IoT for Sustainability

oneM2M White Paper

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oneM2M is the global standards initiative that covers requirements, architecture, API specifications, security solutions and interoperability for Machine-to-Machine and IoT technologies. oneM2M was formed in 2012 and consists of eight of the world's preeminent standards development organizations: ARIB (Japan), ATIS (U.S.), CCSA (China), ETSI (Europe), TIA (U.S.), TSDSI (India), TTA (Korea), and TTC (Japan), together with industry fora and consortia (GlobalPlatform) and over 200 member organizations. oneM2M specifications provide a framework to support applications and services such as the smart grid, connected car, home automation, public safety, and health. oneM2M actively encourages industry associations and forums with specific application requirements to participate in oneM2M, in order to ensure that the solutions developed support their specific needs. For more information, including how to join and participate in oneM2M, see: www.onem2m.org.

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Executive Summary

The topic of sustainability has never been higher on society's agenda than it is at the present. This is partly a reaction to alarms raised by the scientific community. It is also a recognition, by political and business leaders, that current approaches to managing the earth's resources are unsustainable and require action.

A way forward is complicated because of differing interpretations of sustainability, a hesitancy about fundamental change and, a scope that covers environmental, social and governance matters. Bit by bit, however, individuals and organizations are taking action. There are many cases of corporate and national goals to achieve net-zero emissions by 2050. At a regional level, the European Union made a major commitment through its Green Deal initiative. Individual corporations are implementing sustainability strategies and committing to new reporting frameworks. Others are deploying technology-based solutions to enable sustainability in their business operations and by offering solutions and services that their customers can deploy.

Mobile networks and IoT technologies are among the topmost candidates for enabling sustainability. Four capabilities – remote connectivity, low-power and low-cost devices, IoT data and, cross-silo applications – can help organizations to manage their environmental footprint and to tackle different facets of the UN's Sustainability Development Goals.

If these IoT capabilities are to achieve widespread impact, participants in the IoT ecosystem and neighbouring sectors need to focus on long-lasting and scalable deployments. This begins with investments in IoT systems that promote reusability and resource sharing across multiple applications and users. The benefits are a reduction in the risk of 'orphan' or silo investments while enabling the economies of scale that make adoption affordable. It also helps if organizations and their product managers design systems based on interoperability, scalability, modularity, and re-use principles. These are areas where standardization has a magnifying impact.

At the implementation level, there is a need to educate and inform the marketplace, potential adopters, and the workforce of the future. This involves exhibiting innovative solutions and technologies that improve sustainability while also speeding up the adoption process. The current IT curriculum needs to embrace new knowledge and tools associated with promising IoT and sustainability capabilities. While individual interventions might have a marginal effect, their collective impact can be considerable when applied at scale.

oneM2M recently launched a sustainability initiative to promote the role of IoT systems in addressing sustainability goals. An important message from this initiative focuses on the benefits of scalable, open-standard solutions. Since its inception in 2012, oneM2M's members have focused on defining technical specifications for a general-purpose IoT framework that is applicable to a wide range of application domains at a global level. By involving organizations from across the globe, oneM2M set out to avoid a proliferation of competing standardization efforts, at both national and technical levels.

Through an emphasis on interoperability of its specifications, oneM2M avoids re-invention and enables the re-use of established industry standards in home and industry domains. Organizations are therefore free to build scalable IoT systems based on an open standards framework that preserves the value of earlier investments and legacy systems, thereby minimizing the potential for waste.

As the sustainability flywheel gains momentum over the coming years, organizations need to adjust their strategies away from legacy approaches towards sustainable and circular economy approaches. IoT technologies will play a significant role, aided by open standards that foster wide-spread adoption, innovation, and economies of scale. Our intention with this White Paper is to illustrate the potential of IoT systems. We also encourage IoT stakeholders to apply responsible IoT system design and deployment principle as they chart a pathway to achieving global sustainability goals.

1. Why ‘sustainability’ is important

Sustainability is concerned with the well-being of future generations and the treatment of irreplaceable natural resources. It primarily refers to the capacity for the Earth’s biosphere and human civilization to co-exist in the long run.

The communications industry plays a major role in how resources are consumed. Information about resource usage patterns helps to address opportunities to improve efficiency or to reduce waste. In this regard, technologies, services, and applications related to the Internet of Things are fundamental to sustainability. The purpose of this White Paper is to provide a context for sustainability issues and to demonstrate how organizations are addressing sustainability challenges using IoT technologies and solutions. The sheer scale of opportunities and need for many parties to collaborate in this area are arguments for standardization at the technical level and in terms of design practices that promote interoperable, modular, re-usable and scalable systems.

1.1 What is ‘sustainability’?

There are many different definitions and interpretations for the term ‘sustainability’. For example, the term is often broken down into three areas referred to as environment, social, and governance (ESG).

In a similar way, the Triple Bottom Line is a business concept whereby firms commit to measuring their social and environmental impact—in addition to their financial performance—rather than solely focusing on generating profit, or the standard “bottom line.” The Triple Bottom Line consists of “three Ps”: profit, people, and the planet (or economic, social, and environment). Here, the profit or economic link refers to sustainable actions such as investments related to climate-change mitigation or adaptation. In most cases, these areas and their aspects are also considered in sustainability assessments and sustainability or non-financial reporting guidelines. This is reflected in another sustainability framework, known as the Global Reporting Initiative (GRI), which comprises a set of indices for sustainability reporting.

Typically, environmental aspects include greenhouse-gas emissions, energy consumption (which is also considered in the ISO 50001 Energy Management System, EnMS), water usage and pollution, and waste generation and treatment (the latter are considered in the ISO 14001 Environmental Management System, EMS). Further aspects can include resources scarcity/efficiency, Ozone depletion, hazardous substances (also covered by ISO 14001), and product eco-design. Emissions often cover the three Scopes of the Greenhouse Gas Protocol, for example own operations, logistics and product use phase.

Social aspects typically include labour law (e.g., regarding the ILO convention), health & safety (covered in OHSAS 18001 / ISO 45001), diversity and corporate social engagement. This often extends to the respective measures that are to be taken with regard to the supply chain. The latter, supply chain, is an aspect of increasing importance, as can be seen from the attempts to responsible sourcing and other ongoing initiatives.

Governance or economic aspects include the reporting entity's organizational structure, including highest governance level responsible for sustainability, assignment of responsibilities, training and aspects like revenue, cost or investment related to climate change and other environmental aspects. The latter is also considered in the TCFD framework (Task force for Climate-related Financial Disclosure) and in the EU Taxonomy. Over time, the Taxonomy will extend this to the aspects of circular economy and governance.

Finally, the 'circular economy' is another way to consider the topic of sustainability. It has possibly the most relevant cross-over aspect. It connects environmental aspects such as resource efficiency and emissions with the necessary consideration of the entire value chain and new business models that replace the old linear take-make-sell-forget business construct.

1.2 Quantifying the Impact in Key Market Segments

The world emits around 50 billion tonnes of greenhouse gases each year. A useful proxy to rank different industrial sectors according to their impact on sustainability is the breakdown of greenhouse gas emissions by sectors. Figure 1 illustrates the results from [an analysis conducted by Climate Watch and the World Resources Institute using data for 2016](#).

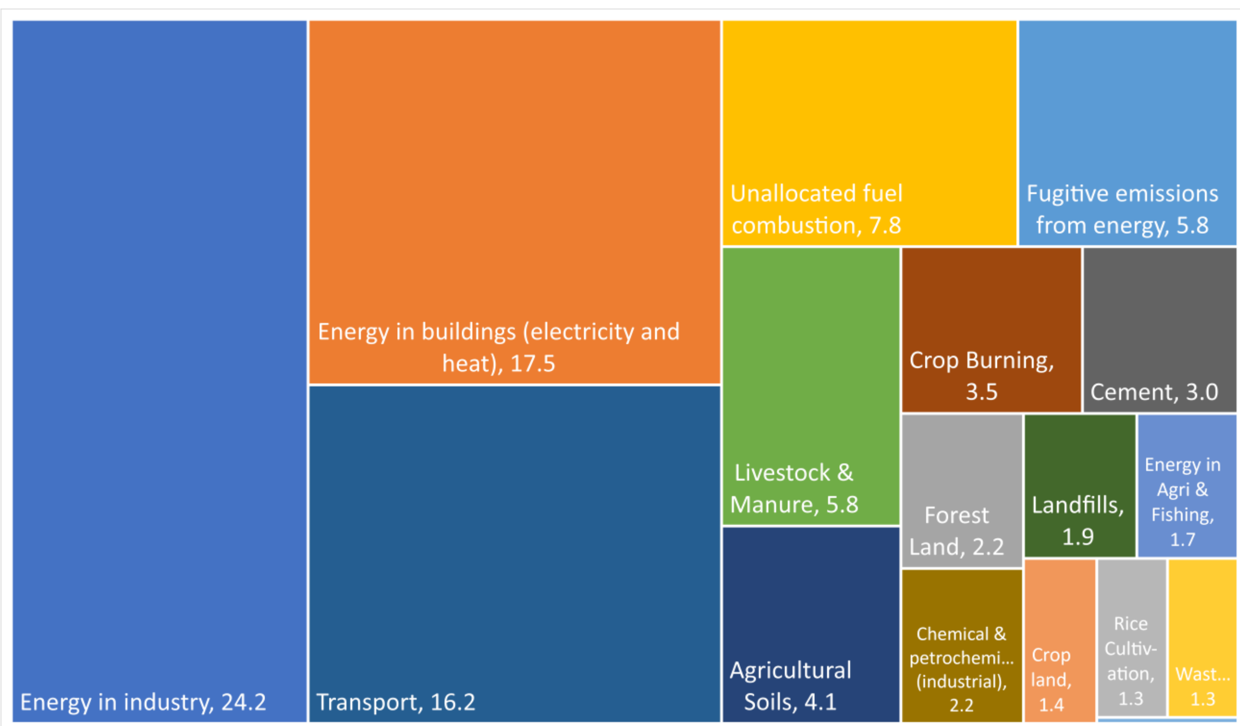


Figure 1 Global Greenhouse Gas Emissions by Sector, (Our World in Data: Where do global greenhouse gases come from?)
Note: Grassland category (not shown) accounts for <1%

- **Energy (electricity, transport, and heat): 73.2%** - energy use in industrial manufacturing processes is a significant contributor to this category, amounting to 24.2% of GHGs. The key industries include iron and steel, and chemical and petrochemicals. The transportation sector contributes 16.2% in this category, driven primarily by fuel emissions from cars, trucks, lorries, motorcycles, and buses. Energy consumption in residential and commercial buildings contributes 17.5% to the category total.

- **Agriculture, Forestry and Land Use: 18.4%** - agriculture, forestry and land use directly accounts for 18.4% of GHGs. Looking across sectors, the food system as a whole – including refrigeration, food processing, packaging, and transport – accounts for around one-quarter of greenhouse gas emissions.

- **Direct Industrial Processes: 5.2%** - carbon dioxide produced during a chemical process in the production of cement accounts for 3% of this category's total. The remainder is due to chemical by-products in the chemical and petrochemicals sector.

- **Waste: 3.2%** - the decomposition of waste matter in wastewater systems and landfills are the two contributors to this category.

1.3 Market Forces are Driving Change

The concept of sustainability, in all its facets, is becoming increasingly important for businesses across all industries. Several factors account for this. The most visible is due to the consequences of climate change, across the world, which are becoming more tangible by the day. Society is also concerned about other far-reaching global problems linked to the loss of biodiversity and to social inequality. This palpability, unprecedented in scope, means that consumers, regulatory bodies, and businesses are under growing pressure to behave sustainably.

Among other factors, end customers are expressing clear preferences for sustainable products and services. This desire is not only relevant in the B2C sector, but runs through the entire market, and is also noticeable in the B2B environment. For example, companies also select their partners and suppliers on the basis of their commitment to sustainability to avoid any negative impact on themselves. This process is turning into a priority as businesses reassess the resilience and sustainability of their supply chains.

Investors are also showing increased interest in the environmental, social and governance performance of corporations and have high expectations of them. In order to meet the needs of the market, it is essential to show authentic commitment in order to accelerate credible change towards sustainable business.

Global policy actions are also adding pressure on businesses. Political initiatives, such as the European Green Deal, are increasingly being launched and aim to cut carbon emissions and detach economic growth from resource consumption. In the future, policy actions will increasingly reward sustainable practices while sanctioning activities that are climate-damaging or otherwise unsustainable.

Accessible and affordable IoT technologies are increasing the opportunities for remote monitoring and control capabilities. This raises the bar for managing shared networks. At the same time, IoT technologies present new security risks to automated systems. Both of these cases raise concerns about the sustainability of public communications networks. In anticipation of rising demand for IoT devices and sensors and their impact on mobile networks, for example, the GSMA's industry guidelines encourage sustainable design and operational practices.

Finally, it is important to note that the private sector and companies operating in it are part of a functioning society and contribute to its well-being. It is therefore of fundamental importance that companies focus not only on short-term profit, but also on long-term value contribution to society. A functioning society depends on the availability of resources and an ecological balance. Therefore, companies must help to ensure that this balance can be maintained in the long term and that natural resources continue to be available.

2. Approaches to Sustainability

There is a hierarchy of approaches to tackling the sustainability challenge, spanning macro to micro levels. This section illustrates a few examples. Although not an exhaustive review, they show how organizations and nations are targeting common themes and different areas for action.

2.1 Macro Approaches to Net-Zero Emissions

Almost 200 nations submitted plans to cut greenhouse gas emissions through the 2015 Paris Agreement. In the intervening years, governments, business organizations and segments of the general population have supported the need for action.

In 2018, the Intergovernmental Panel on Climate Change (IPCC) warned of worsening conditions [if the planet exceeded 1.5 degrees C of warming](). To keep within this goal, the IPCC laid out a target of cutting emissions to net-zero (NZE) by 2050. Net-zero involves a radical change across the entire economy, doing away with fossil fuels and other sources of emissions wherever possible. It involves a future of energy based on renewables, carbon capture and new energy technologies by the 2050s. This is a significant substitution from present day energy sources which are dominated by oil, gas, and coal. For other energy sources, the solution is to match every ton of CO2 emitted with a ton removed from the atmosphere.

Figure 2 below provides recommendations from the IEA (International Energy Agency) on the path to net-zero emissions by 2050. These include behavioural change to moderate and avoid demand, efficiency improvements in different industry sectors, the introduction of alternative sources of energy and, measures to enable carbon-capture, usage and storage (CCUS). Technology innovation and regulatory policies play a significant role in enabling the adoption and proliferation of many of these proposals.

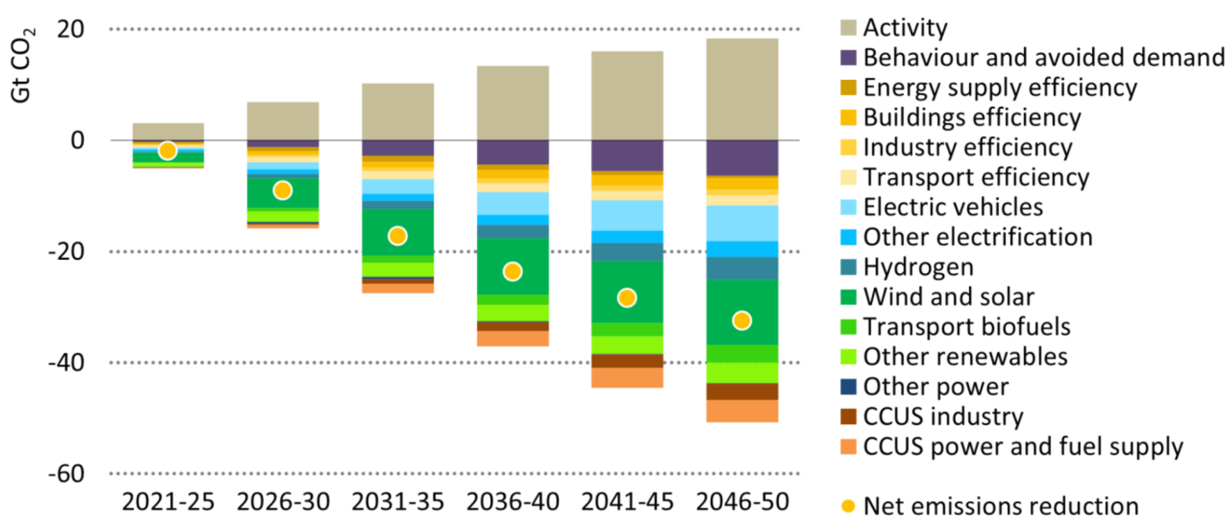


Figure 2 Average annual CO2 reductions from 2020 to Net Zero Emissions in 2050

The rapid deployment of more energy-efficient technologies, electrification of end-uses and swift growth of renewables all play a central part in reducing emissions across all sectors in the NZE. By 2050, nearly 90% of all electricity generation is from renewables, as is around 25% of non-electric energy use in industry and buildings.

Around 2.5% of existing residential buildings in advanced economies are retrofitted each year to 2050 in the NZE scenario to comply with zero-carbon-ready building standards. This compares with a current retrofit rate of less than 1%. A zero-carbon-ready building is highly energy efficient and uses renewable energy directly or energy from a fully decarbonised energy supply.

Government action is central to achieve net-zero emissions globally by 2050. An unprecedented level of international co-operation is needed to accelerate innovation, develop international standards, and facilitate new infrastructure to link national markets. Without the co-operation assumed in the NZE scenario, the transition would be delayed by decades.

2.2 An Example of Regional Action - the EU's Green Deal

The European Green Deal is a set of policy initiatives by the European Commission which aims to make Europe climate neutral in 2050. The European Commission's climate change strategy, launched in 2020, focuses on a promise to make Europe a net-zero emitter of greenhouse gases by 2050 and to demonstrate that economies will develop without increasing resource usage. It includes measures to ensure that nations that are already reliant on fossil fuels are not left behind in the transition to renewable energy.

The scope of action has a broader coverage than emissions targets. It contains initiatives to promote widespread collaboration and change management as reflected in its plans to:

- Invest in environmentally friendly technologies
- Support industry to innovate
- Roll out cleaner, cheaper, and healthier forms of private and public transport
- Decarbonize the energy sector
- Ensure buildings are more energy efficient
- Work with international partners to improve global environmental standards

As a measure of the importance of these issues, funding to support Green Deal initiatives will draw on the EU's seven-year budget as well as an amount equal to one third of the 1.8 trillion-euro investments from the Next Generation EU Recovery Plan.

The impact of the Green Deal in the IoT and Edge Computing domain features two issues. One involves the use IoT and Edge Computing technologies to improve the environmental impact of applications in other domains. The second is to improve the energy footprint of IoT based systems. The scope of this encompasses their use and energy consumption, the disposal or refurbishing of obsolete devices, the design and manufacturing of energy and the design of environment-friendly new devices.

2.3 Private Sector Strategies to Address Sustainability

Investor pressure and sustainability-oriented customer expectations are two factors that are driving private sector change. As a consequence, businesses are responding collectively and through individual strategies tailored to their business models and customer base.

In many cases, the definition of sustainability goes beyond environmental impact factors to include societal, stakeholder and organizational governance considerations. This leads to a wider set of parameters to monitor each organization's performance. The novelty and need for industry wide standards mirror practices that are common in telecommunications sector around standardization and certification. The need for standards-based governance frameworks is reflected in the growing role of institutional alliances and efforts to define measurement, reporting and certification frameworks.

Institutional Frameworks and Corporate Approaches to Sustainability

There are several different facets to sustainability, environmental, societal, stakeholder engagement and organizational structure factors. The relative importance of these factors to any given organization depends on emissions, environmental impact, and circular economy practices. For the telecommunications sector, the latter is important in terms of raw-materials efficiency.

Practical frameworks to manage sustainability performance generally involve assessment and reporting tools. A starting point for a commercial organization is to begin with the Science Based Targets initiative (SBTi). As time goes by, organizations should plan for more stringent targets, such as those linked to meeting goals related to the 1.5 deg. C Climate target. There is some early thinking from the Task Force on Financial Disclosures (TCFD) and the EU Taxonomy for Sustainable Investments. These are complex reporting frameworks, at a high level.

The Global Reporting Initiative (GRI) is an independent organization with a focus on standardizing the reporting of economic, environmental, and social performance issues. One of the organization's achievements is the creation of a common language to disclose key performance indicators. This is useful for reporting organizations and for external stakeholders that want to understand and evaluate businesses and governments.

Standardization provides a common language to enable reporting and understanding, while a digital approach that makes it straightforward to report data. This combination of factors is key to promoting the wider adoption of sustainability measures and solutions.

Individual corporations are taking different approaches to embed sustainability in their business operations. An informal poll of members contributing to this White Paper illustrates a range of initiatives:

- The French telecoms operator, Orange, has aligned its goals with the Paris Agreement and the recommendations of IPCC to achieve net zero carbon emissions by 2040. This is 10 years earlier than the objectives set by the rest of the sector. To achieve this, Orange aims to reduce its CO2 emissions by 30% from 2015 to 2025, notwithstanding exponential growth in the volume of data transiting its networks. The company also plans to increase the share of renewable energies, targeting 50% of electricity from renewable sources in the Group's energy mix by 2025 while continuing to improve the efficiency of its networks and buildings.

- From its base in Germany, Deutsche Telekom has set itself strict climate targets. Climate neutrality for its own emissions is to be achieved by 2025 at the latest, and net zero from production to the customer by 2040 at the latest. These targets build on steps already taken by Deutsche Telekom to make its global network entirely green through the use of electricity from renewable sources.

- Beyond corporate commitments to sustainability, another fruitful avenue involves sustainability offerings to customers using Information and Communications Technology (ICT) solutions.
    - Tata Consultancy services (TCS) offers an Energy and Emissions accounting solution with managed services, for commercial buildings and industries, powered by IoT, to achieve energy efficiency, sustainability reporting, carbon neutral goals by reducing emissions and meet financial and sustainability goals. The solution aligns with two of the UN’s SDGs: SDG 12-Responsible Consumption and Production and SDG 13-Climate Action. The TCS Energy solution connects to a diverse vendor eco-system, via multiple connectivity technologies, to link enterprise and operational data sources to AI applications (for predictive analytics) and a reporting dashboard.

    - IoT technologies can help organizations to reduce their consumption of water and chemicals in agriculture, to optimize traffic and parking in large cities and to reduce energy consumption of heating and cooling systems. Orange uses these drivers to design a range of IoT solutions. One example is a smart home solution that allows household occupants to manage home appliances, even at distance, in order to protect the environment by reducing energy use. Another example involves the community of Saint-Quentin-en-Yvelines which relies on IoT sensors to manage flood risk via a cloud-based platform that reports data to field-operator devices year-round.

    - For the agricultural and confectionery sector, TCS has designed a Farm-to-Fork solution. This helps farmers to enrol in an on-line system for crop harvest data which enables the tracing of location-specific data about agricultural commodities supplied from different parts of the world. The vision of this GIS-powered application is early detection of food toxicity, specifically addressing

SDG3: Good Health and Well-being. It also helps in identifying sustainability risks from the supply chain to better manage fluctuating consumer demand, addressing SDG12: Responsible Consumption and Production. The solution framework has broader applications and can be adapted to provide real-time insights on pandemic, natural disaster, and climate-related risks.

- ADVA, the German optical network equipment provider, began its sustainability journey some 8 years ago. One of several ways it approaches the sustainability challenge is to look at the issue from the perspective of costs and revenues related to climate change. In the case of ADVA's optical networking business, 80% of the climate impact is connected to the operational phase of equipment deployed by its customers. That represents a huge externality for ADVA. Using currently available data, it is impossible to factor what is happening in its customers' businesses – that is the network operators – and their customers whose usage patterns drive network traffic. ADVA's strategy is to invest engineering resources to improve the environmental performance of its future product line. At the same time, it also takes action to deal with the (much smaller) emissions footprint in other areas of its operations, a case in point being its vehicle fleet.

- The Alliance for Internet of Things Innovation (AIOTI) is developing its vision document on how IoT can contribute towards achieving EU Green Deal and UN SDG's objectives. In particular, this vision document focuses on: (1) identifying the high level Green Deal challenges and objectives imposed by key EU Green Deal and Data policies (2) showing IoT and Edge Computing business driven scenarios and use cases that can support these objectives and challenges and the key EU Green Deal and Data policies and (3) mapping IoT and edge computing activities in vertical industries and (4) providing high level research and standardisation recommendations on addressing these high level Green Deal challenges and objectives. With a view to enabling market adoption, the AIOTI's approach looks beyond the Green Deal objectives and concentrates on 'actions' to meet the EU Green Deal targets.

2.4 Common Themes and Areas for Action

With reference to the 2015 Paris Agreement, there appears to be a clear pattern in favour of collective and common approaches to address climate sustainability challenges. While this reflects the position of most governments, public awareness of the physical and societal impacts of climate change are fuelling pressure for government and business to change.

This dynamic has two effects. One is the recognition that fossil fuel dependency is unsustainable and requires a significant course change to substitute renewable sources of energy while engineering new and scalable approaches to sequester carbon from the environment. Achieving this entails a shift from investing in the maintenance existing processes, systems, and technologies to one of using new technologies. In strategy terms, organizations need to reconsider their 'do no harm' strategies and actively target applications that have a positive impact.

The second dynamic involves a broadening of the sustainability agenda to include societal and stakeholder issues alongside environmental ones. Businesses are responding by collaborating to develop new measurement and reporting frameworks based on sector-wide agreements or standards. Currently, these focus on data gathered through audits and conventional, financial reporting metrics. In time, the range of measurements is likely to include operational data and more frequent measurement and reporting intervals. This is where 'digital-ready' reporting standards and IoT technologies are expected to grow in importance.

ICT solutions and service providers already offer remote monitoring and data management solutions to their customers. However, these concepts need to scale and become more widely adopted. Once that occurs, many more applications are likely to emerge, triggering new waves of innovation and sustainability solutions.

ICT solutions are also deployed by organizations to offer services to their customers. An example is the case of a network equipment provider that supplies a mobile network operator which services its business and consumer customers. There will be an onus on the primary providers to develop approaches that allow the life cycle footprint of their equipment to be assessed. This is a form of "greening by ICT" and will require better data gathering allied to collaborative approaches along value chains to apportion and manage environmental impact factors.

3. The Role of IoT in Sustainability

The United Nations' Environment Program (UNEP) monitors progress on a range of metrics associated with each of the UN's seventeen Sustainable Development Goals (SDGs). As shown in Table 1, almost half of these can be addressed with IoT applications, technologies, and systems

Table 1 Key UN SDGs that are addressable by IoT applications and systems

UN SDG		AIMS
SDG 2	Zero Hunger	Use of sustainable agricultural practices
SDG 3	Good Health & Wellbeing	Reductions in mortality linked to air and water pollution
SDG 6	Clean Water & Sanitation	Improvements in water quality and resource management
SDG 7	Affordable & Clean Energy	Focus on energy efficiency
SDG 9	Industry, Innovation & Infrastructure	Reductions in CO2 emissions via circular economy and new production paradigms
SDG 11	Sustainable Cities & Communities	Improvements in public transport and disaster management
SDG 12	Responsible Consumption & Production	Manage the environmental footprint of materials and influence over domestic consumption
SDG 17	Partnerships for the Goals	Promote the use of environmentally friendly technologies

While it is possible to customize strategies in each of these categories, a strategy aiming for re-use and scale would focus on areas of commonality to maximize the value of common IoT capabilities. Four opportunities stand out.

- The first involves the benefits of **remote connectivity** that bring widely dispersed machines and sensors into closer operational reach.

- The second, which is a consequence of the power of remote connectivity, is the availability and **access to IoT data** for the remote monitoring and improved decision making of scarce resources.

- As multiple IoT systems are deployed, a third contribution of IoT is the ability to design **cross-silo applications**. These can involve the sharing of data from a group of IoT sensors across several users and not just for the use of the organization that deployed those sensors. This leads to better use of resources if application developers can avoid deploying dedicated sensors or infrequently used sensor systems. They can reduce the use of materials, energy consumption, and number of site visits.

- Finally, new monitoring requirements call for a significant expansion in the number of IoT sensors. These need to be energy friendly, making efficient use of connectivity networks without disrupting other users. This calls for new technologies based on **constrained IoT devices** that leverage intelligent connectivity capabilities and energy-saving dormancy modes of operation.

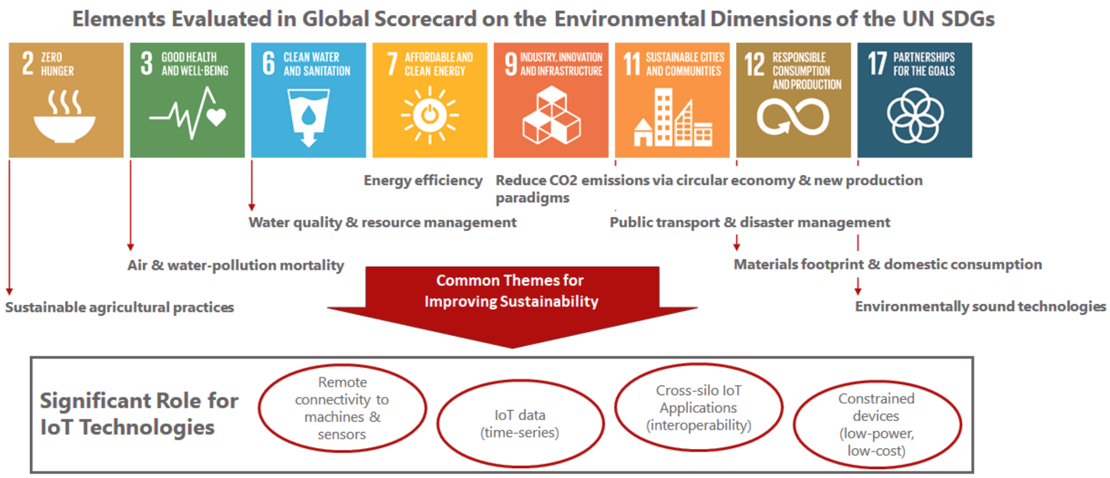


Figure 3 Four Roles for IoT technologies in addressing UN SDGs

Source: UN Environment Program report on [Measuring Progress: Towards Achieving the Environmental Dimension of the SDGS (2019)]

In 2020, Deutsche Telekom conducted an online survey with its IoT experts on the role of IoT and sustainability in helping businesses to meet environmental goals within their business and with supply chain partners. As illustrated Figure 4, the survey results underline high expectations for market demand and considerable scope for product and service innovation.

Figure 4 Deutsche Telekom internal experts see a significant role for IoT in sustainability solutions (2020)

3.1 Examples of IoT in Enabling Sustainability

IoT applications hold great potential to enable decarbonization which is set to drive a fundamental transition in several industry sectors. Another area where IoT will have a major sustainability impact is in resource and energy efficiency solutions by making processes leaner and helping organizations to raise the performance threshold for resource conservation. There are numerous use cases that underpin this idea.

An example that demonstrates gains in operational efficiency and resource management involves the Spanish firm Hidroconta which manufactures water meters and irrigation systems. These meters are used by facility management companies and agricultural enterprises. Before they were enabled with IoT capabilities, Hidroconta employees would take meter readings on-site. The time-consuming process meant that agricultural companies lacked the transparency needed to optimize the water supply to their plantations and to organize it more sustainably. Working with Deutsche Telekom, Hidroconta developed IoT-enabled smart meters using Narrow Band IoT (NB-IoT) technology to transfer encrypted, water consumption data at regular intervals to a connected cloud platform. Agricultural enterprises can now access data in the cloud platform at anytime from anywhere. They can also specify individual irrigation times remotely and thereby regulate water supply efficiently.

Energy consumption in buildings is one of the top three contributors to GHGs. IoT can play a significant role in embedding sustainability capabilities to create smart buildings. An example of this involves ISS, a global company for technical facility management, catering, cleaning, security, and support with over 480,000 employees. Working with Deutsche Telekom, ISS wanted to provide more transparency around comfort parameters and space utilization in order to conserve resources and reduce costs. Their smart building solution features intelligent sensors to monitor CO2 levels, temperature, humidity, light, noise and building usage. This solution lowers energy consumption, saves resources, lowers costs and increases customer comfort.

In India, the Centre for Development of Telematics (C-DOT) is working on an initiative to develop a standards-based and reusable set of capabilities to support commercial IoT systems. This is in the context of C-DOT's role to develop and license new information and communications technologies through solutions that address local market needs. C-DOT's Smart Living Application is based on the oneM2M standard for IoT systems. The solution monitors temperature, humidity, and power consumption to control the HVAC system in a building and to report power consumption statistics of the building. This results in a significant reduction in energy consumption through frugal use of the air-conditioning system. Data from the solution also supports planning and design activities to improve energy efficiency.

C-DOT's strategy of designing to the oneM2M standard offers other sustainability benefits in terms of reusing a baseline technology for applications in other areas. One example that reuses C-DOT's Common Service Platform (CCSP) is a quarantine management system. This combines a personal LoRAWAN device with the CCSP's geo-fencing and notification capabilities to manage boundary violations. Another example of reusing the CCSP's capabilities is a smart vehicle and visitor management system. This use-case involves automating the process of controlling arrivals and departures of authorized and visitor vehicles at campus sites and office complexes.

Another example that illustrates the principle of resource sharing and re-use and resource sharing involves a European research project where the French operator, Orange, is working with 15 partners including the major sea ports of Bordeaux and Thessaloniki. The objective of the project is to define a scientific and technical solution for measuring the environmental impact of commercial harbours, and to identify solutions to reduce their footprint. The solution has been deployed in 4 harbours: Bordeaux, Monfalcone, Thessalonique, Le Pirée. Thanks to IoT sensors and pollution indicators, facilities managers can analyse logistics flows and optimize the organization of harbour activities to reduce pollution.

Outcomes from a Data and Resource Sharing for Smart Regions Pilot Project

Many smart city applications rely on IoT technologies for services that make better use of transport and road-network resources and improve economic efficiency. When combined with an open standards approach, city authorities and transport agencies can share common infrastructure and explore new operating models such as cooperation across boundaries to facilitate commuter journeys and manage traffic at large events.

oneTRANSPORT is a data marketplace service that was initially piloted across four counties in the UK. It used a standards-based platform to source data from over 200 types of data sources such as road traffic sensors, parking occupancy sensors and number-plate recognition systems. Four counties and the national transport agency shared data, using controllable policies, with specialists in journey-planning data analytics, facilities managers, and AI researchers. Some of the operational benefits included:

- Improvement in road safety and congestion management in Watford town centre when 20,000 additional visitors would travel on Premier League match days.

- Implementation of a park-and-ride scheme for visitors to the historic university town of Oxford

- Improved site visibility and management of traffic at the Silverstone racetrack during the Formula 1 race weekend. Over this period, over 250,000 visitor trips are made to the event venue. This calls for coordination of temporary road diversions between the private sector and three neighbouring county agencies.

In addition to the benefits of sourcing IoT data and enabling cross-organizational collaboration, this scenario and the three, application use-cases illustrate the benefits of standardization for re-use, scalability, and data interoperability.

Finally, it is important to note that circular economy concepts will play an increasingly important role in business strategies over the coming decades. This will put pressure on linear economy models, based on the take, make, dispose sequence. Instead, new strategies will focus on approaches that design for no waste, that use products for as long as possible and which preserve or enhance the value of renewable resources.

Circular economy measures are expected to contribute to reductions in energy consumption. They are likely to improve the efficiency of resource use and to trigger improvements in how materials are due to technical progress, information insights and business model innovations. The underpinnings of these will be rooted in advanced digital and communication technologies. In particular, enhanced connectivity will make it possible to optimize operational efficiencies based on novel sensing and digital twin technologies allied to IoT data platforms.

4. Principles for Sustainable Design

Three factors can have an impact on sustainable IoT systems. The first deals with investment in IoT systems and encourages reuse and sharing by multiple users. It is also an approach that minimizes the risk of 'orphan' investments. The second involves the application of principles that promote sustainability by design and where standardization can have a material impact. At the implementation level, the third factor applies to the emerging solutions and technologies that improve sustainability performance. Individually, many of these might have a marginal impact. However, their influence can be considerable when applied together and at scale.

4.1. Invest 'Horizontally' to Maximize Reuse and Longevity

There are several common elements to most IoT systems. These include the functions associated with registering device and application identities, for example. Others include remote device management, communications management, and security. Organizations and their product managers should avoid developing IoT applications in isolation and consider how to reuse or share common service functions. This is generally achieved through the use of IoT platforms that contain frequently used developer tools. This approach ensures that multiple users can share a set of common resources and leverage the economies of scale associated with shared platforms and platform-developer expertise.

Smart buildings and cities, which are shared spaces used by multiple user groups, are relevant examples of where this model can be of practical value. These are environments that house multiple IoT applications. There are also dependencies between applications and user groups, between short-term decisions driven by the pace of technology evolution and constraints on the built environment where assets might be designed to last fifty to a hundred years.

In practice, it is a big challenge for smart cities to engage across all the application areas at once, linking areas which have historically been independent silos. Nevertheless, this is a scenario that calls for a 'horizontal' architecture approach.

Most cities with any track record in this field will have started their smart city journey via a single application, often motivated by a technology-driven means to reduce operating costs. Smart parking, dynamic street lighting and intelligent waste collection are three such examples. The next phase of the smart city journey is typically to build additional applications that leverage early-stage investments. Smart lighting installations, for example, can support environmental monitoring, public safety, and traffic management applications through the addition of sensors and the application of pattern recognition techniques.

Problems may arise when these early commitments begin to limit the ability of a city to improve, innovate and expand its portfolio. This is the dilemma of vertical, single-purpose, fast-to-market strategies that function as silos. With the passing of time, they demand significant new investment in redesign and system integration efforts to avoid becoming 'orphan' or silo investments.

When city authorities launch vertical initiatives to address local issues, they should plan for the future where individual applications must scale vertically (e.g., adding more districts to a smart street lighting system) and evolve horizontally. Take the example of traffic monitoring sensors for a congestion management application. In time, the traffic-related infrastructure could accommodate environmental and other sensors, implying a high potential for re-use at the hardware and communications layers. Then, integration into city planning tools (for housing, green areas, siting of hospitals and aged care centres) can improve citizen health and safeguard wellness in the future. This is where a horizontal design approach from the outset offers long term, sustainability impacts by maximizing reuse and preserving the usefulness of previously deployed assets.

4.2. Principles for Designing Sustainability

In addition to using IoT systems to enable applications that have a sustainability impact, it is also important to encourage developers and service providers to design systems based on sustainability principles. These include design for interoperability, scalability, modularity, and re-use.

Interoperability manifests itself in many ways. One example involves the ability to interchange computing and device components from different suppliers. Another example, higher up the IoT solution stack, allows for the exchange of data across application and operational silos. Each of these interoperability facets can benefit from **standardization**. This is because standardization creates a pathway to **scalability**, through economies of scale from a large and dynamic supplier base.

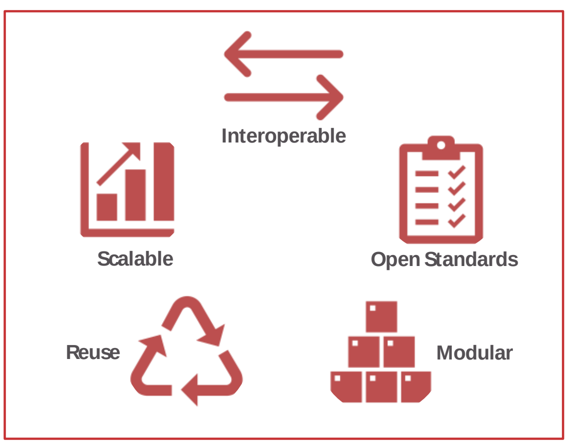


Figure 5 Sustainable Design Principles

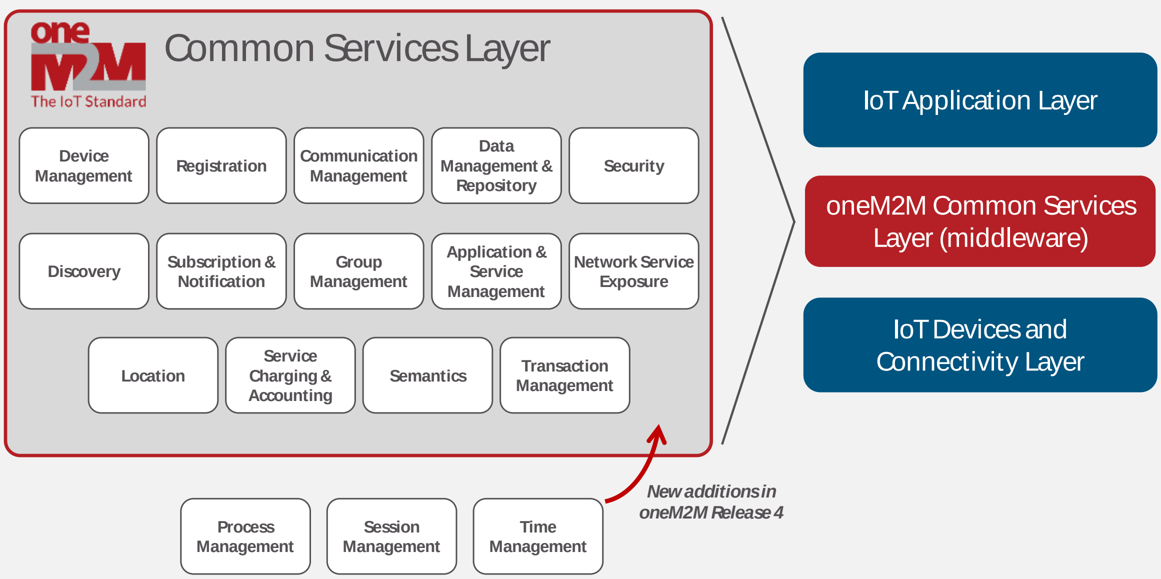
Modularity in system and software design helps designers to combine sub-systems. As a design principle, it helps developers to build IoT systems that combine new capabilities with legacy systems. This preserves some value of deployed systems without foreshortening their useful service lives. This is also an aspect of the **'re-use' principle**. The aim here is to create solutions and sub-systems that other developers can employ to save time and improve their productivity.

The early experience of sustainability in the corporate arena highlights the importance of agreed frameworks and common reporting standards. Examples include the UN's SDGs, the GRI business reporting framework and new initiatives to guide the investor community on corporate sustainability. These principles are equally applicable for the technology and IoT markets, where early support for standardization at the device and connectivity layers is beginning to extend to data (standards data models), data-sharing (semantic interoperability and data licensing) and data-privacy management topics.

Introduction to the oneM2M standard

In 2012, a group of national standardization bodies launched oneM2M to create a global standard for IoT systems. The solution to widespread adoption and affordability of IoT systems relies on minimizing industry fragmentation from local and national approaches. There was an emphasis on defining a general-purpose framework, or a horizontal architecture, that would be applicable to multiple application verticals. This required an analysis of multiple use-cases, spanning several different vertical domains, to identify commonalities for standardization.

oneM2M employs a three-layer architecture, comprising a middleware capability that resides between an upper, IoT application layer, and a lower layer for devices and connectivity technologies. The middleware comprises a family of common service functions in the form of a toolkit that developers can draw upon, as needed, for their deployment requirements.



oneM2M is a continuous standardization body that operates to a release cycle (Release 4 shortly to be launched and work is underway on Release 5 features). As a result, the list of common service functions has expanded over time. It now numbers fourteen items with three new capabilities – Process Management, session Management and, Time Management – set for inclusion in Release 4 of the standard.

4.3 Application of Sustainable Technologies

In the past, much discussion focused on efficient hardware designs to improve the energy performance and service life of constrained, IoT devices. In contrast to smartphones that are charged on an almost daily basis, some IoT devices are expected to survive in remote locations for as many as ten years. However, if devices remain connected to the network during times when there are no IoT applications interested in communicating with these devices, then this results in non-optimal consumption of device resources (e.g., battery) and network resources. Likewise, if applications repeatedly poll devices when these devices have no new information to share or the devices are sleeping and not connected to the network, then this also results in non-optimal consumption of device resources (e.g., battery) and network resources. As a result, there is a need for a new set of operational procedures and related technologies. 'Sleep modes' are one such method for gathering and sending data without a device needing to be constantly switched on or continuously polling the network. This has a major impact on energy efficiency but requires an agreed handshake between device and network combined with software intelligence to optimize connectivity and data transmission.

If communications between networks and devices can be coordinated, then it is possible to design for energy conservation. In the case of IoT applications operating over cellular networks, 3GPP standards define a northbound API for exposing underlying cellular network functionality to configure 'sleep mode' timers for devices. oneM2M has its API for interworking with 3GPP networks which translates 3GPP data structures into a format that IoT developers can use as part of their IoT toolkit. They can therefore define sleep schedules in the context of their application requirements.

In more complex and multiple device scenarios, oneM2M can aggregate and align schedules of devices and the different applications needing to communicate with these devices. This ensures that IoT devices connect to the network at the optimal times to send and receive data from network applications. The complementary nature of 3GPP and oneM2M standards extends the idea of managing networks responsibly as encouraged by the GSMA through its IoT connectivity guidelines to 'do no harm' to mobile networks.

Sustainability for IoT devices means the capability to remotely manage IoT devices and for some of them in a long service life to minimize their obsolescence. In this idea, standardisation can be a powerful tool to specify the procedures to re-purpose devices by updating their software with backward compatible enhancements. From a security perspective, oneM2M is making the security protection remotely upgradable by design with features like firmware update that is essential to face new threat surfaces. Keeping security up to date will reduce the pollution created by "things" that become obsolete.

4.4. A Framework to Preserve Legacy System Investments

The deployment of IoT applications in operational environments generally involves enhancements to existing assets. This may take the form of retrofitting connectivity technologies to enable data capture and remote actuation. It might also involve capturing data from legacy equipment or sub-systems that may employ proprietary or industry-specific protocols. Examples are the use of OPC-UA for industrial control systems and the OCF framework in smart home appliances.

When new (greenfield) and legacy (brownfield) components are being combined, one approach is to customize integration points. This is not ideal when done on a case-by-case basis. A scalable and general-purpose approach involves the use of interworking standards that support data exchanges between subsystems. This principle is enshrined in the cross-domain hub model that is fundamental to the oneM2M standard as illustrated in Figure 6.

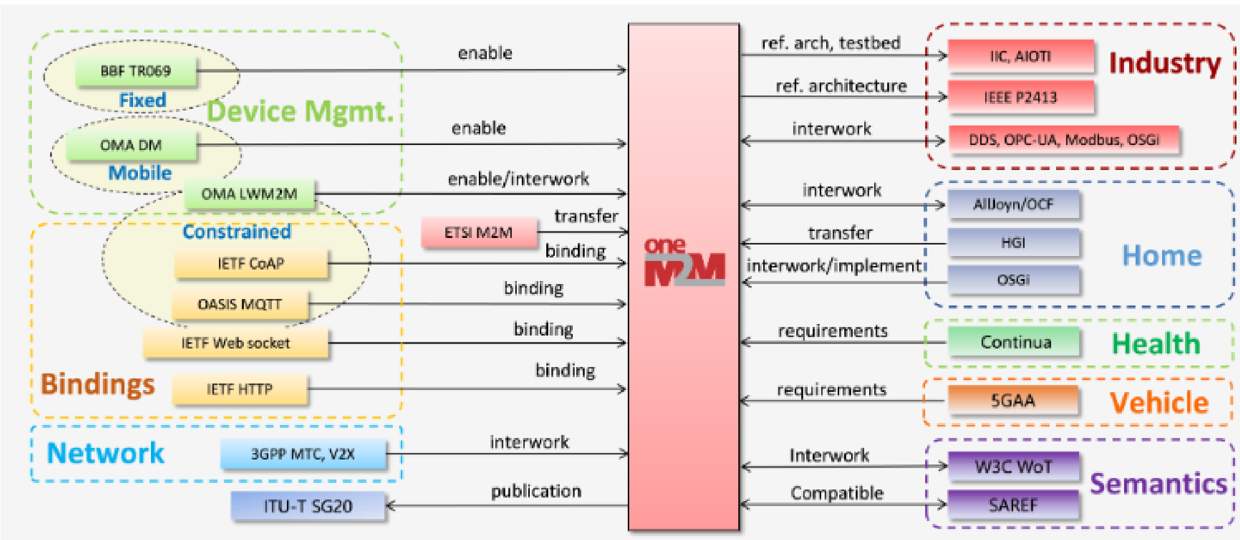


Figure 6 oneM2M unites established standards and addresses emerging use-case requirements

The left side of this illustration shows how oneM2M standards provides an interworking framework across fixed and mobile communications domains by reusing established device management standards. oneM2M also includes bindings for constrained devices and low data payload communications standards.

The right side of Figure 6 highlights the horizontal properties of oneM2M standards and their applicability to several application domains. These include the industrial, home, health, and automotive vehicles sectors. As attention in the IoT sector shifts to higher layers of the technology stack, oneM2M standards also address the need to enable data interoperability through semantic approaches. In this regard, oneM2M is compatible with the SMART Applications Reference ontology (SAREF) and supports interworking with the W3C Web of Things semantic framework.

The oneM2M architecture and body of technical standards provide a framework to combine legacy and new-build IoT systems. In addition to preserving the value of legacy investments, oneM2M's standardization roadmap, through planned release cycles, accommodates new requirements. These can arise from the need for more complex capabilities, such as requirements to handle data-privacy and data-licensing. The same is true of new use-cases, such a public-safety and vehicle-to-vehicle systems, that arise as different industries embrace IoT solutions more systematically.

5. Future Directions for IoT and Sustainability

Am important challenge for the future in one of education. This White Paper is a first step in informing commercial, policy, sustainability, and technology audiences. More education will be required in the future, not solely targeting industry environments but also in training future workers and IT professionals with the knowledge and tools sets to take advantage of promising IoT and sustainability capabilities.

With increasing familiarity about such capabilities, application developers and entrepreneurs will use IoT technologies to deliver new sustainability benefits. The family of IoT technologies will, however, continue to evolve in many different directions as new use-cases, business models and associated requirements emerge. Some of these will tackle hardware issues, as in the case of low-energy and 'non-smart' devices. Other ideas, drawn from 'circular economy' concepts will entail a re-purposing of long service-life devices via programmatic technologies. Others will involve technologies to reduce network energy usage and to protect IoT systems so that their operations remain resilient.

At Orange, research teams are working on the design of the concept of 'no-energy' connected objects. These self-powered objects rely on renewable sources of energy and communicate by recycling ambient waves. They are detectable by wireless networks and smartphones in their vicinity. An experimental project involves the concept of a Crowd-Detectable Zero-Energy-Device (ZED). Such a device harvests solar or ambient light energy to power itself, recycles ambient signals to communicate, and is detectable by a smartphone and the network as soon as it gets close to a smartphone. A transport company attaching a ZED on a package can track it with almost nothing: zero power, zero new signal and zero new network infrastructure, thanks to the anonymous participation of smartphones. Indeed, each time the packet comes across a smartphone connected to the network, the package is automatically detected, located and time-stamped by the network. Prototypes of ZED(s) that reuse ambient TV/4G/5G signals already exist and have been recently demonstrated at the 2021 Mobile World Congress.

Beyond innovations around self-powered devices, other strategies involve different ways to get more from existing resources without expending more energy. An example being trialled by Orange involves an object sending two messages via one amplifier and one antenna. It sends the first message in the usual way and the second without any more information by reconfiguring the radiation mode of its antenna. Each mode carries a "meaning" in bits. The net effect of this double antenna approach is to double the device's bandwidth capacity and to optimize network energy consumption.

IoT is a term that is often associated with connected objects that send and receive data. Another way to think of these objects is as resources that can be used to infer and generate contextual information about the environment. Some of this can take the form of static and dynamic environmental data for parameters such as identity, activity context, behavioural context, physiological context, geographical context, and time context. These are inputs for research projects on context identification by deduction, using IoT types of data related to pressure, temperature, humidity, sound, colour, light, electromagnetic field, angular position, and angular speed. These types of data are useful for merging the physical and digital aspects of everyday environments. Integration gives rise to new areas of ubiquitous, sensitive, and environmental computing as well as new forms of interface between applications and users.

Deep integration involving IT (information technology), OT (operational technology) and ET (engineering technology) data from diverse data sources, both from the Plant layer (real time data) and from the Enterprise layer (transactional data) allows for remote monitoring and management. However, common data model compliant interfaces, ensuring the definition comply with data model standards in terms of semantics, syntax and relationship becomes vital. This is where open standardization becomes a powerful tool for the IoT ecosystem and their partners in different industry verticals.

Cybersecure interoperability is an important characteristic for a sustainable architecture, one that is scalable, modular, reusable and securely performing. Typical IT-OT convergence results in multiple applications connecting to multiple silos of data sources. In such cases a common services framework shall help in a sustainable architecture, both in terms of quality and economics. Security is also a concern because of the potential for IoT systems to expose new threat services. Left unprotected, vulnerabilities could be exploited in ways that would waste resources.

6. Contributors

oneM2M thanks the following for their contributions and insights to this White Paper.

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