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Achieving sustainability in a 5G world

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EXECUTIVE SUMMARY

In September 2015, the United Nations established new global sustainable development goals. In this far-reaching and ambitious initiative, the international body made a commitment to "protect the planet from degradation, including through sustainable consumption and production, sustainably managing its natural resources and taking urgent action on climate change, so that it can support the needs of the present and future generations".[1]

In this paper, I examine the ways in which technology enables public protection, resource management, and overall sustainability. As the world faces major conservation and environmental challenges in terms of water and air quality, energy and transportation, and building design, technology advances are underway that will help people deal with these problems. Understanding the scope of these challenges is vital to determining ways to mitigate their negative consequences and understand which emerging technologies are going to improve service delivery and further economic opportunity.

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5G, THE INTERNET OF THINGS, AND SUSTAINABILITY

The development of 5G broadband technology aims to provide data hundreds of times faster than current wireless technology while enabling less latency in response times. This vision is made possible thanks to the coming together of advances in computing and communications. The network architecture of 5G will enable the expansion of the cellular internet of things and it aspires to bring together a range of existing and new technologies, cloud-based storage, as well as a wide range of newly connected devices and services.[2]

5G will be built on virtualized networks with new multi-radio connectivity to intelligent devices. Innovations in the use of new spectrum and the processing power for new waveform algorithms will allow 5G to facilitate new services and these new services are also made possible with the aid of network innovations such as: Network Functions Virtualization (NFV) and Software Defined Networking (SDN) that allow these new technologies to be programmable across the various parts of a network; Mobile Edge Computing that works to eliminate the latency of going back to the core

of a network for services; and network slicing technology which is going to allow service providers to create multiple virtual networks within the air interfaces. All of this software will divide the network into virtual spaces that support an array of different personalized services.

This network is going to feature billions of sensors, intelligent management through advanced networks, and sophisticated learning through real-time data analytics. In conjunction with supportive policy action, these networks will improve environmental sustainability and help to safeguard public health. Before going into greater detail as to the technological solutions that emerging and advancing technologies can provide, though, an examination of the immediate environmental and sustainability challenges is needed.

SUSTAINABILITY CHALLENGES

WATER AVAILABILITY, USE, AND QUALITY

Water is a limited resource in communities around the world. "Only three percent of the world's water is fresh and two-thirds of that small percentage is not accessible …. At our current level of water management, two-thirds of the world's population could face water shortages by 2025," notes Phillip Tracy, a writer on water management.[3]

To make matters even worse, an aging infrastructure results in water leaks in many places including the United States. According to the American Society for Civil Engineers, "there are 240,000 water main breaks per year" and they lose a tremendous amount of water.[4] And an EPA program known as "WaterSense" estimated that "household leaks can waste more than one trillion gallons annually nationwide.[5]

Another water-related challenge is efficient use of this resource. For example, while the agriculture industry has made improvements to irrigation methods, farmers are still using inefficient 20th century irrigation systems that rely upon pre-set watering levels, regardless of the degree of moisture in the soil. This issue becomes more acute with the onset of climate change and the wasteful distribution of water that exists today where, in some places, there is too little water due to drought or excessive consumption, while in other places there is too much water due to flooding, typhoons, or hurricanes.

These imbalances have serious ramifications for agriculture.[6] According to the U.S. Department of Agriculture, "agriculture is a major user of ground and surface water in the United States, accounting for approximately 80 percent of the Nation's consumptive water use".[7] Due to the increasing cultivation of agricultural land and the deforestation of many areas, water is in great demand and competes with other uses.

Manufacturing plants and industrial applications also require considerable amounts of water as well. Water is used in many parts of manufacturing processes to cool industrial equipment and chillers. Factories need to use this precious resource efficiently and also need advanced energy management systems in place to ensure that water is released into waterways in ways that aren't damaging to local ecosystems. Many energy-generating plants are located near the water, and their effluent pollutes the rivers and lakes into which it flows.

The United States recently experienced a vivid example of this problem. In 2014, the city of Flint, Michigan switched its water supply to the local river rather than treated water purchased from out-of-town sources. It wasn't long until

children who drank it were breaking out in rashes, diseases were spreading, and people were dying. Scientists tested the water and found unsafe lead levels in at least 5,000 homes.[8]

The case sparked a national outcry about unsafe drinking water and decaying urban infrastructure. Public health studies estimated that 8,000 children in Flint were exposed to lead toxins and that the chemicals would reduce person-lives there by a total of 18,000 years. Overall, experts claim that the episode will cost city residents $400 million in damages based on lowered I.Q. levels, diminished productivity, and higher expenditures in the criminal justice system.[9]

Inexpensive sensors can detect unsafe chemicals in water and pro-actively notify authorities about possible health risks.

The tragedy of this case is that digital technology could have alerted city officials and the general public to the threat very early in the switchover. Inexpensive sensors can detect unsafe chemicals in water and pro-actively notify authorities about possible health risks. And, the advanced data analytics that is coming with future technology solutions have the true potential to provide early warning systems that save people from debilitating harm.

AIR QUALITY

Air pollution is a problem in most major metropolitan areas around the globe. According to the World Health Organization, "more than three million people die prematurely each year because of ambient air pollution caused by high concentrations of small and fine particulate matter."[10]

In many cities, air pollution is caused by automotive exhaust and emissions from manufacturing. According to the Texas A&M Transportation Institute, "traffic congestion caused [U.S.] drivers to waste more than three billion gallons of fuel and kept travelers stuck in their cars for nearly seven billon extra hours.[11] The worst cities in terms of traffic included Washington, D.C. (with 82 hours of delay each year per commuter), Los Angeles (80 hours), San Francisco (78 hours), New York (74 hours), and San Jose (67 hours). In Europe, there also were substantial delays as Germans spend 39 hours and Belgians devote around 44 hours to being stuck in traffic.[12]

The situation in China and India is even worse. The Beijing Municipal Commission of Transport estimates that drivers "spend 20 more minutes in traffic each weekday compared to statistics from 2012."[13] In India, 49 percent of drivers say they are in a car at least 12 hours per week. That is more than drivers in China, Thailand, the Philippines, or Australia.[14]

Figuring out how to improve air quality, monitor pollutants, and mitigate the causes of pollution is a crucial task. Dirty air damages the health and well-being, and impedes the overall quality of life for people living in urban settings. Developing better systems for managing transportation is crucial for a modern economy and unless societies can do a better job on this front, it will also be difficult to achieve desired environmental objectives.

ENERGY AND TRANSPORTATION

Transportation poses a number of environmental and energy challenges. Research by Donald Shoup has found that up to 30 percent of the traffic in metropolitan areas is due to drivers circling business districts in order to find

a near-by parking space.[15] That represents a major source of traffic congestion, air pollution, and environmental degradation. Cars are thought to be responsible for "approximately 30 percent of the carbon dioxide (CO2) emissions behind climate change."[16]

In addition, it is estimated that anywhere from 23 to 45 percent of metropolitan traffic congestion occurs around traffic intersections.[17] Traffic lights and stop signs are inefficient because they are static devices that do not take traffic flows into account. Lights are pre-programmed to remain green or red for set intervals, regardless of how much traffic is coming from particular directions.

Developing better systems for managing transportation and promoting energy efficiency is vital for modern economies. Energy and transportation are major components of urban life and economic development. Without more efficient and effective ways of handling these issues, countries will not be able to achieve the environmental and economic benefits that they want.

BUILDING DESIGN AND EFFICIENCY

Buildings account for "42 percent of the world's energy use," according to a University of Pennsylvania research project.[18] This includes power for lighting, heating, cooling, and building operations. Having designs that operate efficiently is crucial for future sustainability.

According to Stephen Harper, global director of environment and energy and sustainability policy for Intel, the key consideration in electrical systems is "net energy usage." Architects can use modern computer-aided design software to develop buildings that operate efficiently and take advantage of natural light and energy sources to minimize the amount of grid-derived electricity needed for normal operations. Sophisticated building energy management systems help to optimize daily operations to achieve buildings that are net zero energy consumers or even energy-positive buildings that generate more electricity than they consume.

One of the goals of contemporary designers is buildings that make more efficient use of cooling and heating designs. In the United States, there are over five million commercial buildings and industrial facilities with a combined annual energy cost of more than $202 billion.[19] It is estimated that the U.S. could save $20 billion if all commercial and industrial buildings increased their energy efficiency by just 10 percent.

In order to manage these systems, experts have devised technology solutions for the evaluation, monitoring, management, and verification of energy usage. Advanced building systems are designed to help these managers operate their networks in an efficient manner. That is vital to obtaining a sustainable future.

SUSTAINABILITY INITIATIVES

While there are a host of environmental and energy challenges, existing and emerging digital technologies offer hope of improving resource management and sustainability. Cities are crucial to these efforts because, according to Susan Tauzer of Intel, they are being faced with many sustainability challenges as a result of intensive urbanization. As a result, cities are "crucibles for many new smart technologies and vertical solutions such as environmental monitoring, transportation, energy, and buildings."[20] Urban areas are implementing many examples of applications that help with water, air quality, traffic management, and building design.

Following on that idea, AT&T has pioneered innovative work in this area. Its people have been working on smart city efforts and have found that it is important to optimize resources by deepening relationships with cities and municipalities in the areas of energy and utilities, public safety, citizen engagement, transportation and infrastructure. According to Mike Zeto, general manager and executive director of the firm's Smart Cities program, the company feels that the technology that weaves through smart cities has the potential to enable large-scale carbon emissions savings and can help the company meet its goal of enabling carbon savings 10 times the footprint of its operations by year-end 2025.

Jack Weast, principal engineer and chief automotive systems engineer at Intel, adds that "the value of 5G is adding usage and capabilities."[21] Through new applications in automated driving and other areas, the new era of 5G will bring together improved connectivity, cloud-based storage, and an array of connected devices and services.[22] In the automotive area, for example, these new capabilities will produce safer vehicles on the highway.

Urban areas are implementing many examples of applications that help with water conservation, air quality, traffic management, and building design.

5G is not simply an extension of 3G and 4G. Instead, it is a transformative ecosystem that includes a heterogeneous network that integrates 4G, Wi-Fi, millimeter wave, and other wireless access technologies. It combines cloud infrastructure, a virtualized network core, intelligent edge services, and a distributed computing model that derives insights from the data generated by billions of devices. With 5G, we will be moving from a user centric world to one of massive machine type communications where the network will move from enabling millions to billions of devices—an era that will connect these devices intelligently and usher in the commodification of information and intelligence."[23]

Connected devices allow people to enjoy more personalized, immersive, and enhanced experiences whenever and wherever they are. With the costs of devices and sensors coming down considerably, connectivity will be ubiquitous and unobtrusive. Rather than having to make a conscious decision to issue a computing command, people will have systems that take actions based on the pre-determined preferences of that individual. All of this will enable new applications in resource management and energy efficiency.

WATER MANAGEMENT

As noted in the Flint case, inexpensive sensors can detect unsafe chemicals in the water supply. That is an easy way to warn people in advance that something risky has been released into the water or air and people should be on guard for possible health hazards.

Sensors also are useful in water management. For example, they help in identifying and managing leaks in water lines. Some studies have estimated that communities in the United States "can be losing as much [as] 30 percent of their product along the way to leaks in the distribution system."[24] To help with this, sensors and advanced metering infrastructure can be installed in treatment plants and underground pipes and help managers see when leaks take place and how much water is being lost before it reaches the end-user. In cities, with aging infrastructure, this represents a way that officials can monitor leaks and manage water in real time.

Smart meters allow people to know how they are using water and where they might be able to economize given their usage levels. In California, for example, "metering, when coupled with effective pricing structures, reduces water use by 15 percent to 20 percent."[25] Miami-Dade County is another place that has garnered positive results from advanced water meters. It is a large area encompassing 263 different parks. Overall, these recreational areas use 360 million gallons of water each year and cost $4 million in sewer and water expenditures. After installing a smart city system, the parks service was able "to remotely monitor water consumption, detect leaks and share information colleagues at other parks and facilities…. The parks department estimates a 20 percent reduction in water use annually with a savings of some $860,000 per year."[26]

In Malaysia, farmers are using sensors in the soil to measure moisture levels. That helps them apply the optimal amount of water to the field. They don't want to over-flood the area or apply too little. Sensors take the guesswork out of agriculture by adding concrete information to farmers' decision-making.

Dale Hadden, a farmer in Illinois, has praised the efficiency enabled by digital agriculture applications. "We can take our data, walk right into the fields with an iPad or iPhone, pinpoint exactly where we are in the field, and see what the planting rate is, what the amount of nitrogen is, and figure out what we should be doing with each parcel of land. If we have a performance issue in a certain area, we can do something about it," he noted.[27]

Precision agriculture includes a number of new techniques designed to promote sustainable farming: yield monitors, soil properties mapping, yield maps, guidance systems, and satellite imagery. Researchers found that the tools enabled farmers to save over $25/acre.[28] Among the most popular features were GPS guidance systems, sprayer controls, aerial imagery, field mapping, soil electrical conductivity mapping, soil sensors, and chlorophyll sensors.[29]

In manufacturing, virtual chillers monitor water usage in real-time and optimize chiller operations. Most industrial equipment is not fully utilized and often operates in a low-power state that is not very efficient. By making use of real-time analytics, digital technology can help operators get the most out of their equipment.

Some companies are moving towards automated factories where data analysts can make changes remotely. They see data on their computer screens based on factory or data center operations and can adjust equipment accordingly. The combination of automation, robotics, and data analytics allows them to operate their centers very effectively in terms of water and energy.

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For example, satellite imagery helps in monitoring water runoff. In one case, at the Chesapeake Conservancy, experts use high resolution satellite pictures of the Bay Area to examine water flows and sea level changes. These images enable officials to determine how quickly the landscape is changing and where problems are emerging.

In the developing world, river sensors warn of rising water levels. According to a United Nations Broadband Commission, "water flow sensors are also being used to help collect hydrological data in developing countries where local data on river flow and levels may not be regularly collected. These sensors can also provide early warning of floods."[30] These types of systems are being used in Honduras and other places.

AIR QUALITY

Air quality represents another area where digital technology provides people with tools to monitor and improve quality. As an example, the city of London has set up over 100 air quality monitoring stations around town as part of a London Air Quality Network. In one pilot, three of these devices have been augmented by 80 lower budget instruments that cost around 1,000 British pounds and measure pollutants and particulates at a street level. Readings are sent electronically to the cloud for use in regulation and enforcement. Firms that emit too much pollution can be fined and subjected to clean-up requirements.

In San Jose, California, sensors measure the air for five different chemicals. By having an end-to-end monitoring system, city planners can look at chemical traces in different locations and report when there are problems with dangerous air quality levels. This helps authorities identify offending businesses and fine them for poor compliance with environmental laws.

These illustrations demonstrate how technology can be helpful in resource management. Many bad business and consumer practices derive either from a lack of information about usage or incentives that move people in the wrong direction. One of the virtues of information systems is that they enable people to monitor and track their usage patterns and then make more informed choices. Technology helps people better align their goals with their personal behavior.

ENERGY EFFICIENCY

Digital technology offers great possibilities in terms of power generation and consumption. It helps to improve efficiency by managing peak loads, integrating renewable energy sources into the electric grid, making production and operations more efficient, and boosting service delivery.

Several projects have demonstrated a concrete improvement on greenhouse gases and energy efficiency. As an example, "ICT-enabled solutions offer the potential to reduce GHG (greenhouse gas) emissions by 16.5 percent, create 29.5 million jobs and yield USD 1.9 trillion in savings," according to the Global e-Sustainability Initiative.[31] In addition, an analysis by the Pacific Northwest National Laboratory found that a smart energy grid could reduce energy usage and carbon impact by 12 percent directly and six percent indirectly.[32]

Smart meters have been heralded as a terrific way to conserve energy and 50 million have been installed throughout the United States (in around 43 percent of residential homes). Yet research suggests that these meters have not been very effective at altering consumer behavior. A survey by the Smart Grid Consumer Collaborative uncovered "that only eight percent of people were already using 'online analysis of your specific energy usage.'"[33] Experts suggest that people need in-home displays about their energy utilization in order to alter their behavior. Getting information about pricing and power consumption helped residents make the most efficient decisions about their households.

London provides an additional example of how technology can be impactful. After the Olympic Games, in 2012, the region that intersects four local boroughs is being developed as an exemplar Smart Sustainable District. Various sensors and a wide-area digital network are being used to help ecologists and park managers in their day-to-day operation of this development. A district datastore and dashboards help inform environmental factors such as energy usage, air quality, and noise levels.

This information is compiled in open source data bases, which enables researchers and other people to use it for their own purposes. It is available through the London Data Store and is integrated into the city's smart city platform. Its Smart London Board is comprised of representatives from government, business, and academia. Their task is to make use of the information and help public officials make effective decisions using real-time information. Rather than guessing about air quality in certain neighborhoods, officials have actual data that helps them determine the source of particular problems and possible ways of ameliorating those issues.

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One observation based on air monitoring around schools is that air pollution increases early in the morning and mid-afternoon when parents drive their children to school and pick them up. During these periods, cars are idling and contributing to a spike in air particulates. Researchers tracked this by comparing air quality around schools during the school year versus on holidays. They found substantial differences in air pollution based on drop-off and pick-up times.

Audio monitors around parks help officials monitor noise levels. Microphones in various places track sound in decibels and process it for elevated noise recordings. Researchers look for patterns when noise spikes up and the factors that contribute to those readings. This helps them identify solutions for noise abatement.

TRAFFIC MANAGEMENT

Transportation is an area where there have been significant quality improvements through digital technology. For example, intersections have traditionally been one of the least efficient urban operations. Traffic lights are programmed to turn red or green based on fixed intervals of traffic flows. They don't incorporate information on flow variations for particular streets or at various times of the day. Rather than being dynamic in nature, they are completely static in how they handle traffic.

Through digital technology, however, there are intelligent traffic signals with dynamic functioning. They gauge the actual traffic in real-time and adjust traffic lights based on vehicular volume. They are not static but adjust continuously throughout the day as conditions change. By adding the real-time element, they improve the efficiency of traffic flows and thereby help protect air quality and congestion.

In addition, smartphone apps help drivers determine the quickest traffic routes. Rather than having to guess where traffic congestion is, these applications let people know which routes are backed up and therefore to be avoided and which ones are a better option. That helps drivers get to their destinations more quickly and not sit in traffic wasting their time and polluting the atmosphere in the process.

Similar efficiencies have been derived from real-time mass transit guides and car sharing services. Many transportation authorities have put their bus line or subway schedules online. Research has demonstrated that people like the convenience of online transit information and this has reduced their waiting time and increased their usage of the service. Reliance upon car sharing services has cut "driving by 27 to 56 percent" according to a research study.[34]

Mobile apps help drivers find available parking places in congested urban areas. Sensors attached to individual parking spots can be integrated into geographic information systems and provide maps showing available parking spots. That means drivers don't have to circle the block aimlessly trying to find an open space but can go directly to those places, thereby reducing traffic congestion, driving time, and vehicular pollutants.[35]

Once autonomous vehicles are phased in and represent a large part of the traffic, car-mounted sensors will be able to operate in conjunction with an Intelligent Traffic System to optimize intersection traffic flow. Time intervals for green or red lights will be dynamic and vary in real-time, depending on the amount traffic flowing along certain streets. That will ease congestion by improving the efficiency of vehicular flows.

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Driverless cars are expected to help in terms of energy savings, productivity and air pollution. Bridget Karlin, managing director of Intel's IoT group, predicts that cruise control, automated braking, and other automated driving features can deliver a 20 to 30 percent improvement, as well as largely eliminate traffic congestion due to smoother driving styles and actively managed intersection and traffic patterns. According to a recent Morgan Stanley report, there will be "$150 billion in fuel cost savings and $138 billion in productivity gains in the U.S. as a result of autonomous vehicles."[36] More efficient traffic management will enable this energy savings as well smoother acceleration and deceleration will help in terms of carbon dioxide emissions and traffic congestion through automated driving.

SMART BUILDINGS

Effective building design starts with the lighting, heating, and electrical systems. They are the backbone of smart building construction. Incorporating sensors in conjunction with lighting systems helps to make them more efficient. Lights in buildings as well as along streets can be dimmed when no one is around. Through smart design, experts have "seen up to 70 percent reductions in energy consumption" in modern buildings.[37] Some places have smart trash bins that have embedded sensors that wirelessly communicate when they are full and need to be emptied.[38]

Smart thermostats further help with energy conservation. People remotely can raise or lower the temperature depending on when they are in a room. By having a dynamic system, it allows individuals to be comfortable when they are around, but energy efficient when they are not. In many office buildings, lights are on all the time, regardless of whether anyone is using the space.

Temperature sensors are starting to be tied directly into heating, ventilation, and air conditioning systems so that people don't need to touch the thermostat. These devices can determine when people are in the room and what the temperature should be given interior and exterior conditions. Zones can be set up in buildings for people's comfort levels. Carbon dioxide levels, another measure of occupancy, can also be monitored continuously and feedback data to air conditioning systems to ramp up or down, depending on the indoor air quality and occupancy.

That is particularly the case with conference rooms. Ceiling sensors can recognize whether the room is being used and adjust the lights accordingly. This is a simple way to gain greater efficiency and save money in the process.

Further, modern smart lighting solutions can detect natural background lighting levels and dim or brighten, depending on the time of day and whether it is overcast or sunny outside.

The Empire State building in New York City represents an example of how to save energy. It has over 100 tenants, and has developed "sub meters" that measure the energy usage of each tenant and helps them optimize their utilization. Based on these monitoring tools, the building has reduced energy costs by 38 percent.

Engineers can program dashboards for buildings so that real-time information is available to them. They can see how many people are using different spaces and what the temperature and air quality is. According to Dr. Duncan Wilson, Director of Intel's ICRI Sustainable Connected Cities, "one percent of extra investment in a building produces great savings in people's time and comfort."[39] Reflecting the rising interest in these ideas, "the smart building technology market will generate global revenues of $8.5 billion in 2020, up from $4.7 billion in 2016".[40]

The Empire State building in New York City represents an example of how to save energy. It has over 100 tenants, and has developed "sub meters" that measure the energy usage of each tenant and helps them optimize their utilization. The meters provide detailed data on chillers, air handling, ventilation, insulation, and occupancy, and makes recommendations on how to cut usage. Based on these monitoring tools, the building has reduced energy costs by 38 percent, earned an energy star that puts it in the top 10 percent of office buildings in the United States, saved $4.4 million annually, and reduced it carbon dioxide emissions by 105,000 tons each year.[41]

POLICY RECOMMENDATIONS TO IMPROVE SUSTAINABILITY

There are a number of steps that would advance sustainability and help people take advantage of 5G technologies. These include improvements to: procurement policy, building and community design, interoperability, spectrum availability, and security protection. Each of these actions promotes sustainable practices and resource management. With appropriate policies and incentives, it is possible to encourage consumers and businesses to deploy energy-saving measures.

PROCUREMENT POLICY

Procurement policy is an important area for sustainability. According to AT&T officials, "cities are buying in silos as opposed to holistically."[42] This means that many agencies are not getting full economies of scale from their own purchasing power and therefore are not able to achieve the impact that they want.

Reforms in purchasing practices represent an effective way to achieve greater impact. Through their purchasing power, cities can make sure that suppliers practice healthy sustainability. Government agencies and businesses can insist that firms within their supply chain implement best practices and adopt effective resource management policies. They also can encourage alignment on industry standards, support and innovation in new products, such as smart meters, smart energy grids, and sensors that monitor air and water quality in order to speed adoption of sustainable practices.

Many communities are investing both in vertical (such as public safety and transportation) and horizontal (devices, infrastructure, apps, and tools) applications. This puts them in a strong position to encourage expenditures in underserved areas. According to Karl Bream, the head of Nokia's IoT strategy, we need "infrastructure in places where it is not available to provide social services."[43] These investments will facilitate smarter designs, more efficient use of resources, and the integration of data analytics in decision-making.

BUILDING AND COMMUNITY DESIGN

It is important to integrate energy-saving standards in new building design. Making sure that buildings have energy certificates and displaying them in their lobbies is one way to encourage energy conservation. These efforts should be dynamic in nature and not based on one-time measurements. There needs to be continual monitoring and assessment of energy usage in buildings in order to produce the best results.

Tremendous energy savings have been achieved through smart lighting and smart energy grids. Those initiatives employ dynamic systems that gear energy usage to when people need lighting, cooling, and heating. They help to use energy more efficiently and reduce consumption when individuals are not around.

In order to install smart grids or smart lighting, city governments should work closely with utility companies. They often own the light poles on which digital equipment gets deployed. In order to get the devices installed, government agencies and private businesses have to coordinate their activities.

The U.S. Environmental Protection Agency has incentive programs for energy efficiency such as the Energy Star rating system and the Green Power Partners program that focuses on renewable purchases. Many of these are voluntary in nature and seek to achieve specific objectives.

The European Union features a "holistic" approach in its environmental activities. It seeks to integrate various department initiatives and find comprehensive solutions to major problems. It often organizes large projects and reorganizes frequently in order to improve its results.

INTEROPERABILITY

Improving interoperability of connected devices is crucial in the 5G world. Billions of sensors and monitoring devices will not deliver the expected value unless they can communicate and share data with one another. As noted by Bridget Karlin, "for smart and connected cities, we have to tie them together through interoperability." Urban areas now feature a host of digital devises and mobile solutions. But the key is to connect them so they can share data and researchers can analyze the data in real-time. Enabling interoperability through agreed-upon technical standards is a way to gain the benefits of the digital revolution.

SPECTRUM

As 5G systems reach the marketplace, spectrum availability is a crucial consideration. Resource management and sustainability initiatives require sufficient bandwidth to power digital and mobile applications. There needs to be a combination of licensed, licensed-shared, and unlicensed spectrum in low, mid, and high-frequency bands. No single one of these frequencies will suffice for the emerging applications.[44]

Frequencies that are near, or adjacent to, one another can be leveraged for inclusion in a single product design even if they are not all available across all countries. Finding frequency ranges which are available in major markets, or where the available frequency bands are close enough to be supported within a single radio is critical to achieving the economies of scale necessary to support the business case for both manufacturers and operators. Harmonization of major markets creates commonalities in regulatory requirements and technical specifications which will then aid in reducing the cost and complexity of implementing and enabling 5G on a global scale.

As 5G systems reach the marketplace, spectrum availability is a crucial consideration.

Several countries have made progress on this, according to Michael Kraemer, senior manager of European spectrum strategy at Intel.[45] Korea, and the United States have already decided to use the 28 GHz band for 5G trials and/or commercial deployments. Japan also is actively considering this band as part of their 5G trials. Other countries are looking at the 26 GHz band which is one of the key bands that the International Telecommunication Union (ITU), a United Nations specialized agency for information and communication technologies, is considering for 5G use. The proximity and partial overlap of these two bands will enable the above-mentioned global economies of scale. The European Union is also active and has developed an action plan to maintain its own leadership with 5G networks which is focused on the 26 GHz band as a high bandwidth for the new network.[46] These efforts are propelling forward fixed and wireless applications and position member nations for future action.[47]

SECURITY

Security is another area that warrants considerable vigilance. According to Raj Samani of Intel, it is "the very fabric of everything we are going to be doing as a society."[48] In a connected world, everything is going to be integrated and therefore people have to be cognizant of security and privacy implications. For example, smart meters collect transactional information on electrical devices. This includes which appliances are being used in the home, when they are being used, and how long people are using them. When fully phased in, "electric utilities will have more data than Facebook" and they will "move from being utilities to data brokers," noted Samani.

As a result, manufacturers need to integrate security in both the hardware and the software at the onset, and businesses are going to have to adapt better controls on devices, develop stronger anti-virus software, implement encryption safeguards, and protect energy systems from malicious intrusions. Businesses have to decide how much they are willing to pay to add various security measures to their operations and equipment. Since energy grids increasingly are under attack from foreign adversaries as well as amateur hackers, it is crucial to take these risks seriously.

CONCLUSION

Sustainability advancements require progress in the private and public sector. Businesses as well as municipalities must make operational changes and establish systems of operation that promote energy efficiency and improve air and water quality. Today, a number of companies and cities are deploying existing technology solutions that help with resource management and monitoring. And tomorrow, intelligent devices including sensors and other connected devices coupled with flexible network capability, will enable never before seen data analytics that will result in social

and economic benefits including things like traffic alleviation, smart building design and energy management—all informed using advanced intelligent networking capability.

In government, one of the challenges in the environmental area is that statutes were written decades ago to regulate water, air, waste, and chemical toxins. Each has their own legal framework and implementation processes and the result has been a "siloing" of enforcement efforts that often is not well-integrated or comprehensive in nature. Enforcers tend to focus on specific areas, not how the various public laws can collectively work together for optimal outcomes.

For this reason, officials should be cognizant of the rule of unintended consequences. Policymakers sometimes adopt measures that improve outcomes in some areas while hindering other ones. Recognizing the importance of maintaining technology neutrality, and supporting open, standards-based performance rules are a much better approach than issuing technology mandates.

With the emerging 5G network and the internet of things, it is possible to deploy technology in ways that protect the environment and promote long-term sustainability. These new technology innovations have the potential to become an integral part of and accelerate global efforts to address the challenges of sustainability. With 5G, governments, industry, communities, and individuals will have the connectivity, capability and agility to meet many of the challenges the world faces as we work towards ensuring the lasting protection of the planet and its resources.

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