On the supply side, electricity production alone contributed 25% of GHG emissions in 2019 in the US. It is the second highest sector in terms of emissions. Some 62% of electricity was generated from fossil fuels such as coal and gas.[68] Demand for electricity is expected to increase, leading to CO_2 emissions from petroleum, natural gas, and coal of 4.8 bn tons annually by 2050.[69]

The U.S. Energy Information Administration (EIA) calculated losses from electricity transmission and distribution (T&D) in the US and found that 5% was lost from 2016 to 2020.[70] A grid that operates with information about real-time demand will lead to production efficiencies and be able to incorporate a higher share of renewables, which will improve the sustainability of the entire value chain.

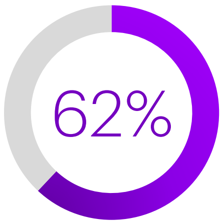
On the demand-side, inefficient or inadequate Heating, Ventilation, and Air Conditioning (HVAC) controls in commercial or industrial buildings leads to poor management of heating and cooling, which, along with overuse and wasted lighting, can lead to unnecessarily higher energy consumption at scale.

The same inefficiencies can be recognized in residential buildings, both single family and multi-unit dwellings, over extended periods of time.

Many use cases for connected technology in buildings and the energy sector that could turn this around have not yet been implemented due to limitations in latency, too few devices supported, or the need for wired data connections. To fully realize the energy savings and emissions reductions possible within buildings, devices and sensors must be able to seamlessly integrate into a scaled network architecture.



of GHG emissions in 2019 in the US was from electricity production



of electricity generated from fossil fuels such as coal and gas in production

5.2 bn tons of CO_2 emissions estimated from petroleum, natural gas, and coal in the US by 2050

A 5G-Enabled Energy Ecosystem

Improved efficiency in grids and buildings comes primarily from two sources: 1) better grid optimization and 2) better demand management.

In both cases, 5G will play a key role in making grids and buildings smarter, enabling companies to monitor both production and consumption in real time with little manual intervention. For a grid to be smart, it must safely and seamlessly integrate power generated by multiple sources in an optimal way. And to manage demand better, companies need real-time data about consumption to make estimates for optimal production.[71]

The range, latency, and device capacity characteristics of 5G offer a generational leap in the technological performance needed to collect and process data from across power plants, transmission lines, meters, and buildings. 5G enables two-way communication between devices, which help smart grids optimize the generation and transmission of energy to meet demand as it arises. Transmission and distribution losses can be reduced by identifying points of loss and enabling predictive maintenance and fast fixes. We expect this will be done with secure, private 5G networks, which companies can also use to run their buildings more efficiently.

Abatement Impact Estimate

5G use cases reduce emissions by creating energy savings via real-time monitoring, enabling more use of renewable energy, and reducing travel with remote operations.

Our calculation shows that 5G use cases in energy and buildings will total 21% of all analyzed 5G-enabled carbon abatement in the US by 2025. At that point, the 5G use cases in smart energy can enable up to 5.4 $MMtCO_2e$ emissions reduction while 5G use cases in smart buildings can enable 62.5 $MtCO_2e$ emissions reduction.

Building energy management systems, commercial HVAC controls, and smart meters potentially contribute annual carbon abatement of 11.1, 32.2, and 19.2 $MMtCO_2e$, respectively, in smart buildings. Additionally, smart grids and renewable microgrids (solar and wind) can contribute 3.0 and 2.3 $MMtCO_2e$ respectively to carbon abatement from smart energy.

The carbon abatement from smart buildings and energy by 2025 (67.9 $MMtCO_2e$) is equivalent to the electricity needed to power 12.3 million homes in one year.[72]

Use Case Spotlight: Building Energy Management Systems and Smart Meters

Heating, Ventilation, and Air Conditioning (HVAC) account for one-third of a building's energy use on average, according to the US Department of Energy.[73] 5G-enabled temperature and motion sensors can detect the temperature, air quality, and number of people using different spaces in a building to automatically adjust these factors in real time to conserve energy.

Similarly, Energy as a Service (EaaS) solutions are made possible with the enhanced network connectivity of 5G. EaaS can reduce electricity costs and thus emissions by up to 20-50%, according to Accenture research.[74]

Washington State's Peninsula Light Company partnered with Verizon to replace old meters with smart meters to remotely configure, monitor, and manage end points on a near real-time basis, reducing the need to travel to end points for servicing.[75] The network is currently using a 4G LTE connection. When enhanced to 5G, response times will improve, and more devices can be connected.

AT&T is using an energy and building management solution across 250,000 of the locations it manages, including 2,500 buildings in which staff work. It helps the company collect data from 80,000 HVAC units to optimize heating and cooling.[76] Using smart meters in residential and commercial settings can improve planning for energy demand. Such solutions exist now and will only get better and more pervasive with the widespread rollout of 5G.

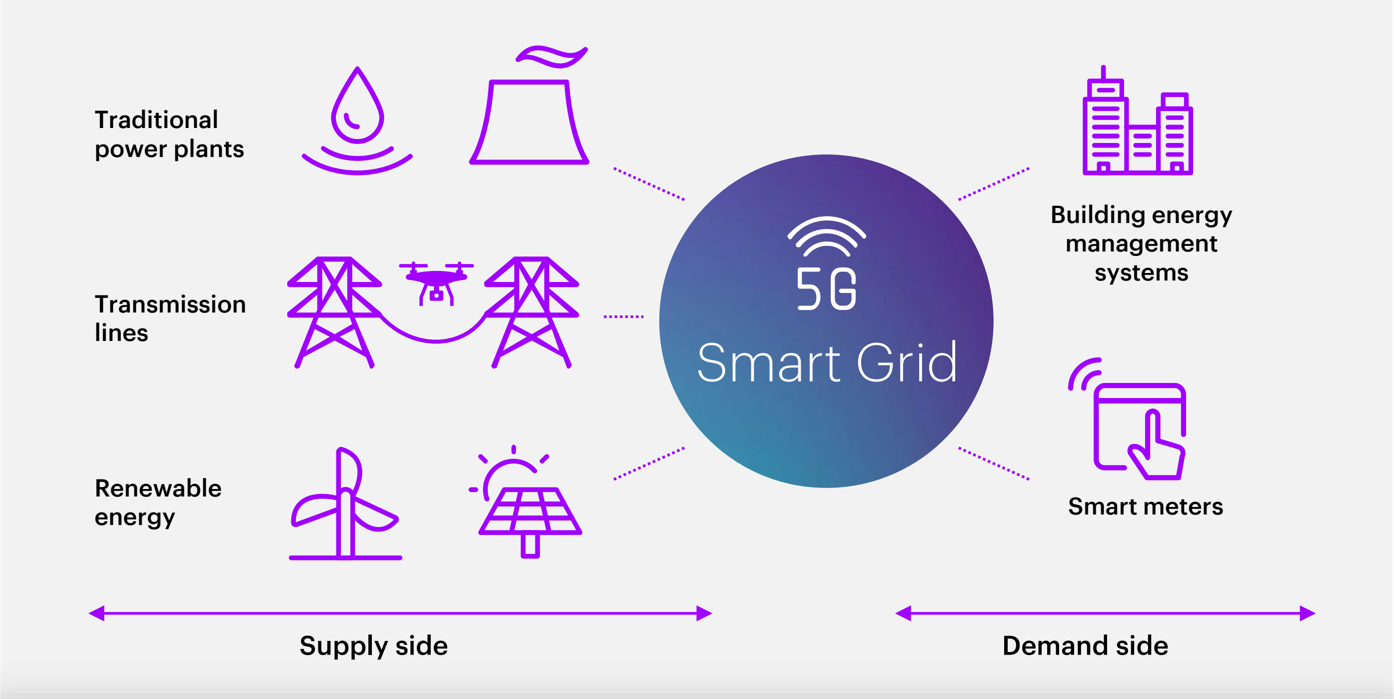
62.5 $MMtCO_2e$ = Emissions from 11.3 million homes' electricity use for one year

Use Case Spotlight: Smart Grids and Renewable Energy

5G's high throughput and low latency can help integrate clean energy sources like wind into the grid. In the UK, Fine Energy, a British renewable energy producer, has shown it can help reduce emissions through the remote control of wind turbines. 5G in remote areas, where wind parks are usually located, also helps reduce the number of trips technicians must take to the sites.[77]

The New York Power Authority (NYPA) is piloting a private wireless LTE network for test flights of drones that will remotely inspect transmission lines.[78] The NYPA is working together with Nokia on the pilot. Applications already being tested with earlier technology are expected to become more stable, scalable, and efficient once 5G is widely available.

Figure 4 **Smart Grid**



5.4 $MMtCO_2e$ = Emissions saved from changing 205 million incandescent light bulbs to LED light bulbs

Agriculture

27.8 $MMtCO_2e$
abatement in
agriculture sector

Agriculture

In the US, agriculture contributed to 10% of GHG emissions in 2019, mostly via livestock such as cows, agricultural soils, and rice production, according to the EPA.[79]

Emissions growth in this sector is driven by both consumers and producers, as the population grows, and producers and companies seek to expand their operations to meet demand.[80] Another source of emissions and wasted resources are inefficiencies across the agricultural value chain.

5G has the potential to reduce sector-wide emissions by supporting multiple use cases in smart agriculture. 5G's high bandwidth, low latency, and support for high device density mean the industry can adopt new connected technologies that improve agricultural productivity and reduce the waste of resources, thereby abating carbon emissions. In our model, we estimate that by 2025, 5G for connected crop management can contribute up to 27.8 $MMtCO_2e$ in carbon abatement annually – the equivalent to removing emissions from burning 30.7 billion pounds of coal during that same timeframe.[81]

Some examples of use cases where 5G can increase efficiency are precision farming, smart farm machinery, pesticide spraying via drone, and weed and crop monitoring.

For instance, using sensors with real-time monitoring enabled by 5G connectivity can limit emissions from the agriculture sector by reducing the number of times people must travel to agricultural sites.

Devine Organics, a California farm, and WaterBit, a remote irrigation planning service, partnered with AT&T to help asparagus farmers deploy small solar powered sensors across the fields to monitor the crop and soil.[82]

Farmers were able to control when and how long the crop was watered through a smartphone app. This reduced the number of times they had to drive to and through the fields, which in turn realized an estimated 5% GHG emissions reduction in the first season of use. In another instance, T-Mobile launched access to a 5G network and edge computing platform for two agricultural sites in Snohomish County, Washington. On-site soil sensors relay temperature, water content, and oxygen levels, providing greater insight into resource usage while reducing the need for in-person monitoring.[83]

Working, Living & Health

81.1 $MMtCO_2e$

abatement in
working, living, and health sector

Working, Living & Health

5G will help increase work-life balance and help people manage their health, while reducing the need for travel. Increased device throughput, reliability, and connection speeds will enhance the ability of many workers across the US to adopt or continue with remote work. 5G promises to reach many homes – particularly in rural areas – that were previously unserved with high-speed internet through fixed wireless access (FWA). Instead of using fiber-optic or cable lines running into households, FWA uses wireless links between fixed points, such as a carrier's cell tower and an antenna on a customer's roof.

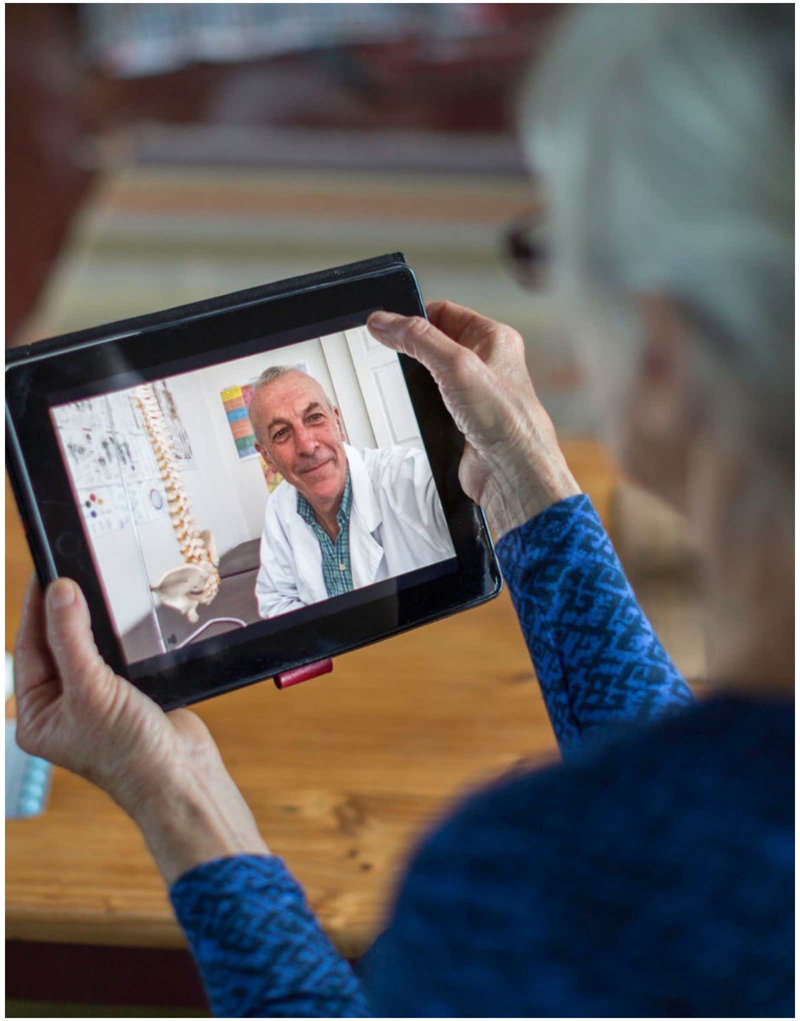
In our model, we project that 28.7 $MMtCO_2e$ of potential abatement will come from increased teleconferencing and work from home capabilities, of which 2.7 $MMtCO_2e$ will come from 5G fixed wireless access to more rural residents.[a] The potential abatement of 28.7 $MMtCO_2e$ is the same as the emissions generated from powering 5.2 million homes with electricity for one year. We further project that by 2025, remote work enabled by 5G fixed wireless access, can save around 187 million hours annually in US commutes, which amounts to over 6.7 billion miles annually.

> 5G fixed wireless access will save the average rural commuter 121 hours or 4,600 miles a year through teleconferencing and remote work

[a] Savings from fixed wireless access teleconferencing and work from home were calculated by using average commutes as measured from the 2019 American Community Survey from the US Census Bureau, and census tract-bade classification (RUCA) codes to classify areas by population density and journey-to-work commuting characteristics.

Not only will 5G help reduce the amount of travel for work, but also for health consultations and follow-ups. 5G will enable new extended reality (XR) technologies, which in turn make telemedicine like an in-person consultation. The increased use of telemedicine is not only a win for previously underserved remote communities who can now access top quality health professionals in the comfort of their homes, but it also reduces emissions, as patient and health staff will travel far less.

In California, the University of California Los Angeles (UCLA) hospital system provides qualifying patients with computer tablets as part of post-surgical recovery disease monitoring kits. This allows staff to remotely receive updates about recovery using videos of incision sites and data taken from monitors and oximeters provided in the kit. The UCLA healthcare team can then proactively detect problems such as fluid retention and negative reactions to medications without requiring the patient to travel to a clinic.[84] While the UCLA use case was deployed with prior generation network technology, we can expect 5G to increase the speed, quantity, and reliability of virtual telemedicine capabilities.



SECTION 04

Paths to Success

More must be done to drive the abatement of greenhouse gases. Technology enabled by 5G is a key tool that many industries can use to contribute to a greener future. Business leaders in these industries can take immediate actions to chart the path towards this future. We have four suggestions to get started.

Develop and integrate a sustainability strategy and track against it

It will be impossible to efficiently capture the energy-saving effects of 5G, if they are not part of a larger sustainability strategy focused on changing behaviors. Leaders must first be able to assess their organization's track record for environmental, social, and governance (ESG) indicators. In performing such an assessment, leaders must account for the effects their organization has on all stakeholders. They must also select strategic initiatives to pursue and KPIs to measure them against, based on evolving customer needs, technological advances, climate imperatives, and the regulatory environment. Ideally, organizations determined to implement sustainability at their core will establish a value realization office to manage the ESG performance process. Finally, leaders must work across the organization to capture and make sense of vital ESG data to gain real-time visibility into the impact they are having, to make better decisions, and to report to stakeholders.

Design operating models with sustainability at its core and technology as its enabler

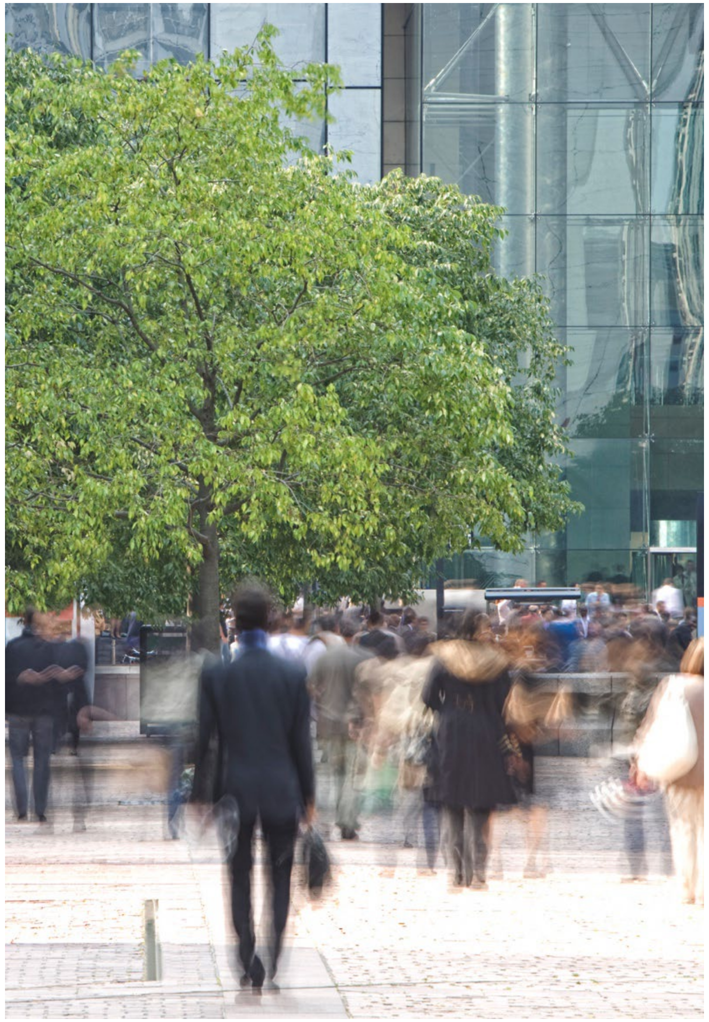
Leaders need to identify where they can reduce the most emissions (both Scope 1 and Scope 2) with 5G-enabled technologies by identifying use cases that are relevant for their organizations. Leaders then need to map such use cases against the current way of working to understand what will need to change to make the organization more sustainable. Some leaders will discover that operations need to be made leaner, perhaps through divestments. Among the things leaders need to do, they should: assess value propositions for customers, optimize their portfolios toward net-zero, and explore non-traditional growth opportunities, including partnerships. They must consider how the chosen path will impact the business model over the near and long term to understand if the transition will be incremental or fundamental.

Recharge innovation as an organizational imperative

Best-in-practice sustainable organizations will not only capitalize on energy-saving use cases enabled by 5G, but they will establish a culture of ongoing innovation to develop future-proof business models and ways of working. Leaders will create an environment that encourages and rewards the sharing of ideas and solutions that consider sustainability alongside innovation. They must continuously reassess R&D capabilities and implement digital transformation programs. Leaders must aim to become digital pioneers that use technology for operational efficiencies, new products, and business models.

Collaborate and rethink the ecosystem to boost the common good

To implement carbon abatement-enabling technologies across entire industries and geographies, companies and organizations will have to work together. This is especially true for stakeholders in historically harder-to-abate industries. Organizations will need to reimagine their ecosystem partnerships — within the sector, across sectors, with governments, and with enablers in the wireless communications industry. This may even mean working alongside competitors to bring about sector-wide change. To reap the benefits, we will need an ecosystem of cross-sector and technology partners working together to reengineer the current system. Leaders must identify partners with complementary skills across industries with whom they can develop joint offerings and go-to-market strategies. Organizations and stakeholders across the sector should consider establishing consortiums to share ideas, funding, and resources.



Appendix

How 5G Drives Technical Efficiency

Beamforming

Beamforming is a technique that uses advanced antenna technologies both within the mobile device and in networks' base stations to focus a wireless signal in a specific direction rather than broadcasting to a wide area, helping to increase channel efficiency and data transmission rates while reducing interference. By focusing transmission signals directly at client devices, beamforming can reduce energy consumption per bit of data transmitted. Research published in the European Scientific Journal found that 5G networks using beamforming consume approximately four times less power than comparable 4G networks.

Massive Multiple-Input, Multiple-Output (mMIMO)

Massive multiple-input, multiple-output (mMIMO) is a radio antenna technology which deploys multiple antennas in an array at both the transmitter and receiver to increase the quality, throughput, and capacity of the radio link. mMIMO uses techniques known as spatial diversity and spatial multiplexing to transmit independent and separately encoded data signals. Spatial diversity (SD) is a technique in which each antenna receives a slightly different version of the signal, which can be combined algorithmically to improve the quality and reliability of the transmitted signal.

Working together with SD, spatial multiplexing (SM) works on the capacity front by allowing multiple data streams to travel simultaneously through the same frequency band. This means that multiple messages can be transmitted simultaneously without interfering with one another. Given this streamlined process, spectral and energy efficiency can be significantly improved. Industry experts explain that if one were to spatially multiplex 10 users with double the energy spend, then that process is still five times more energy efficient than the alternative without it.

Millimeter Wave Spectrum (mmWave)

The existing reliance on older networks is likely going to place a burden on efficiency gains arising from the shift to 5G technology. Millimeter wave spectrum (mmWave) is one way in which these losses can be minimized. mmWave refers to the spectrum of wavelengths above 24 GHz, and its utilization is expected to increase the volume of data which can be transmitted, as well as decrease the overall energy spend on this transmission. Furthermore, this data will travel through new mmWave "overlay" cells, which are smaller and easier to power, and increase the efficiency of existing 3G/4G/5G macro cells. This powerful capacity to overlay cells will serve to ease issues which arise from running a 5G network simultaneously with older networks.

Smart-Sleep Mode Technology

5G New Radio (NR) technology brings new capabilities to radio infrastructure – allowing them to “sleep” when there is no traffic. LTE technology currently does not support this function and must consume power through the active transmission of idle signals (e.g., synchronization signals, reference signals, and system information), even when there is no demand on the base station. As a result, the current process causes significantly greater energy consumption. The shift to 5G and new “sleep state” capability will ensure lower energy consumption, without detriment to performance or capacity.

Virtualized Radio Access Networks (vRAN) & Network Function Virtualization (NFV)

Network Function Virtualization is a general term to describe the processes that decouple software from hardware. These processes are an essential building block for network slicing, which is a technology central to various key 5G use cases. One such application of NFV is through Virtualized Radio Access Networks (vRAN), in which baseband functions are virtualized on commodity server hardware. By centralizing computing resources, vRAN networks take advantage of economies of scale inherent to large data centers through centralized cooling, lighting, and electricity purchasing agreements.

vRAN also makes the network programmable, allowing for dynamic bandwidth adjustment that will enable increased energy efficiency. Virtual networks are more energy efficient because resources use can be scaled down when there is less demand on the network and less power is being used. Furthermore, when demand increases, vRAN helps ensure that there is less over-provisioning and wasted power on unused resources.

Abatement Methodology & Assumptions

Overview

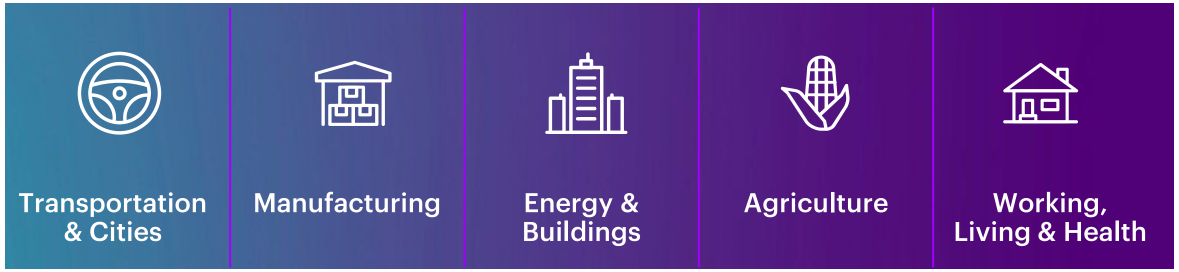
The Accenture model is an adaption of the published methodology and use case analysis created by GSMA in "The Enablement Effect" report.[85]

Avoided Emissions [kgCO2e] = **Avoided Emissions Factor [kgCO2e/QTY]** x **Quantity [QTY]**

The focus of this study is on the carbon abatement opportunities presented by 5G across industry verticals in the US. Accenture has developed a carbon abatement model to quantify the incremental opportunity that 5G provides.

We compiled 31 use cases in which 5G can be used to reduce carbon emissions. We selected those device types to include in use cases that will have the most material impact in carbon abatement across all industries.

Every use case falls under one of the following five broader industry verticals:



In approaching the model, a couple of necessary assumptions were made upfront. First, this model assumes as a baseline that 5G networks have already been widely deployed. Second, since data volumes are on the rise, we assume data demand and consumption will continue to grow in the period for which we are making forecasts. Our estimates represent the upper bound of a "business as usual" because:

1. Induced demand from 5G rollout could increase economic activity and drive up energy consumption to meet this demand
2. The number of connections may overestimate the number of users because each user could have multiple connections

Abatement Methodology & Assumptions

Below are the definitions and variable-specific assumptions or forecasts used in the Accenture model:

Avoided Emissions Factor [$kgCO_2e$/QTY] x **5G Driven Quantity [QTY]** x **5G Downstream Enablement** = **Avoided Emissions [$kgCO_2e$]**

Avoided Emissions Factor

The avoided emissions factor represents avoided emissions generated per unit of mobile technology. In most use cases, the factor is either in terms of $kgCO_2e$/ M2M connection or $kgCO_2e$/ smartphone. For our analysis for the US, the avoided emissions factor is considered equivalent to the North America avoided emissions factor stated in the GSMA report.

Since the GSMA report was produced in 2018 when 5G networks were not widely available, the Accenture model assumes GSMA's avoided emissions factor reflects 4G and prior technologies.

5G Driven Quantity

The 5G-driven quantity in most use cases can be tied to one of two types of quantities: 1) the number of M2M connections or 2) the number of smartphone users.

1) M2M connections for each use case (in the US) are calculated by applying the percentage of 5G M2M connections in the US to M2M connections in North America of respective use case reported in the GSMA paper

2) For smartphone users, smartphone connections (from GSMA) are used as a proxy. Smartphone connections for each use case (in the US) are calculated in the same way as M2M connections in the above case

5G Downstream Enablement

The 5G Downstream Enablement variable is used to account for the greater potential 5G has in unlocking downstream applications over 4G and prior generations. In the model, a higher 5G Downstream Enablement variable was used for use cases where the quantity variable was a M2M connection. With real-time capabilities and low-latency data transmission, 5G supports existing M2M connections better and makes possible use of new, innovative smart technologies that previously could not be supported by 4G and prior networks. In this way, on a per connection basis, 5G networks enable each M2M connection to do more and therefore increase the abatement potential of the use cases.

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