The exponential growth of digital connectivity has had a sweeping impact on our society in the last decade. It is widely understood that this increase in connectivity – and the technological innovation it spurs between people, products and systems – can create significant new sources of value for citizens and economies, whilst also creating new challenges for regulators and policy makers. Understanding and harnessing the potential of this “Fourth Industrial Revolution” for society, the economy and the environment is the theme of the 2016 Annual Meeting of the World Economic Forum. This report on intelligent assets – a key feature of the fourth industrial revolution – and how they can be paired with Circular Economy principles is, consequently, both an important and a timely contribution to the new economics agenda.

As we look to the next decade, the prevalence of connectivity, through the Internet of Things and the creation of ‘intelligent assets’, will accelerate. The question remains: how can these technological advances be harnessed to enable smarter economic growth, resource and food security, and an improved infrastructure? The Internet of Things is already increasing efficiency in our current linear ‘take, make, dispose’ economy. Could it also, however, enable a less resource-dependent circular economy that is restorative and regenerative by design? And, in turn, could embedding circular economy principles in smart connected systems and devices significantly bolster the opportunity? These are the questions we asked ourselves, and experts across the field, when writing this report.

This report illustrates opportunities for innovation and creativity across a spectrum of industries and sectors: it looks at how we manufacture and use electronics and advanced equipment, how we create our energy infrastructure, how we build and transform our buildings, and how we produce food. It assesses how smart cities might evolve to become a focal point for the transitions to follow. There are profit opportunities for companies to play for but perhaps more importantly, there’s an opportunity for society to redefine its relationship with resources.

This document aims to provide the rationale for these opportunities that the intersection of the circular economy and smart connected devices could unlock for your business, city or region. While open questions remain to be explored, we believe the perspective shared here offers a compelling vision for intelligent assets in a circular economy. We invite you to add your voice to this conversation, and look forward to engaging with the first movers and leaders to act on this opportunity.

This report is the product of Project MainStream, an initiative that leverages the convening power of the World Economic Forum, the circular economy innovation capabilities of the Ellen MacArthur Foundation, and the analytical capabilities of McKinsey & Company. We are grateful to all the businesses and institutions that engaged with us to create this report, and to the Project MainStream Steering Board for its continued collaboration on the transition towards a circular economy.
There exists a great opportunity for aligning IoT innovation with a circular economy.

Carlo Ratti
FOREWORD

It could be that the early part of the 21st century is seen as the era when system-wide connections changed the economy and our way of life more profoundly than we realised at the time.

Intelligent Assets delivers a landmark study of the opportunity and challenges ahead. It draws upon the important combination of circular thinking and connectivity, canvassing the views of a number of highly-regarded stakeholders on how to achieve a circular economy at scale.

If new business models are designed correctly, they can be built at lower cost, offering improved quality of service while using fewer resources. This is an opportunity that must be seized by both businesses and governments to propel us into a new era of sustainable maturity.

While the principles of a large-scale circular economy are being embraced in industrialised countries, no greater potential for circular operating models can be seen than in emerging markets. The opportunity to transition towards new modes of industrialisation is profound. This has the potential to improve billions of lives while minimising intensive use of natural resources. We must manage our rapidly growing global population with this in mind.

It is vital that key stakeholders continue to work together to develop concrete proposals that meet the challenges posed in this report. This document will be a vital reference point for future collaboration if we are to deliver on the real promise of sustainable innovation.

Cisco and Philips are proud to be global partners of the Ellen MacArthur Foundation, contributing dedicated resources and impassioned advocacy for the design of circular business models. Both our companies embrace circular values in our strategies, pioneering new technologies and solutions that we hope will shape our industries and build a more sustainable global future.

Frans van Houten
Chief Executive, Royal Philips
Chuck Robbins
Chief Executive, Cisco Systems

PROJECT MAINSTREAM

This report was written under the umbrella of Project MainStream, a multi-industry, global initiative launched in 2014 by the World Economic Forum and the Ellen MacArthur Foundation, with McKinsey & Company as knowledge partner. MainStream is led by the chief executive officers of nine global companies: Averda, BT, Desso BV (a Tarkett company), Royal DSM, Ecolab, Indorama, Philips, SUEZ and Veolia.

MainStream aims to accelerate business-driven innovations and help scale the circular economy. It focuses on systemic stalemates in global material flows that are too big or too complex for an individual business, city or government to overcome alone, as well as on enablers of the circular economy such as digital technologies.

DISCLAIMER

A team from the Ellen MacArthur Foundation produced this report in collaboration with the World Economic Forum. The Ellen MacArthur Foundation takes full responsibility for the report’s content and conclusions. While the contributors listed in the acknowledgements provided significant input for the development of this report, their participation does not necessarily equate to endorsement of the report’s full content and conclusions.

SUPPLEMENTARY INFORMATION AVAILABLE

Extended versions of select case studies are available from the Ellen MacArthur Foundation website. www.ellenmacarthurfoundation.org/publications/intelligent-assets

ENHANCED DIGITAL CONTENT AVAILABLE

The digital version of this report contains audio tracks with additional comments from selected contributors. Click on the symbols to listen.
The Internet of Things and circular economy practices are mutually reinforcing – bundled together they present immense opportunities — for business and society at large — leading to systems that are resilient, decentralised, self-repairing and scalable without experiencing complexity problems. The natural world – life itself – is network based, and bio-inspired systems are already standard. Looking forward, the Internet of Things will provide information about what resources we have and what we are losing. With objects becoming increasingly self-aware, the sharing platform of the future could have assets making themselves available for use in real-time. Enhanced tagging and tracking capabilities, such as insect-inspired swarm intelligence, present enormous economic opportunities to plug leaks and make use of materials previously considered to be waste.

Janine Benyus
Co-founder of the Biomimicry Institute

Information is at the heart of ensuring that businesses around the world can make the right decisions to eradicate waste and use resources effectively. The Internet of things, with its smart sensors and connected technologies, can play a key role in providing valuable data about things like energy use, under-utilised assets, and material flows to help make businesses more efficient. Their role in building a future with a more circular economy is critical and we are excited about the role technology will play in realising this vision.

Kate Brandt
Lead for Sustainability, Google Inc.

We have tremendous challenges ahead of us. We have to improve the human condition around the world as the population grows, while at the same time learning to tread more lightly on our planet. The only way we’ll meet them – and I’m confident that we will – is with a combination of technological progress, innovation, markets and goodwill.

Andrew McAfee
Co-Director, MIT Initiative on the Digital Economy; Author, The Second Machine Age

 Truly circular economies arguably cannot exist without the Internet of Things. No amount of clever design ensures a complex system will remain useful and efficient over time. To be sustainable, a system must be responsive; actions and behaviours must be connected via data and knowledge. With the embedding of intelligence in almost every object, we can imagine systems that adapt and respond to change in order to remain fit for purpose.

Tim Brown
Chief Executive Officer, IDEO

For the SDGs [Sustainable Development Goals] and the search for sustainable growth models, the Internet of Things combined with big data and data analytics has the potential to turbocharge promising circular economy models, in part via the impact on the efficiency of use, maintenance and longevity of assets. This surely will advance us several steps towards growth models that allow for expanding prosperity while maintaining and augmenting the natural capital base of the global economy and our existence.

Michael Spence
Nobel Laureate; William R. Berkley Professor in Economics and Business, NYU

The coming profusion of smart sensors and connected technologies that makes up the Internet of Things will have a profound effect on our cities. Cities are already leading the way in reducing carbon emissions and deploying smart systems, and the circular economy is the next big opportunity that a city like London is best placed to drive forward. London already has a strong and growing low carbon goods and environmental services economy and I foresee the same opportunity presenting itself in the circular economy.

Boris Johnson
Mayor of London

The projected addition of high tens of billions of IoT devices in the next several years will dramatically intensify connectivity among individuals and various units, organic and inorganic. Future advances in systems integration on chips or stacked chips with nanoscale devices for both dense memory and fast logic, versatile biosensors, neuromorphic computing and deep machine learning capacity will rapidly increase the intelligence of machines, robots, equipment and connected things, thus helping to strengthen the circular economy. The growth of the circular economy will in turn enlarge the optimisation problems domain, generate immensely big data, identify new needs and call for more innovations in future electronics, thereby feeding each other in a continuously evolving and sustainable ecosystem for a better world for all.

Sung-Mo Steve Kang
President, Korea Advanced Institute of Science and Technology; Chair, Global Agenda Council on the Future of Electronics

IN SUPPORT OF THE CIRCULAR ECONOMY AND INTELLIGENT ASSETS

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A rapid increase in the number of intelligent assets is reshaping the economy, and this development will create significant value. The number of connected devices is expected to grow to 25–50 billion by 2020, from around 10 billion today. A growing body of research indicates that this Internet of Things (IoT) offers a trillion-dollar opportunity, brought about by improved production and distribution processes and, perhaps more importantly, a significant shift in the way products are utilised.

As author James Bradfield Moody1 puts it, the “processors are starting to communicate beyond the confines of their device, and are sharing information that has never been shared, or even collected, before. This brings us to [a] big idea that will govern how we innovate in a resource-limited world – the convergence of the digital and natural worlds.”

Pairing this digital revolution with circular economy principles can indeed transform the economy’s relationship to materials and finite resources, thus unlocking additional value and generating positive outcomes. The circular economy helps decouple economic value creation from resource consumption. Its four value drivers – extending the use cycle length of an asset; increasing utilisation of an asset or resource, looping or reclaiming an asset through additional use cycles, and regeneration of natural capital – can be combined with one (or several) of the three main intelligent asset value drivers – knowledge of the location, condition, and availability of an asset.

In this systemic change perspective, IoT becomes the new, virtualised infrastructure that governs assets use and movements along the value chain. Digital tools – such as exchange platforms allowing multiple useful lives and embedded product information – become as important as physical tools when it comes to determining and steering asset flows. IoT value created can extend beyond direct business benefits, and generate significant wider societal benefits. In mobility, for example, IoT-enabled apps helping drivers to find a parking space and avoid busy roads not only deliver a direct user advantage, but also reduce congestion and emissions, hence benefiting society as a whole.

Businesses are already exploiting the interactions between the circular economy framework and intelligent assets today, across several sectors, and with a focal point in cities. By breaking down structural barriers established over time between production and consumption or use, an IoT-enabled circular economy offers considerable opportunities for a multitude of sectors including manufacturing, energy and utilities, built environment and infrastructure, logistics and waste management, and agriculture and fishing. Both large incumbents and disruptive innovators are rethinking their models and value chains, indicating that the digital revolution is not a niche market but the underpinning of a new economy. With over 80% of global GDP generated in urban areas and multiple opportunities to optimise materials flows, cities are at the forefront of the upcoming transformation.

What is at stake is not incremental change or a gradual digitalisation of the system as we know it, but a reboot: pervasive connectivity rolled out at scale has the power to redefine value generation, whilst helping emerging economies bypass heavy upfront investments and material-intensive solutions. For instance, an ecosystem of intelligent asset-enabled services could jointly open widespread access to reliable, grid-free renewable energy. Solar panels could be provided as a service to individuals and businesses without access to the capital to buy solar panels themselves, through weekly online payments. Battery health monitoring, predictive maintenance of panels, automated management of distribution systems and other IoT-enabled services could complement this model to avoid the massive investment in capital and resources needed to develop a centralised grid infrastructure.

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Such a promising horizon entails redefined collaborative mechanisms between technology and the framework within which it operates. At the confines of innovation and regulation, creativity needs to be called upon in order to manage the complex questions raised by data circulation and capture, compatibility of systems and intellectual property. Several experts consulted have remarked that companies need to shift away from a protective approach and closed innovation, towards more open-source, collaborative data platforms. At the same time, the proliferation of sensing equipment in society raises important questions about data security and privacy. Addressing these challenges requires new rules of the game that will allow the fast-moving technology and market trends to evolve. Companies and policymakers would need a multi-stakeholder approach to create such conditions; if successful they could lay the groundwork for solving several of the core challenges for designing an economy that is truly restorative and regenerative.

The impending digital transformation holds the potential to redefine the very basis of our materials-reliant industrial economy. Enabled by intelligent assets, a new model of development gradually gaining independence from finite resource extraction is emerging. Can pervasive connectivity become the new infrastructure: enable effective material flows, keeping products, components and materials at their highest value throughout their useful lives, and in which farmers can monitor and regenerate areas of their land which have been over-exploited? Where shared and multimodal transport help citizens to quickly and safely navigate to their destination, even during rush hour. A system where the primary advantage is not the reduction of transportation costs, but a reboot: pervasive connectivity rolled out at scale has the power to redefine value generation, whilst helping emerging economies bypass heavy upfront investments and material-intensive solutions. For instance, an ecosystem of intelligent asset-enabled services could jointly open widespread access to reliable, grid-free renewable energy. Solar panels could be provided as a service to individuals and businesses without access to the capital to buy solar panels themselves, through weekly online payments. Battery health monitoring, predictive maintenance of panels, automated management of distribution systems and other IoT-enabled services could complement this model to avoid the massive investment in capital and resources needed to develop a centralised grid infrastructure.

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Early signs of this transformation are perceptible, as this report highlights, yet clarifying and scoping out the depth of change at play in the global economy is necessary to harness the full potential of this positive wave of development.

EXECUTIVE SUMMARY

Digital technology is fast becoming a pervasive feature across a wide variety of products. Equipped with the ability to sense, store and communicate information about themselves and their surroundings, these ‘intelligent assets’ are poised to unlock tremendous opportunities for businesses and individuals. Will this development - by many regarded as the impending ‘fourth industrial revolution’ - lead to an acceleration of the extractive, ‘linear’ economy of today, or will it enable the relative decoupling of resource consumption from economic development and accelerate the transition towards the circular economy? To what extent could intelligent assets contribute to capturing circular economy benefits? And importantly, what are the key challenges to address in order to realise the potential opportunity?

This report is the first of its kind to discuss these questions, by studying the interplay between the value drivers of circular business practices and intelligent assets. Its goal is to shed light on the value creation opportunities that are emerging from this interplay, and to give a directional perspective on potential opportunities in the medium to long-term. In doing so, it seeks to initiate a discussion inspiring businesses, innovators, and policymakers to explore the synergies that circular economy and intelligent assets can generate.

The report builds its arguments on aggregated insights from a collection of case studies and stand-alone opinion pieces from a wide range of thought-leaders - reflecting today’s ongoing developments but also what the future could bring and what it takes to get there. Around 40 businesses and institutions have been consulted in the process of creating this report.

“Discovery of new phenomena is what opens the pathways to innovation.”
Bernard Meyerson

**USEFUL DEFINITIONS**

**Internet of Things (IoT).** The networked connection of physical objects. For simplicity, this term is used in this report to indicate all objects, systems and processes that are exchanging information through the Internet, instead of differentiating them by additional definitions (e.g. the Web of Things, Internet of Everything or Industrial Internet of Things).

**Intelligent assets.** Physical objects that are able to sense, record and communicate information about themselves and/or their surroundings. This definition incorporates IoT objects but also includes assets that are not continuously transmitting information, and things that do not feature wireless communication.

**Asset.** A physical object, such as a machine, building or material. Components of objects are also described as assets because they are frequently treated individually during or after a use cycle.

**Resource.** A flow or stock of materials or energy that can be transformed into assets or consumed to make assets function.

**Performance models.** A business agreement in which the customer pays for the use, or the performance, of a product rather than the product itself. The rationale is that there is no inherent benefit in owning the product. On the contrary, ownership can entail additional costs (upfront investment), risk (unpredicted repair, maintenance or obsolescence), and end-of-use treatment costs. Performance models go under several names with different specificities, e.g. service contracts or ‘servitisation’, leasing or asset centralisation. The emergence of IoT has also led to the popular notion of ‘anything-as-a-service’. The term ‘performance model’ is used to encompass all these varieties in this report.

**Remanufacturing.** A process of disassembly and recovery of an asset at a product and component level. Functioning, reusable parts are taken out of a used product and rebuilt into another. By definition, the performance of the remanufactured component is equal to or better than ‘as new’.

**Reverse logistics.** The process of moving goods from their typical final destination to concentrate them at a central location, either for the purpose of capturing value (through reuse, remanufacturing, refurbishment, parts harvesting or recycling), or for proper disposal.

**Negative externalities.** Negative externalities can be defined as cost suffered by a third person or society as a whole resulting from an economic transaction, e.g. pollution including CO2 emissions or noise, health issues including obesity, asthma or allergies.
Research to date has demonstrated that the circular economy is a clear value creation opportunity. It is an appealing and viable alternative to the linear ‘take, make, dispose’ model, and businesses are starting to implement circular principles into their operations. The circular economy aims to enable effective flows of materials, energy, labour and information so that natural and social capital can be rebuilt. This new economic model seeks ultimately to decouple global economic development from finite resource consumption.
AN OUTLINE OF THE CIRCULAR ECONOMY

The linear ‘take, make, dispose’ model, the dominant economic model of our time, relies on large quantities of easily accessible resources and energy, and as such is increasingly unfit for the reality within which it operates. Working towards efficiency – reducing the resources and fossil energy consumed per unit of economic output – will not alter the finite nature of their stocks but can only delay the inevitable. A more fundamental change of the operating system is necessary.

The concept of the circular economy has attracted attention in recent years. It is characterised, more than defined, as an economy that is restorative and regenerative by design and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. It is conceived as a continuous positive development cycle that preserves and enhances natural capital, optimises resource yields and minimises system risks by managing finite stocks and renewable flows. It works effectively at every scale.

The circular economy rests on three key principles, shown in Figure 1:

1. **Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows – for example, replacing fossil fuels with renewable energy or using the maximum sustainable yield method to preserve fish stocks.**

2. **Optimise resource yields by circulating products, components and materials at the highest utility at all times in both technical and biological cycles – for example, sharing or looping products and extending product use cycles.**

3. **Foster system effectiveness by revealing and designing out negative externalities, such as water, air, soil, and noise pollution; climate change; toxins; congestion; and negative health effects related to resource use.**

BENEFITS OF THE CIRCULAR ECONOMY

Multiple research efforts and the identification of best practice examples have shown that a transition towards the circular economy can bring substantial net material savings: In the first two reports from the Ellen MacArthur Foundation, detailed analyses of the benefits of a circular economy scenario. Considering only the sectors of medium-living complex goods (e.g. consumer electronics) revealed estimated cost savings of up to USD $630 billion annually in Europe after 2020. For the fast-moving consumer goods (e.g. food and beverages, clothing and packaging), the economic opportunity was estimated at more than USD 700 billion annually on a global scale, or materials savings of roughly 20%.

Reduced exposure to price volatility: A natural consequence of net material savings would be a shift down the cost curve for raw materials. For steel, the global net materials savings could add up to more than 100 million tonnes of iron ore in 2025 if applied to a sizeable share of the material flow (i.e. in the steel-intensive automotive or other transport sectors, which account for 40% of demand). In addition, such a shift would move the steel industry away from the steep (increasing) right-hand side of the raw materials cost curve, thus likely reducing demand-driven volatility.

Increased economic development: The study Growth Within: A Circular Economy Vision for a Competitive Europe conducted in the 2030 Agenda for Sustainable Development

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Increased economic development: The study Growth Within: A Circular Economy Vision for a Competitive Europe conducted in the 2030 Agenda for Sustainable Development

- Improved health: The implementation of circular economy principles, encouraging higher land productivity, less waste in the food value chain and the return of nutrients to the soil, will enhance the value of land and soil as assets.

TIME FOR A STEP CHANGE?

Despite the repeated demonstration of the benefits of the circular economy for businesses as well as societies, the introduction of some of its core practices – such as performance models – has to date been slower than expected, globally, without taking into account the hidden costs of increased fertiliser use, loss of biodiversity and loss of unique landscapes. The application of circular economy principles, encouraging higher land productivity, less waste in the food value chain and the return of nutrients to the soil, will enhance the value of land and soil as assets.

- The circular economy does indeed seem promising.

For good reasons perhaps: existing circular business models at scale demonstrate the importance of information and feedback-rich systems, and that it takes time and effort to get it right. Could the onset of intelligent assets perhaps provide the missing link to make a step change in the uptake of circular business models – removing barriers that prevent sharing, leasing and performance models from becoming the ‘new normal’? Could the digital revolution offer a blueprint of the infrastructure needed to keep materials in circulation – or could the infrastructure in fact be fully virtualised? The match between the digital development and the circular economy does indeed seem promising.
To understand the potential, consider the French tyre company Michelin. The company wants to add sensors to its tyres, to understand wear over time. For customers this is great. They will learn when to rotate tyres or replace them – unique to their specific driving conditions. This saves money and improves safety.

But there is more to play for. Armed with usage data, the company is even better equipped to shift its business model from selling tyres to leasing them (which it began before sensors made this model even more attractive). After all, GE and Rolls-Royce don’t sell jet engines but lease them with service contracts on the side – why not tyres too? The data collected by the sensors tell the company how the tyres can best be maintained.

The consequence of this shift in business model is profound. The tyre company now has a vital commercial interest in making tyres to last as long as possible, since the firm still owns them. And it has a new financial interest in using materials and processes that make recycling old tyres as efficient as possible.

Thus the technology that offered a benefit to consumers (cost savings and safety) and the bottom line of companies (new business models) has a society-wide benefit too, in terms of sustainability. These sort of ‘triple play’ wins – for consumers, companies and society – will become commonplace as the Internet of Things and big data increasingly become a part of everyday life. As such, the Internet of Things could become the ‘soul’ that animates objects in the circular economy.

However, making this a reality requires overcoming obstacles that risk impeding the circular economy. Regulators will be suspicious of algorithms that offer probabilistic answers rather than certain ones, especially in healthcare but in cars too. Yet correlational answers that are not causal is precisely how machine-learning artificial intelligence algorithms work, which fuel the Internet of Things.

Moreover it is unclear who actually owns the data: the company that invested in collecting and analysing it, or the entity from whom the data was collected? Here, Europe and America may move in different directions, promising more heartburn on both sides.

What to do? As a first step, business leaders and policymakers need to take a more permissive approach. They need to find ways to fit Internet of Things technologies into existing regulatory frameworks rather than oppose it. The battles over Uber and Airbnb around the world show this won’t be easy.

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INTELLIGENT ASSETS – BUILDING A SMARTER ECONOMY

Offering a trillion-dollar opportunity, intelligent assets are already unlocking new sources of value creation for both companies and individuals. They are in the process of significantly changing business operations, from product design to the supply chain to how value is created after sale. From a public sector perspective, intelligent assets have already started transforming important parts of societies’ ecosystems, including resource networks, transport systems and built environments.
A TRILLION-DOLLAR OPPORTUNITY

An estimated 10 billion physical objects with embedded information technology already exist today and many more smart cars, homes, cities, factories, energy systems, and other networks of connected devices are being built. Many companies have already begun to integrate IoT technologies into their operations and projections for future penetration, while spanning a big range, all point towards significant growth. Research firm Gartner predicts that by 2020 ‘around 25 billion connected “things” will be “in use” and their “disruptive impact will be felt across all industries and areas of society”. A recent report by DHL and Cisco suggests that the number of connected devices and objects in 2020 will reach 50 billion. Similarly, future value propositions come with a lot of uncertainty but show tremendous promise. McKinsey Global Institute predicts that the IoT will have a total economic impact of USD 3.9–11.1 trillion per year by 2025 (70% within business-to-business (B2B)), with customers capturing most of the benefits. Research by Cisco suggests that the “Internet of Everything” – the networked connections between people, data, process and things – will create an economic opportunity of USD 14.4 trillion for companies and industries worldwide during the next decade alone, corresponding to an opportunity to increase global corporate profits by about 21%

How these figures vary when different policy and investment trends are taken into account can be illustrated by recent research from Accenture which estimates that, under the current scenario, the IoT would add about USD 500 billion to China’s cumulative GDP by 2030. However, by taking additional measures to improve industry’s capacity to absorb IoT technologies and increase IoT investment, China could boost its cumulative GDP by USD 1.8 trillion by 2030.

CHANGING THE WAY VALUE IS CREATED

McKinsey states that ‘the ability to monitor and manage objects in the physical world electronically makes it possible to bring data-driven decision-making to new realms of human activity – to optimise the performance of systems and processes, save time for people and businesses and improve quality of life’. As pointed out by Daniel Keely at Cisco, as assets become more intelligent they learn to communicate and collaborate amongst themselves, eliminating the need for human intervention. These advances in autonomous ‘machine learning’ technologies enable the automatic optimisation of a digitised process, which goes beyond providing decision support for asset owners or managers. Where physical interaction is still required, machine to machine (M2M) collaborative networks are able to deploy autonomous devices to attend to a problem (e.g. drones). These advances in IoT technology are likely to represent the next major step change in asset productivity.

As illustrated by the following examples, intelligent assets profoundly change the way value is created in a business environment as the information generated by a connected machine, device or product becomes a critical component of value creation. Firstly, with the rise of IoT solutions, variations can not only be minimised but also responded to. For instance, through real-time transmission of data regarding external factors (e.g. humidity or temperature) that impact the quality of a product in the manufacturing process, the product can be routed to a different stage of the process that is not adversely affected. Secondly, recent IoT technologies enable products or machines to continuously create value even after they have left the supply chain. Through intelligent assets delivering information concerning their location, condition or availability, companies and end users can capture value in new ways throughout an asset’s use cycle. In addition, the manufacturer could use the information generated by the asset to further improve the product design. Finally, thanks to the ease of connecting people and things via mobile devices, the idea of sharing or leasing assets has become a significant economic opportunity for businesses and individuals across multiple sectors. A well-known example is Zipcar, which increases the utilisation of cars.
FUTURE MARKET
ARE THE IOT'S OPEN INNOVATORS to allow us to establish and certify the pedigree are emerging. This type of technology will start track our assets all the way along supply chains. Looking forward, IoT platforms that enable us to produce, own, use, repair, and trade assets. Models that could dramatically change the way new, systematic, whole-life IoT models emerge – IoT models generate. The coming years will see organisations to more effectively overcome defined problems and challenges. And finally, increased data sharing will allow organisations to more effectively overcome challenges and profit on IoT opportunities. Because IoT value resides mainly in the variety and volume of data, organisations sharing data on assets and resources, whether IoT or not, will again find synergistic value creation opportunities.

While circular economy business models can yield increasing asset and resource productivity, IoT plays an important role in making data available and turning that data into useful knowledge. It is truly a question of being able to maximise the use of data. Since both the IoT and circular economy perspectives imply systems thinking and cross-sector collaboration, market leaders in this space will be those who most successfully collaborate, share and use an open approach to innovation.

Conversely, the need for large-scale interoperability demonstrators is key. It is essential to deploy test beds facilitating open-source interoperability creation, and they should also assist real-life collaboration using best practice tools aimed at creating systematic approaches to IoT.

Secondly, there is great synergistic value in open innovation that needs harnessing. Businesses, government and innovators will eventually realise that it is more profitable to collaborate than innovate as individual entities. Moving away from the existing, siloed approach to one of open innovation will enable IoT value creation above and beyond what we are seeing today. An effective market environment is one where challenges are opened up to the best innovators and researchers, emerging as well as incumbent, using collaborative approaches with clearly defined problems and challenges.

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The interplay between circular economy and intelligent asset value drivers provides a fertile ground for innovation and value creation. Circular economy value drivers include extending the useful life and maximising the utilisation of assets, looping assets, and regenerating natural capital. Intelligent asset value drivers include collating knowledge about the assets’ location, condition, and availability. A broad range of opportunities emerges when these value drivers are paired. While it is impossible to predict all possibilities going forward, there are already numerous conceivable ways in which this interplay could drastically change the nature of both products and business models.
Both IoT and the circular economy are about exploring connections and feedback. IoT seeks to make assets of all kinds more intelligent and the circular economy to mobilise assets to deliver reusable use from economic development. Their visions are complementary but, for these models to thrive, it is critical to find smart, effective ways to maximise the utilisation of assets and keep them in the inner loops of their possible cycles (see page 17). Intelligent assets are already presenting solutions to many resource challenges faced by circular economy innovators. The feedback-rich nature of circular economy models might conversely make them particularly suitable to help extract value from the large amount of data generated by intelligent assets.

To understand the value creation opportunities created by the interplay between circular economy value drivers and those of intelligent assets, it is useful to think in terms of an ‘interaction matrix’ (Figure 2). In this matrix, using one (or several) of the intelligent asset value drivers together with one (or several) of the circular economy value drivers unlocks new value. The interaction matrix presents examples of a range of conceivable opportunities, and offers a framework to accommodate an even larger number of yet inconceivable ones.

### CIRCULAR ECONOMY VALUE DRIVERS

- Knowledge of the location of the asset.
- Knowledge of the condition of the asset.
- Knowledge of the availability of the asset.

#### Extending the use cycle length of an asset
- Guided replacement service of broken component to extend asset use cycle.
- Predictive maintenance and replacement of failed components prior to asset failure.
- Improved product design from granular usage information.
- Optimised sizing, supply, and maintenance in energy systems from detailed use patterns.
- Changed use patterns to minimise wear.

#### Increasing utilisation of an asset or resource
- Route planning to reduce driving time and improve utilisation rate.
- Minimised downtime through predictive maintenance.
- Precise use of input factors (e.g. fertilizer & pesticides) in agriculture.
- Automated connection of available, shared asset with next user.
- Transparency of available space (e.g. parking) to reduce congestion.

#### Looping / cascading an asset through additional use cycles
- Enhanced reverse logistics planning.
- Accurate asset valuation by comparison with other assets.
- Accurate decision-making for future loops (e.g. reman vs. recycl).
- Improved recovery and reuse / repurposing of assets that are no longer in use.
- Digital marketplace for locally supplied secondary materials.

#### Regeneration of natural capital
- Automated distribution system of biological nutrients.
- Automated location tracking of natural capital, such as fish stocks or endangered animals.
- Immediate identification of signs of land degradation.
- Automated condition assessment using sensors such as fish shoal size, forest productivity, or coral reef health.

### CIRCULAR ECONOMY VALUE DRIVERS

Four key circular economy value drivers for generating asset and resource productivity can be identified:34 Their value creation potential mainly result from extending the use cycle length and count, increasing asset utilisation, while reducing the creation of new products from virgin materials and producing less waste – especially structural waste including negative externalities.

#### Extending the use cycle length of an asset.
Keeping products, components and materials in use for longer means that the need to produce more assets from new resources is reduced, while the value added through manufacturing is retained.35 This can be achieved by designing products that are more durable and easier to upgrade, repair or maintain, and deploying predictive maintenance to prevent irreversible failures that would end an asset’s use cycle. This value driver also implies reducing consumption of a finite resource, fuel or fossil-based energy.

#### Increasing the utilisation of an asset or resource.
Maximising the utilisation of assets by either sharing them among users (peer-to-peer sharing of privately owned assets or public sharing of a pool of assets) or enabling greater asset or resource productivity in operations. In this report, the definition also includes designing out negative externalities – which implicitly enhances the utilisation of finite resources – as well as increasing access to and utilisation of renewable resources.

#### Looping or cascading an asset through additional use cycles.
Moving end-of-use assets or resources from one use cycle to a new one. Looping includes i) reusing the asset as is with a new user; ii) remanufacturing or refurbishing the asset before entering a new use cycle; iii) recycling materials to replace virgin resources in making new assets. Cascading assets or resources could either mean moving them to secondary markets or into lower-value uses.

#### Regeneration of natural capital.
Preserving and enhancing the long-term productivity of natural systems such as soil, oceans, forests and wetlands. This includes returning biological nutrients and carbon to the land, avoiding topsoil erosion and the leakage of nutrients from one system to another, replenishing lost nutrients and soil layers, as well as managing maritime stocks in such a way that they are able to maintain a healthy population.

### INTELLIGENT ASSET VALUE DRIVERS

Broadly speaking, intelligent assets can supply three main forms of knowledge about assets and resources that enable value creation in a business environment:36 (see Figure 2):

- Knowledge of the location of the asset. Asset tracking – determining the location of an asset, either in real time or based on connected checkpoints – is a significant enabler of sharing models. It is also an important opportunity for users to avoid paying the costs of logistics and other operations, and use their resources more effectively. This is especially important for businesses that have mobile, high-value assets deployed across multiple locations, since operational performance depends on balancing resource utilisation, rapidly redeploying resources, and keeping assets in service.37 Tracking assets can also greatly facilitate auditing, helping companies comply with accounting standards at a much lower cost.

- Knowledge of the condition of the asset. The collection38 of sensor data that monitors an asset’s condition – the technical or biological performance or state of an asset, including specific responses to environmental conditions – enables users and/or suppliers to use defined thresholds or rules to initiate actions or notifications that allow for condition-based (predictive or preventative) maintenance, repair, decommissioning, or change of use practices. Knowledge of the condition of an asset includes recording the use pattern of the asset, as well as an asset’s material composition and its potential change39 during the use cycle – as for example recorded in embedded product inventories.40

- Knowledge of the availability of the asset. Data on an asset’s availability – including whether an asset is idle but also the supply/demand dynamics for an asset, network – allows for the increased sharing of assets among different users as well as the development of new business models that promote the shift towards a more service-oriented economy. Availability also includes knowledge about asset ownership, and in energy systems availability includes knowledge about usage and demand of energy at a given location and a given point in time.

![FIGURE 2 INTERACTIONS OF CIRCULAR ECONOMY AND INTELLIGENT ASSET VALUE DRIVERS AND EXAMPLE OF VALUE CREATION OPPORTUNITIES](image-url)
KEY BARRIERS AND ENABLERS

The circular economy is an inherently feedback-rich system, and innovation will depend on the provision of new information for designing business models as well as physical products. Going forward, there is little doubt that the information generated by probing the circular economy–intelligent assets interplay will be able to enhance the information feedback loops and drastically change the way products are made, used, paid for, and looped back into the value chain. However, for the full value potential provided by the interplay between the circular economy and intelligent assets to be realised, a number of barriers and key enablers need to be addressed.

DATA SECURITY AND TRUST

Since much of the value created by the interplay between circular economy and intelligent assets lies in the ability to collect and interpret data, it is crucial to address concerns about how innovators, companies and government agencies use, share and protect personal data. Moreover, as intelligent assets’ capabilities expand, mechanisms need to be developed to prevent potential criminal activity that could harm private individuals as well as businesses. Stakeholders, including policymakers, research institutions and industry players need to work together on challenges related to the management of IoT systems in order to foster innovation, while minimising security risks. Experts including Neil Crockett, Nic Cary and Sophie Hackford, highlight the lack of a legal framework and research in this area, as well as the need for standards, to prevent potential criminal activity that could harm private individuals as well as businesses.

INTEROPERABILITY OF INTELLIGENT ASSETS AND IOT NETWORKS

As pointed out by Neil Crockett of the Digital Catapult United Kingdom, most of today’s intelligent assets have been designed in closed innovation processes and therefore work largely in silos. In this ‘pre-standards phase’ of the IoT landscape, devices or networks created by different manufacturers or technology companies are often unable to integrate or run on a common operating system. As a result, companies today mainly use sensor data for anomaly detection and control but not for optimisation, prediction or discovery. More sophisticated sensing and analytics technologies could unlock value sources such as performance data for predictive maintenance, or workflow data to optimise operating efficiency, and companies and industries seeking to tap into this potential would benefit from developing infrastructure horizontally rather than creating vertical stacks of integrated products.

FLEXIBLE BUSINESS MODELS THAT CAN RESPOND TO PRICE VARIABILITY AND THE RAPID EVOLUTION OF TECHNOLOGY

To date many IoT systems require significant upfront capital investment, while at the same time lack a clearly defined return on investment in what are still often untested and immature technologies. To add complexity to the investment decision, industrial IoT components need to be built with maintenance and updates in mind because industrial systems need to be continually modified and maintained to meet changing requirements.

Reorienting the business strategy to allow for this rapid evolution of technology could be an important step towards making operations more circular. Companies are also likely to benefit from identifying their partners within the intelligent asset/circular economy ecosystem, and determine whether they want to join a partner’s platforms or develop their own. The development of joint lighthouse projects, where technologies and processes are tested and findings are shared, could benefit the development of intelligent assets on a broader scale.

Resilient IoT market evolution can be informed through biomimicry – the study and emulation of life in our natural world. The way in which natural systems access, store, and share information about themselves can – and should – be considered in order to design intelligent assets that harness maximum asset and resource productivity.

Janine Benyus

43 Chris Murphy, Internet Of Things: Untangling the Complexities of the Next Big Thing (Altimeter Group, February 2014).
INNOVATORS TODAY SHOW WHAT TOMORROW’S BUSINESS ECOSYSTEMS COULD LOOK LIKE

A rapidly growing number of businesses is harnessing the synergies between circular economy and intelligent asset value drivers. These businesses are present in a wide range of sectors, including manufacturing, built environment and infrastructure, energy and utilities, agriculture and fishing, and logistics and waste management, as well as smart cities. They include large incumbents as well as disruptive innovators. The solutions created by these businesses unlock not only direct value for the customer or end user, but could profoundly change the resource productivity of societies by forming new ecosystems of services that eliminate negative externalities or the need for some resources altogether.
Previous research has highlighted that digital technology is a core enabler for circular economy business models. In a similar way, pairing IoT-enabled innovation with circular economy principles can help identify new value creation loops and look at the ongoing digital revolution using the combined lenses of intelligent assets and circular economy. Revealing that numerous businesses (and cities) are already unlocking value in this realm – for instance optimising capacity utilisation, implementing predictive maintenance, and automating sales and inventory management. The examples given in Figure 3 are by no means exhaustive, but show that businesses are already active in most of the matrix’s intersections. Some are familiar multibillion-dollar corporations; others are emerging innovators.

This chapter introduces promising innovations (and their resulting benefits) in five industrial settings: materials and manufacturing; energy and utilities; built environment and infrastructure; logistics and waste management; and agriculture and fishing. Individual case examples are discussed for each setting, and a broader perspective is then applied in order to explore the wider opportunity that follows from a transition to a more circular economy. In addition, the opportunities emerging in the context of smart cities are explored.

Performance contracts, predictive maintenance, and remanufacturing are already well-established (circular) practices in some sectors of the manufacturing industry. Intelligent assets are helping these feedback-dependent operations perform better and with increased flexibility – making them accessible to a broader range of companies and consumers. In addition, the unprecedented amount of information generated by connected assets is enabling designers to translate feedback data into product improvements. Finally, complexity and material demand in various production processes is being drastically reduced through the ability to utilise product features via cloud technology.

Imagine a world in which all high-value assets belong to their manufacturer, who is incentivised to maintain and improve them on an ongoing basis. Not only your car, but computer, washing machine, lighting system, fridge – they all have the inbuilt ability to securely communicate with their manufacturer, sending real-time information about their use patterns and the condition of different components on the basis of which they are maintained, updated or replaced and recycled/cascaded into a different use cycle. With a growing number of businesses incorporating both intelligent assets and circular economy principles into their strategies and operations, the need for human intervention to maintain, reuse or recycle materials is being minimised.

**MORE PRODUCT CATEGORIES, BETTER PERFORMANCE MODELS**

Manufacturing – particularly of advanced, expensive equipment – has been a focal point of circular economy studies for many years as it offers one of the biggest potentials for economic and environmental impact of any sector. Material savings alone in the European Union could amount to USD 630 billion in an advanced circular economy scenario. These savings stem from a combination of the main three circular value drivers: extending the use cycle (due to predictive maintenance), increasing utilisation (due to reduced unplanned downtime and increased overall equipment effectiveness), and looping or cascading the asset (due to improved information of the condition and use history of individual components).

Performance-based business models – where a supplier retains ownership of the product and the customer pays on a per-use (or performance) basis – provide the supplier with a fixed contract revenue stream while offering incentives to maintain, simplify and increase the reliability and productivity of the product. Done right, it also reduces total asset costs, while increasing profitability and customer service value. The retained ownership can enable, but is not critical for, the taking back of products after use and refurbishing/remanufacturing them before taking them to market again.

The business case for such circular models is quite intuitive for advanced equipment: its manufacture is resource intensive and therefore expensive, and products are often robust enough to be repaired or refurbished either throughout or at the end of use cycles. It should therefore be no surprise that the pioneers in the field began their operations long before the circular economy was established as a concept. Most notably, Rolls-Royce’s ‘power-by-the-hour’ model for airline engines was invented in 1962 and pioneered the performance-based business model. Caterpillar founded its Cat Reman business line in 1973 and is still a well-respected example of remanufacturing operations.

While Rolls-Royce and Cat Reman are proving that circular business models can work without IoT, intelligent assets have the potential to significantly improve the user’s and/or supplier’s ability to service and repair products in a predictive maintenance scheme. Comprehensive real-time data is key to effective predictive maintenance, enabled by knowing the condition (such as engine health), and therefore IoT technology is currently revamping the way giants such as Rolls-Royce or Philips conduct their operations/services. Information and communications technology (ICT) players such as Cisco and IBM are also active in this field, helping clients move towards maintenance schemes supported by data monitoring and predictive analysis. For example in the healthcare industry, Cisco and Philips point out that decisions regarding the replacement of medical equipment at hospitals are currently based mainly on the equipment’s age and estimates of utilisation. With sensor technology revealing the actual condition of the equipment, such decisions could be made on a case-by-case basis, which would save resources. The data would
also enable more flexible performance contracts benefiting both the hospital management and equipment’s manufacturer. Fanuc – a computerised numerical control (CNC) systems and industrial robot company, and a partner with Cisco – accesses data streams from its robots located around the world via the cloud. Apart from streamlining the spare parts supply chain, such shared information could also greatly enhance machine learning among the robots.68

As indicated above, predictive maintenance in performance contracts is not a novel development at enterprise level. However, recent technological development increasingly enables performance models to trickle down to small and medium-sized enterprise (SME) customers where previously the tracking and logistics were prohibitively costly.69

Notably, this development can be seen in consumer electronics and IT equipment, a product category notoriously difficult in terms of component recovery and reverse logistics. HP launched its ‘Instant ink’ service in early 2014, providing printing as a service to individuals and small businesses. Subscribers pay a monthly fee based upon the number of pages they print, and the connected printer notifies HP when the cartridge is about to run dry and signals to deliver a new one without the subscriber having to interact. HP collects empty cartridges to include them in its ‘closed-loop’ recycling programme. Instant Ink is approaching a million subscribers and HP reports that the design enables elimination of up to 67% of waste associated with the number of pages printed, and a very high customer retention rate. In fact, as John Ortiz of HP notes, the ability to build stronger customer relationships is one of the key values unlocked by an IoT-driven, circular performance model, and it could very well be applied to other types of electronic products such as personal computers.

KNOWING WHEN TO REUSE, REMANUFACTURE OR RECYCLE

To date, reverse logistics and remanufacturing have been subject to several risks, including the fluctuating demand and supply of used products/components, and the widely varying condition of the returned components. Ideally an enterprise would choose the next use cycle for each returned product – e.g. sell for scrap value, recycle, recover components through parts harvesting, remanufacture, or reuse – by taking into consideration a combination of factors regarding the product’s condition as well as the current market situation. Only with the ability to collect large quantities of product and customer data, and an analytical model to make sense of it, does such a decision-making model become feasible.

REDEFINING DESIGN

When data on the composition and real-time condition of assets becomes abundant, product design can be transformed. For Rolls-Royce, aggregation of IoT-generated information on an engine’s condition provides insights into more productive, durable and long-lasting engine design opportunities, while the servitisation model provides incentives to apply those insights. In a similar way, HP is looking to apply its IoT-generated data to inform its product design processes. In sum, the augmented information generated by intelligent assets contributes to improving future product generations – both by extending their use cycle (making them more durable and easier to maintain) and enabling further looping (improved design for remanufacturing and design for disassembly).

Moreover, IoT could drastically increase resource productivity by virtualising all but the core physical function of equipment. As suggested by Cisco’s Daniel Keely, processing, analysis and visualisation functionalities within a medical scanner could be moved to a secure cloud service, making upgrades simpler and in turn driving further use cycle extension. The broader set of cloud data that will be made available could potentially be leveraged by designers and engineers to further improve the machine, provided the data is mined in a secure way.
A surge in innovative and disruptive business models in the energy sector is currently under way. Developed markets are seeing a proliferation of intelligent assets to optimise energy use in many settings, from homes to street lighting. In addition, IoT technology is enabling distributed energy systems, particularly in developing markets.

New businesses are emerging that enable off-grid renewable energy as a service at affordable prices. Such new business models could be crucial in giving broader access to renewable energy sources to many more end users. Moreover, these models could make it increasingly viable for developing markets to build entirely distributed energy systems and avoid the significant resource and capital costs tied up in a centralised energy system.

Imagine all individual households, factories and public buildings in your city generating their own electricity from renewable sources, which can be stored in different batteries, including the ones in your car or at home – reducing your electricity bill by up to 25%. All of those energy-generating entities in your area are connected through a grid, allowing them not only to be self-sufficient but also to contribute to the grid stability of the whole region. Or imagine that each community in a developing country has access to affordable solar-powered energy, giving people the comfort of electrical light and appliances, and enabling them to better educate themselves and increasingly participate in global economic activity.

Next to food and water, energy is arguably the most vital human need in a modern society. Despite ongoing improvements in energy efficiency that bring down per capita consumption in developed economies, significant sources of structural waste associated with energy systems still need to be addressed. In energy production and distribution, substantial losses are associated with power grids, and the emergence of (small-scale) renewable energy generation is challenged by problems of distribution and storage, particularly in remote locations.

**Energy and Utilities**

*Creating a Smarter Energy Infrastructure*

Using intelligent assets to improve efficiency in energy consumption is a recognised and growing practice.

- Cisco uses an IoT-enabled system called Cisco Energy Management (CEM) to accurately measure and manage energy use (and CO2 emissions) at their manufacturing facility in Malaysia, with a goal of reducing energy consumption by 20%.
- Philips provides ‘lighting-as-a-service’ to their customers, continuously optimising power consumption as they have live and reliable data on the use patterns of their customers, and can therefore enhance the light installations.
- GE recently announced its ‘energy-as-a-service’ platform, aiming to take 10–20% off customers’ energy bills as well as enable better distribution for utilities.
- Silicon Valley-based Enlighted provides an IoT-based energy service system, claiming it saves their clients 60–70% on lighting and 20–30% on heating/cooling, while the IoT infrastructure additionally enables further smart solutions.

Philips CityTouch is a similar service for cities, providing connected outdoor light points and management software. Authorities can change light intensity remotely depending on natural light and street conditions, replace individual components based on actual burning hours rather than on assumptions, and reconfigure installations to adapt to changing environmental factors. In the same vein, California-based Sensity Systems uses sensors in its large-scale installations (e.g. in airports) to both monitor use...
patterns and automatically adjust power to the individual LED lights depending on the number of people beneath them.

The above examples also provide resource-productive knock-on effects. For instance, Philips CityTouch increases the ability to manage heterogeneous use cycles of different asset components in detail, and can loop assets back into production at the end of their use cycle. In addition, the cloud-based service uses exactly the amount of remote computing power needed, eliminating the need for in-house servers. Philips estimates that such a set-up leads to at least 30% less energy consumption in computing.

Models creating transparency about usage have also begun to appear in the residential space. For example, Nest Labs’ smart thermostats build a heating schedule around space. For example, Nest Labs’ smart thermostats build a heating schedule around space. For example, Nest Labs’ smart thermostats build a heating schedule around space. For example, Nest Labs’ smart thermostats build a heating schedule around space. For example, Nest Labs’ smart thermostats build a heating schedule around space.

Another important area for optimisation is the life cycle of power generation assets. Distributed energy systems such as industry infrastructure upgrades. Connecting both energy-generating and consuming devices could also help businesses to increasingly provide their own energy.

Intelligent monitoring systems can also be used to create energy saving incentives. Basing its business model largely on established behavioural psychology principles, GPower is incentivising individual consumers to reduce their energy bill by providing the company with personalised energy reports that compare their usage data with a large database of other users. Utilities such as E.ON in Europe and Dominion in the US similarly offer detailed reports and connected power switches to help customers reduce their consumption. This type of precise use data from intelligent assets coupled with behavioural feedback could have interesting wider applications, e.g. for municipalities to create incentives for citizens to reduce excess resource use, or to plan for effective utility infrastructure upgrades.

For intelligent assets to create value in the circular economy the development of an open and global payment protocol is required. The technology behind the Bitcoin blockchain has the potential to enable the billions of internet devices that will negotiate with each other to unleash market forces, to bring down the costs of goods and services for all. Nic Cary

DISTRIBUTED RENEWABLE ENERGY IN DEVELOPING MARKETS

On the energy production side, large-scale renewables such as wind and solar power have seen impressive improvements in efficiency and cost reduction over the last decade. Making these assets more intelligent is one driver behind their improved efficiency. GE, for instance, makes wind turbines that automatically change gear according to wind conditions, and more recent solar panels are able to optimise their angle to the sun. Using IoT technology to monitor the condition of these capital-intense assets also creates more accurate knowledge about their real productive knock-on effects. For instance, the internet of things is revolutionising the way we use our lighting. The use of intelligent assets has also begun to appear in smaller-scale energy generation systems. SunPower, a US-based, integrated solar energy service provider, says it is making important strides in the IoT space, introducing ‘smart’ solar panels that are connected to other devices in the home, enabling energy consumption to be matched to generation – e.g. optimising the timing of energy-intensive activities such as laundry, refrigeration or dishwashing, with power generation. Cateva, a start-up supported by Siemens, has developed an energy management tool that allows homes outfitted with photovoltaic systems to rent out part of their battery power to network operators.54

So far, the growth of solar power has been most prominent in developed markets, and has been deployed largely without the help of intelligent assets. A number of companies are now using IoT to take solar power to developing markets where cheap, and preferably renewable, power is in desperate demand.55 The company BBOXX as well as Sun King provide cheap solar panels or solar-powered devices, such as radios and reading lights, which can facilitate dramatic improvements to the users’ standard of living and education.56 Through collaboration with companies such as ProductHealth and Angaza, these products are intelligently and connected.

Although comparatively cheap, the solar devices offered in regions such as Sub-Saharan Africa are often too expensive for their target users. Angaza therefore offers a ‘pay-as-you-go’ platform that allows users to receive the product for a small down payment and to pay for the usage (usually on the basis of number of hours or kWh). Payment is made via a web or mobile interface, and the connected device knows when to switch on and off depending on the user’s account balance. When the full cost of the product has been paid, the new owners can use it as much as they wish.57

The implications of using intelligent assets for energy generation and storage can be tremendous. Not only does it bring power and increased living standards to millions of people, their use could potentially allow regions currently off-grid to develop grid infrastructure to prioritise distributed energy systems (e.g. micro-grids or even off-grid) over developing a grid infrastructure from scratch, avoiding huge capital expenditure and resource consumption. According to Marty Neese at SunPower, the promise of IoT applies to developed markets as well – where the proliferation of solar and wind energy sources, which are approaching price parity with conventional, centralised energy sources, will have a drastic impact on the demands for energy distribution systems. Coupled with the increasing range of business models and technologies to improve efficiency and optimise energy distribution (in (local) smart grids), the emerging ecosystem of intelligent devices will make this option increasingly viable.

For intelligent assets to create value in the circular economy the development of an open and global payment protocol is required. The technology behind the Bitcoin blockchain has the potential to enable the billions of internet devices that will negotiate with each other to unleash market forces, to bring down the costs of goods and services for all.
An estimated 55–68% of total office space is not used even during office hours.64

Structural waste is prominent also in infrastructure; every instance of unplanned maintenance for roads, bridges and other important infrastructure constructions causes large disruption and, despite road infrastructure being hugely oversized, congestion occurs regularly.

The road system is taking up 50% of the built environment space while peak traffic only covers 10% of the roads.44

Intelligent assets have begun to be incorporated into the built environment. Building service providers and construction companies are already using IoT to optimise the energy efficiency of buildings and larger communal systems (such as street lighting). Large building service providers, such as Johnson Controls and Honeywell, use IoT to help the tenants of their buildings to reduce the cost of their energy bills, while enabling utilities providers to better plan their energy production and avoid wasteful peaks.55

CHANGING HOW MATERIALS ARE MAINTAINED AND REUSED

In a more novel approach, intelligent assets are now increasingly being deployed to address the sources of waste and resource inefficiencies at several stages across an asset’s use cycle. Knowing the location of building components as well as their condition gives asset owners unprecedented monitoring capabilities, enabling both new business and financial models. These models enable extended use cycles of buildings as well as improved potential to loop or cascade building components and materials in new use cycles at the end of the building’s (or component’s) use. For example, the automatic embedded product inventories generated by Dutch company BAM’s building information management software allows multiple stakeholders to treat the constructions as a ‘resource bank’, enabling the assets to be returned when a building is decommissioned. IBM and Delta Development are collaborating on incorporating connected sensors into the new Schiphol Trade Park, which will provide an extremely rich flow of data that can be used to optimise resource use, predictive maintenance, reuse and functional design.

The infrastructure space is also seeing the introduction of connected sensor devices. Arup, for example, has supported the installation of an intelligent monitoring system in Hong Kong to enable predictive maintenance for roads and other key infrastructure constructions. Moreover, Arup recently projected a new bridge for heavy traffic over the Firth of Forth, Scotland, which will be equipped with more than 1,000 sensors to monitor its condition through a simple-to-operate, advanced and fully integrated structural health monitoring system.48 Cisco and the Hamburg Port Authority have recently launched the ‘smartROAD’ proof of concept study, a pilot

The incorporation of intelligent assets into the built environment goes beyond improving energy efficiency. It is reshaping both asset utilisation and material management within the sector. Connected buildings and building components are starting to enable the wider use of performance contracts and predictive maintenance schemes, while at the same time dramatically increasing the potential for improved asset utilisation through sharing. The future is likely to entail a built environment that is flexible and modifiable and which, through its interconnectivity, can feed the wider system (the city or the traffic grid) with information that enhances both traffic management and urban planning.

Imagine a world in which all roads, bridges, public spaces, sports facilities, office buildings and private homes represent the biggest valuable materials deposit for the built environment. In this world these assets are connected to a digital library, revealing up-to-date condition of the assets’ components to not only enable predictive maintenance and performance models, but also to be a platform for a secondary materials market. Imagine how the connectivity of constructions could pave the way for closing the material loops to be a platform for a secondary materials market. Imagine the world these assets are connected to a digital library, revealing up-to-date condition of the assets’ components to not only enable predictive maintenance and performance models, but also to be a platform for a secondary materials market.

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aiming at improving aspects of infrastructure, including resource management and traffic flow, through the use of sensor technology and analytical tools. The first phase of the project focuses on monitoring the health of the infrastructure while subsequent phases are planned to monitor and optimise traffic flows and lighting.

Miniwiz, a company that turns post-consumer waste into high-performance material, explains that despite the distance left to cover before intelligent assets provide granular information about the stocks and flows of building materials, such information could enable a harmonisation of design of new assets with the availability of local materials. Enabling design software to ‘scout’ the market for available resources could allow design decisions to be based on what materials are locally available. As such, the IoT-enabled transparency of material flows could facilitate the emergence of local, secondary material markets, similar to the Scottish Material Brokerage Service.69

PROLIFERATION OF PERFORMANCE MODELS AND ASSET SHARING

Intelligent devices also increasingly allow for the use of performance models in the built environment. For instance, Delta Development has introduced a ‘Products of Service’ leasing model for elevators in the new Park 2020 and ongoing Schiphol Trade Park project. Data transmitted by the elevators enables predictive maintenance and better end-of-use looping or cascading of the assets, and lets Delta act on its incentive as product owner to maximise the elevators’ utilisation and quality. More IoT-based monitoring is likely to proliferate performance models and further shift asset ownership and management within the built environment. As Rainer Zimmann at Arup points out, there is a clear business case for extending the performance model to more types of building components, including facades and interiors, or even materials. It is not inconceivable that materials manufacturers, facing reduced demand for raw materials, could shift towards providing, for example, ‘steel-as-a-service’ to railways, provided the right monitoring system is available.

Knowing the availability of a specific space, for example an office, can significantly increase its utilisation if this knowledge is used to enable sharing between users. Cisco’s ‘Smart+Connected Personalized Spaces’ solution helps businesses increase the utilisation of desk and office space by dynamically allocating workspaces to employees. The system can reduce real-estate costs by up to 35% and enable an office space to accommodate 75% more employees. By connecting all office-related functions to the same platform, including lighting, heating, ventilation, air conditioning and IT devices, an additional 7–18% of energy costs can be saved as the devices only need to be switched on when an office space is occupied. Cisco estimates that the personalisation of the workspace enabled by this connectivity also improves workforce productivity. System managers can follow up on usage data across locations, spaces and services, and continually improve utilisation of the workspaces.

As the built environment becomes more sensitised and connected, more flexible use patterns and resource management could emerge. One conceivable scenario is one in which buildings’ use cycles become shorter – but where modular design, performance-based use of components and granular embedded product inventories allow for cheap repurposing and a faster turnover of usage. More frequent repurposings of buildings enable both a more flexible adaptation to market demand and an opportunity to gradually upgrade and transform the building with state-of-the-art technology. Julie Pithers of the modular interior supplier DDRT agrees that this scenario is likely, and adds that one could eventually see a home market where buildings are tailored to specific needs without having to include the average need of the next inhabitant. Hyper-flexible interiors that ‘remember’ their history could be exchanged on a large online market – at a fair price since their age, condition and therefore value is known – allowing families of five to move into properties that previously housed a small firm or studio, and vice versa. IoT-enabled local sourcing of materials for new buildings – as mentioned by Miniwiz – could be further reinforced by the faster turnaround of building materials.

LOGISTICS AND WASTE MANAGEMENT

GETTING THE RIGHT TOOLS TO THE RIGHT PLACE

The latest developments in sensor technology and connected IoT systems mean that companies can now track almost any kind of asset, almost anywhere in the world in real time. Even though asset tracking has been standard practice in the logistics sector for some decades, new technologies are now increasing asset and resource productivity by enabling reverse logistics programmes as well as real-time route optimisation. Similar developments are seen in waste management where, in addition to real-time waste collection route optimisation, new systems are able to precisely sort and recycle multiple types of materials as well as monitor and incentivise waste disposal behaviour. Such progress could potentially reshape the way assets and resources are reused and recycled across industries, unlocking material value by providing transparency in reverse logistics and materials separation operations.

Imagine a world in which you can track any of your business’s assets on your tablet, no matter whether they’re on land, at sea or in the air, or how fast or slowly they are moving. Risk of damage and delay would be minimised and global demand for resources, including food, materials or pharmaceuticals, could be met faster and more cost-effectively. Every product would come with a digital identity that reveals material components or ingredients, manufacturing processes and producers, making every aspect of the supply chain transparent and allowing you to make well-informed choices about what to buy. Imagine your waste collecting company receiving real-time data about the amount and type of materials in public and household bins, allowing them to pick up on demand and to connect with manufacturers to redistribute used or unwanted products and materials.

OPTIMISING THE ROUTE

Incipient satellite technology – enabling new forms of data collection from intelligent assets as well as through observation of the Earth – is changing how humans understand and manage materials and energy. Emerging business models in this field exploit enhanced tracking capabilities to unlock value in the logistics sector through new route optimisation capabilities that essentially increase utilisation of assets. For instance, San Francisco-based Spire uses its privately owned nano-satellite constellation to provide a platform for globally tracking just about any asset, from trucks and trains to ships and planes, enabling intelligence generation for global production and trade. This enhanced visibility means that damage or loss of assets can be minimised. For example, the shipping arm of a large commodity company uses Spire’s technology to oversee its global fleet, enabling the client to minimise fuel consumption, determine optimal routing mid-voyage and reduce waiting time in ports. This kind of information about global supply chains also has knock-on effects in a variety of areas, just as the financial markets do, informing expectations about price and demand.

As mentioned by Miniwiz, the potential for data-driven optimisation is considerable. Imagine your waste collecting company receiving real-time data about the amount and type of materials in public and household bins, allowing them to pick up on demand and to connect with manufacturers to redistribute used or unwanted products and materials.
INTELLIGENT ASSETS HELPS
GETTING THE RIGHT STUFF TO
THE RIGHT PLACE BY...

1. TRACKING PRODUCTS THROUGH THEIR USE CYCLE

2. OPTIMISING FLEET EFFICIENCY
   INFORMING THE MOST EFFICIENT TRANSPORT, FROM TRACKS AND TRAINS TO SHIPS AND PLANES

3. OPTIMISING DELIVERY ROUTES
   REAL-TIME DATA SHOWING GOODS & TRANSPORT LOCATIONS: FASTER ROUTING, REDUCING FUEL, MINIMISING DAMAGE AND ASSET LOSS

4. TRACING PRODUCTS THROUGH THEIR USE CYCLE

5. AVOIDING WASTE
   DATA INFORMS WASTE GENERATORS OF HOW TO CONTINUALLY IMPROVE THE SYSTEM AND DESIGN OUT WASTE

6. SORTING RECYCLED MATERIALS
   MULTIPLE TYPES OF MATERIALS ARE PRECISELY SORTED, READY FOR REUSE AND RECYCLING, INCLUDING INCENTIVE BONUSES FOR CITIZENS AND BUSINESSES

7. AN EFFICIENT REVERSE LOGISTICS SYSTEM
   DATA ALLOWS ASSET OWNER TO QUANTIFY THE COST AND BENEFITS OF ALL REVERSE LOGISTICS OPTIONS

MOBILE TRACKING FOR ASSET OWNERS

SATELLITE TECHNOLOGY
PHOTOGRAPHS AND COMPONENTS CAN BE LOCATED, TRACKED BY MANUFACTURERS THROUGHOUT THEIR USE-CYCLE TO ENABLE A MORE EFFICIENT REVERSE LOGISTICS SYSTEM

INTELLIGENT ASSETS: A TOOLKIT FOR CREATING A CIRCULAR ECONOMY

When it comes to getting a product to market, asset tracking is already very advanced. Logistics giants like DHL, or FedEx are able to determine the exact location and trajectory of every single parcel in their logistics chain. However, the application of these best practices to the reverse supply chain – the in-bound flow and storage of assets and related information – has so far been very limited (to a large extent because of prohibitive costs). Knowing the location and conditions of assets and resources is a key enabler behind most reverse logistics programmes, and the proliferation of cheap, connected devices could help extensive tracking systems become the norm in the reverse cycle. Businesses that know where their assets and materials are, and the mechanisms required to track persistent and real-time data about an asset’s location and condition, are equipped to quantify recovery value on a product-specific level, enabling the looping and cascading of assets across multiple use cycles.

One challenge of reverse cycle operations is that a collected product is often grouped with other similar second use-cycle products, which might differ in value depending on how they were treated and maintained throughout their first use cycle. Industry experts indicate that if an asset is aggregated or ‘pooled’ with other used assets and in this process the information on its individual quality is lost, it can get significantly undervalued. Increased transparency regarding the history, real-time location and condition of a product resulting from improved intelligent asset tracking could enable managers to reduce asset and resource value loss and increase the profitability of reverse logistics models. In addition, the ability of an intelligent asset to communicate its real-time location and condition means that reverse operations can be accurately timed, facilitating system optimisation capabilities.

An emerging ecosystem of innovators is aiming to deliver cheaper, more sophisticated IoT-enabled solutions for better asset tracking. For instance, UK-based Provenance uses blockchain technology to help businesses and their customers gather and keep track of data along and across the multiple use cycles of their assets. By tracking items geographically and revealing qualitative and quantitative product-related information, the Provenance system can identify assets that are not in use so they can be collected and launched into additional use cycles. According to Provenance, the model has the potential to assist the intelligent assets market to overcome existing interoperability challenges by laying the foundations for an open, secure global registry for all material items.

Getting assets back through reverse logistics can be challenging due to regional regulations. For multinational companies operating in a number of different markets, the web of trade policies relating to the import, export and handling of ‘waste’ or used products can be onerous to navigate, and can discourage them from setting up reverse supply chains. For instance, Brazil, China and Russia do not have legal standards that distinguish remanufactured products from used products, and therefore they do not permit their importation. In an attempt to overcome such barriers, governments such as those in Denmark, Finland, the United Kingdom and the United States are currently investigating how to adjust existing regulations. IoT technologies could help in the effort to amend these regulations. The online trading platform eBay, for instance, notes that embedded IoT technology (which could store and transmit the history, composition and present state of a repair of a product) could help overcome logistical hurdles, such as those involved on delivery and cross-border compliance.

Another intriguing innovation in this space is IBM’s Reuse Selection Tool (also see the manufacturing section of this chapter). This platform will be able to compile and analyse IoT data about an asset’s location and condition, allowing users to quantify the cost and benefits of various reverse logistics options, including reusing, remanufacturing or refurbishing. Optimising resource use in real-time could be instrumental in enabling aspiring businesses to maximise profits in the inherently complex area of reverse logistics operations.
Intelligent assets are also augmenting capabilities in waste management and recycling. Sensing technology is, for instance, beginning to be used in this sector to achieve higher recycling yields through more precise sorting activities, as well as allowing operators to optimise waste collection routes and incentivise citizen and business waste disposal activities.

Tomra, a multinational corporation that creates sensor-based solutions for optimal resource productivity, uses its technology to establish state-of-the-art recycling through both reverse vending and waste separation, thereby helping its customers to improve their resource productivity by recovering materials through precise sorting processes during production. These services give insights into the composition of multiple types of materials, enabling both improved utilisation and looping (in this case recycling) of resources across additional use cycles. Tomra states that these improved processes helped mitigate some 22 million tonnes of CO2 in 2014.76

Intelligent assets are also increasing the feasibility of optimising waste collection routing, reducing costs associated with fines on overflowing bins and incentivising certain waste disposal behaviour in specific areas. For instance, Amey, a UK-based infrastructure support provider, is currently developing a programme that uses intelligent bins capable of monitoring their capacity in real time, allowing optimal waste collection routing and the avoidance of fines. Looking forward, a system like Amey’s intelligent bin network may be complemented with user-based identification tags allowing for more. The BURBA prototype, for instance, an EU-funded project whose name stands for ‘Bottom Up Selection, collection and management of URBan waste’ – uses such ‘user’ or ‘disposer’-based tracking mechanisms. The prototype uses an app to inform the waste disposer about the location of specific bins in the area, making it easy for users to correctly dispose of their waste. Encouraging correct disposal behaviour could both increase the quantity of materials recovered and reduce misallocated waste streams (a major cost for recycling facilities).

In addition to the logistical benefits of connected bins, data collected by these bins can also be analysed to help local authorities understand the waste disposal behaviour of citizens and businesses. This information can be used to firstly optimise infrastructural elements (e.g. the placement of bins). Radio-frequency identification (RFID) or mobile user-based recognition at the point of disposal, together with data collected in the waste treatment plant, could also assist local governments in launching successful incentives to reduce waste volume and improve recycling rates. These include, for example, more directed information and capacity-building programmes, the introduction of differentiated collection taxes or fees based on performance, or ‘good’ behaviour reward schemes.

76 Tomra investor presen- tation (22 October 2015) www.tomra.com/investor-relations/
Intelligent assets are reshaping humans’ ability to manage the Earth’s natural capital. IoT-driven insights into the complex dynamics of natural resources are enabling conventional agricultural systems to significantly increase asset productivity while simultaneously enabling the regeneration of land. Crop production and wild catch fishing are two industries starting to develop new ways of unlocking the value created by combining circular economy and intelligent asset value drivers. Further technological and system advancements have the potential to expand on these solutions and enable these sectors to increase global food production while minimising resource use and environmental damage.

Imagine a world in which agricultural producers – through the ability to monitor and manage their crops and livestock more effectively – will meet the increasing global demand for food without having to transform more ecosystems to farmland. Imagine local farmers being able to reduce pesticide, fertiliser and water use to regenerate their land, while at the same time producing more fresh produce. Imagine the world’s oceans rebuilding their richness of fish and other living creatures as a result of satellite tracking of fishing activities and the subsequently improved enforcement of international regulation.

An expected 60–70% more food is needed by 2050 to feed the world’s growing population and meet the demands of a growing middle class.76

**INTELLIGENT ASSETS ON LAND**

Sensing technology and so-called precision agriculture are transforming the agricultural sector, helping to overcome land and resource productivity challenges. Farming today is increasingly becoming a high-tech profession with farmers being supported by sophisticated management software, helping them monitor, for example, soil nutrients, moisture content, pest and disease control, yield per square metre or nutrient content. Venture investment figures show the enthusiasm about future value creation opportunities associated with these applications.

While over the past decades productivity in industrial agriculture has continuously increased on a per square-metre basis, it has come at the expense of additional input factors (e.g., fertilisers, pesticides and fuel). However, the recent development of sensor technology and cloud-based management systems enables farmers to greatly enhance asset productivity by generating the same or increased output with less input. As illustrated by the examples below, real-time IoT-enabled knowledge about the location and condition of their assets allows managers to optimise resource applications and improve the input/output ratio, as well as reduce soil compaction costs and other negative externalities associated with farming activities.

The Spain-based company Libelium, together with a large number of hardware and software partners, develops open source sensor platforms and a large number of hardware and software partners, develops open source sensor platforms and cloud solutions that allow their clients to observe, measure and respond to the environmental conditions, diseases and pests that affect their agricultural production. This so-called precision agriculture enables growers to take action at the field level by matching farming practices to crop needs, and thereby reduce the use of pesticides, fertilisers and water, while boosting yield. Similarly, California-based start-up OnFarm developed data-feed management decision tools that allow clients such as Capay Farms to effectively organise,
The evolution of connected sensors and digital management platforms could also help farmers to regenerate their natural capital by improving the ability of their land to maintain or even replenish nutrients and topsoil. Maintaining or improving soil structure involves many factors, including achieving a healthy level of microbial activity, high levels of organic matter and reversing or preventing soil compaction. These factors are often interrelated and have positive effects for soil water and nutrient-holding capacity, and ultimately reduce soil degradation.

However, the regeneration of natural capital in conventional industrial agriculture is not easily achieved and sometimes requires drastic actions, such as a reduction of overall yields in the short term, combined with more long-term changes.

As pointed out by such practitioners as the Balbo Group in Brazil, a regenerative agricultural system needs to begin with the right design principles — intelligent assets are not a plug-and-play solution. The challenge is to measure the right things. According to Fernando Alonso of the Balbo Group, there is a risk that the information collected by the sensors prompts the farmer to optimise for short-term productivity rather than long-term regeneration, since what’s best in the long term could be difficult to deduce from the data.

Yet, as illustrated by the following examples, connected sensors can significantly improve a farmer’s ability to understand what is needed to maintain topsoil health and avoid degradation — an important development towards land regeneration.

• Sensors monitoring soil nutrient content allow farmers to observe and manage nutrient threshold levels and determine if and when intercropping, crop rotation or other management practices are required to prevent irreversible soil degradation associated with loss of nutrients.

• IoT enables high accuracy of data on pest levels and a shift from a preventative full pesticide application approach to directed treatment of infected specimens — either by spraying only when necessary or quarantining or destroying the affected crops before the damage spreads which reduces pesticide use as well as the risk of ‘super bugs’ evolving. Libelium notes that sensing technology has been crucial to move towards a balanced and resilient viticulture, as documented in customer case studies in vineyards in Europe.

Imagine you are meeting friends for dinner in a nice restaurant in the city centre. But you’re running late; it’s rush hour, the roads are busy and you have no idea where to park your car. Now imagine you’re in a city where an app aggregates real-time traffic data and reporting from drivers to show you the quickest route, and LED lights downtown help you and other motorists set a smooth pace so that the car you picked up from the city’s sharing pool gets there as swiftly as possible and waiting times at red lights are minimised. Finally, another smartphone app guides you to the nearest available parking space.

The average private car spends 15% of its driving time in congestion and 20% looking for a parking space. Improving transport flows and introducing intelligent parking systems will reduce congestion and therefore emissions.84

If your friends convince you to stay for another drink, you can top up your parking meter directly from your mobile, while real-time transport displays inform you about available buses, trams or trains you can take to get home. Because the temperature has dropped, your phone will ask the heating system in your house to warm up 30 minutes before your arrival. Lights will switch on and the kettle will boil hot water for a cup of tea just seconds before you approach your front door.

With 60% of the world’s population expected to be living in urban areas by 2030, cities are focal points for both consumption and (structural) waste. Consequently, they provide a fruitful ground for solutions that combine the design and implementation of intelligent assets with key principles of the circular economy. These solutions are driven both by businesses and entrepreneurs – forming synergetic ecosystems of services that increase asset and resource productivity – and policymakers, who are in the position to make large-scale infrastructure investments, design regulation and use sensor-generated data to create incentives for more effective resource use.

SMART CITIES
FOCAL POINTS TO IMPROVE RESOURCE PRODUCTIVITY

With 60% of the world’s population expected to be living in urban areas by 2030, cities are focal points for both consumption and (structural) waste. Consequently, they provide a fruitful ground for solutions that combine the design and implementation of intelligent assets with key principles of the circular economy. These solutions are driven both by businesses and entrepreneurs – forming synergetic ecosystems of services that increase asset and resource productivity – and policymakers, who are in the position to make large-scale infrastructure investments, design regulation and use sensor-generated data to create incentives for more effective resource use.84

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Valuing the activities of populations that live in the forest and depend on it for their livelihoods is one of the most important ways of strengthening the mega-diversity of the Amazon and other important Latin American areas. Up to now these regions have been characterised by an economy of destruction and not by any form of natural knowledge economy. An economy based on the knowledge of nature, however, can only flourish if it supports itself on the practices of those whose production systems are already part of the forest’s living dynamics. It requires the participation of at least three central actors: the traditional populations that inhabit territories with rich socio-biodiversity, the companies that purchase their products and the consumers themselves.

But how would it be possible to establish effective contact among worlds so far apart? The answer lies partly in being able to communicate the origins and journey of these products – and here intelligent assets can be critical enablers. Brazil’s biggest bread-producing industry, Wickbold, will soon be including a QR code on its packaging that will enable the consumers of its products to know the story of the Brazil nuts in their bread: where they come from, who took part in their production and other information about the threats to protected areas and how to address them. In other words, digital technology creates transparency on what benefits sustainably produced food are creating, enabling a fairer valuation on the market.

Indigenous groups, riverside communities and those who live in extractive reserves are being trained to enable them to include the relevant information in digital devices so that the industry can offer its customers information about the socio-environmental bases of what they are consuming.

This initiative already enjoys the participation of several Brazilian companies and will be the starting point for expanding the system. It is a fine example of how digital technology can draw peoples with very different lifestyles closer together and can strengthen the feeling that the prosperity of all depends on our ability to value the activities of those who exploit the standing forest in a sustainable way.
INTELLIGENT ASSETS | ELLEN MACARTHUR FOUNDATION

The US Environmental Protection Agency found consumers could reduce energy usage by 10–30% using schedules and temperature settings of programmable thermostats.88

Yet despite the heated house and hot drink, you are feeling ill the next day. Imagine you stay home and do a health check remotely using a table-top device that analyses a blood sample and sends the results to your hospital. If needed, a prescription can be sent directly to your local pharmacy within minutes. Not only will you save time, but the hospital will also save important resources and be able to devote more attention and space to seriously ill patients.

Cities consume 75% of natural resources globally. They produce 50% of global waste and 60–80% of green house gas emissions.89

At the same time, since cities function as concentrators of materials and nutrients, they are the perfect stage for designing out structural waste as well as capturing residual value in secondary material streams. In areas such as energy, waste management, built environment and healthcare88, connected devices can help increase resource productivity while dramatically freeing up capital and time – and help city authorities to develop an urban planning approach built on circular principles. Smart city solutions can help governments achieve many of their core objectives, including improved health services, minimised waste and resource use, sustainable domestic water usage, decreased emission and pollution levels and the improved flow of transport systems. A circular economy perspective can help unlock the value intelligent assets can potentially bring to the urban environment. Intelligent assets can add value by providing guidance through every stage of the development and implementation of smart city solutions, and by widening the arena for their application.

INTELLIGENT ASSETS MAKING CITIES SMARTER BY...

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86 Berg Insight, mHealth Guardian, 22 January 2014.
87 HBR, How Smart Cities and Home Monitoring can help city authorities to develop an urban planning approach built on circular principles. Smart city solutions can help governments achieve many of their core objectives, including improved health services, minimised waste and resource use, sustainable domestic water usage, decreased emission and pollution levels and the improved flow of transport systems. A circular economy perspective can help unlock the value intelligent assets can potentially bring to the urban environment. Intelligent assets can add value by providing guidance through every stage of the development and implementation of smart city solutions, and by widening the arena for their application.

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For example, with 9% of global electricity, 10% of gasoline and 33% of solid waste flowing through 27 of the world’s biggest megacities alone, urban environments provide enormous potential for mainstreaming the idea and the broader application of ‘closed loop’ thinking. Cities could aim to use intelligent assets to close the resource loop through, for example, improved cycling infrastructure, as well as the deployment of asset tracking technologies.

Although limited in how much additional resource productivity they enable individually, the ecosystems of smart city solutions could together revolutionise the way resources are used and consumed in cities. Benefits are wide-ranging for citizens (reduced time and monetary investment, improved health, less stress), entrepreneurs (space for innovation), the public sector (lower resource use, reduced costs) and the environment (reduced emissions and pollution, and increased utilisation and longevity of assets).

In the transport example outlined above, asset tracking paired with mobile technologies enable multiple car-sharing models such as Zipcar, DriveNow or Car2Go. The proliferation of these models means that a larger number of people can reach their destination with fewer assets and less time invested. The driving pattern of shared cars encourages electrification since they would often be parked in designated bays that could feature chargers, and the sharing pattern incentivises the design of cars that are more durable and easy to repair. Apps such as Parker reduce both the driving time looking for a parking space and the associated energy consumption. Apps such as Waze help drivers minimise their total driving time by real-time route planning. Intelligent traffic lights further reduce congestion and lead to smoother driving with less wear on vehicles. All in all, the impact on resource productivity in this example could be massive.

Transport is only one of the urban systems in which intelligent assets can unlock value synergistically. Asset tracking means that products are reused or cascaded back into a different use cycle rather than discarded. In that way, resources would remain in the city’s ecosystem for longer (or ideally forever) and waste, as well as costs for sourcing new resources or raw materials, would be re-directed to a minimum. A future city could source its share of the USD 21 billion worth of gold and silver that goes into the electronics manufactured each year from its own waste. Its lifts, escalators, fridges, lighting and heating systems, desks, chairs, phones and laptops could be owned and tracked by their manufacturer, who will either maintain and improve them or take them back and reuse them when your company decides it wants to get new ones or move to a different location. And the family housing could be much cheaper because the construction company owns and tracks the materials to reuse or sell at the building’s end of life.

Overcoming humanity’s greatest resource challenges requires a comprehensive, integrated understanding of technology and data [...] Nowhere else is this clearer than in cities.

Melanie Nutter
It is imperative for cities to adopt circular systems to conserve global resources, reduce waste streams and emissions. For this reason circular economy (and circularity of resource flows) should be a founding principle for smart city planning.

Joanna Williams

A plan for converting data into useful information to achieve specific city resource management goals is key to best-practice smart city strategy.

Morten Højér

With about 30 village dwellers moving to a city every minute, India is urbanising at an unrivalled rate. City authorities have recognised that to address the resulting challenges of that movement, India’s cities need to become a magnet for investment. With the announcement of transforming 100 cities into smart cities, the government is laying the foundation for improved security, water management and energy use.98

For a more extensive description of these policy instruments, please see Ellen MacArthur Foundation, Delivering the circular economy: an action plan for policy makers (2015).

PUBLIC SECTOR DATA IS ONE OF THE SINGLE LARGEST SOURCES OF INFORMATION IN EUROPE WITH AN ESTIMATED MARKET VALUE OF EUR 32 BILLION, WITH EUR 56 BILLION OF ADDITIONAL GAINS IF BARRIERS WERE REMOVED AND THE DATA INFRASTRUCTURE WAS IMPROVED. AS POINTED OUT BY NEIL CROCKETT OF DIGITAL CATAPULT UNITED KINGDOM, INCREASED DATA SHARING WILL ENABLE ORGANISATIONS TO MORE EFFECTIVELY OVERCOME CHALLENGES AND PROFIT FROM ‘IoT OPPORTUNITIES’. THE REUSE OF PUBLIC DATA FOR SMART CITY SOLUTIONS COULD ENABLE INNOVATIVE AND UNIVERSAL APPLICATIONS AND SERVICES, WHILE CREATING NEW BUSINESS OPPORTUNITIES, JOBS AND GREATER CHOICES FOR CONSUMERS.99 TO CAPTURE THE FULL POTENTIAL THAT SMART CITY SOLUTIONS CAN OFFER, CITY OFFICIALS HAVE THE IMPORTANT ROLE OF UNDERSTANDING AND MANAGING THE CHOICE OF INFORMATION TO ACQUIRE, AND HOW TO USE IT TO MEASURE WHAT HAPPENS AROUND US AND TO RESPOND DYNAMICALLY. NEW MEANS OF SENSING THAT IS ALREADY THREE YEARS OLD). A LOT OF THIS DATA IS PRODUCED IN CITIES, THROUGH ‘SENSING’ – THE ABILITY TO MEASURE WHAT HAPPENS AROUND US AND TO RESPOND DYNAMICALLY. NEW MEANS OF SENSING ARE SUFFUSING EVERY ASPECT OF URBAN SPACE, WHERE ‘INTELLIGENT ARTIFACTS’ REVEAL THEIR VISIBLE AND INVISIBLE DIMENSIONS. ‘IoT OFFERS NEW WAYS TO UNDERSTAND AND MANAGE THIS INFLUENCE. MOBILE PHONE PLATFORMS ARE BECOMING KEY ‘IoT ENABLERS AND HOLD GREAT POTENTIAL FOR UNLOCKING CIRCULAR ECONOMY VALUE IN THIS SPACE.

To harness the vast range of opportunities offered by the spread of intelligent assets, the citizen must be involved in the process of managing resource use within cities. citizens hold the ultimate control of their surroundings, and IoT tools have the potential to give them the possibility to better understand and manage this influence. Mobile phone platforms are becoming key ‘IoT enablers and hold great potential for unlocking circular economy value in this space.

In order for us to scale up the opportunities by the interplay between intelligent assets and circular principles, it is critical that an increasing number of people – users and developers of IoT – are involved by making big data and information public. In other words, big data should become open data to have a big impact on our lifestyle and cities.

CIRCULARITY OF RESOURCE FLOWS

To respond dynamically. New means of sensing that is already three years old). A lot of this data is produced in cities, through ‘sensing’ – the ability to measure what happens around us and to respond dynamically. New means of sensing are suffusing every aspect of urban space, where ‘intelligent artifacts’ reveal their visible and invisible dimensions. IoT also offers new ways to understand and manage this influence. Mobile phone platforms are becoming key ‘IoT enablers and hold great potential for unlocking circular economy value in this space.

Big data today is getting really ‘Big’. According to a well-known quantification by Google’s Eric Schmidt, every 48 hours we produce as much data as all of humanity until 2003 (an estimation that is already three years old). A lot of this data is produced in cities, through ‘sensing’ – the ability to measure what happens around us and to respond dynamically. New means of sensing are suffusing every aspect of urban space, where ‘intelligent artifacts’ reveal their visible and invisible dimensions. IoT also offers new ways to understand and manage this influence. Mobile phone platforms are becoming key ‘IoT enablers and hold great potential for unlocking circular economy value in this space.

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FROM IDEAS TO ACTION

The surge in intelligent assets is expected to irreversibly transform industries and societies, and when paired with circular economy principles, this transformation has the potential to unlock tremendous value opportunities. However, for the full potential of these value opportunities to be realised, both private and public stakeholders must play an important role in addressing a number of technological, policy and business-related issues. As technology develops, there is a growing need for innovators and regulators to work together to leverage the richness of data generated while at the same time ensuring the privacy and integrity of organisations and individuals. Looking ahead, intelligent assets deployed in concert with circular principles could play a crucial role in facilitating the transition towards an economy that is truly restorative and regenerative.
Taken together, the value creation opportunities emerging in the sectors discussed in chapter 4 indicate that the synergies created there could indeed be major contributions to the acceleration of the transition towards the circular economy. However, the examples and expert perspectives presented in this report converge on the need to overcome several challenges to capture the full value at stake: reducing the costs of complexity and enabling interoperability; making technologies more transparent and accessible to the customer/user; and ensuring the security and privacy of data. If they don’t address these challenges, businesses and other stakeholders could miss out on capturing the full value creation potential presented by recent technological development. For example, while 73% of companies across all sectors are already investing more than 20–30% of their technology budgets in big data analytics and a majority expect to increase spending in that area in the coming years, in 2015 businesses missed out on an estimated USD 544 billion, or 47%, of the total value created by IoT during that year.100

Since much of the potential highlighted throughout this report lies in the evolution of new business systems that reinforce restorative or regenerative practices among independent stakeholders, there is also a risk that a stalling development of innovation or data-sharing platforms prevents the more ‘circular’ benefits. Since circular business models and innovation need an extensive flow of information, limiting this flow may also limit resource management solutions to increase efficiencies. That is, IoT will no doubt increase the resource efficiency of assets and processes, but it is less clear to what extent it will be able to foster system effectiveness and propel the development of circular business models. As pointed out by several experts, the right enabling conditions for open innovation and data sharing are key to this development.

How should the key challenges be addressed? And where could this interplay lead if the challenges are adequately addressed? While there is of course no ‘one size fits all’ answer, this chapter outlines a series of questions and enabling activities to help private and public decision-makers to begin addressing challenges that could prevent them from capturing the full value at stake while driving the shift towards the circular economy.

NICOLAS CARY
CO-FOUNDER, BLOCKCHAIN

The greatest barrier to the acceleration of IoT is a broken financial trust and security model. You cannot have the circular economy and a network of intelligent assets without the widespread adoption of a global open financial protocol for value transfer. Current payment rails are antiquated, proprietary, slow and expensive. They also exclude billions of people and are fraught with fraud and risks. Thanks to the development of blockchain (the technology behind the crypto currency bitcoin), we now have the opportunity to democratise the financial system and let people who do not know or trust each other complete an economic transaction without relying on intermediary.

Let’s step into the future a little. Imagine a world in which a Barbie guide in the Saharan desert can instantly send a payment, to anyone in the world, at near zero cost. Imagine a world where your intelligent refrigerator detects you are running low on eggs and automatically orders them from Amazon with expedited drone shipping. Your friend books the funds with a geolocational trigger, and when the drone arrives the payment is instantly done. Or better yet, imagine a world where you are running late for a flight and the Heathrow Express is severely delayed. Well, good news, you can order your self-driving, self-repairing and motorised refunded drone to pay it a surcharge fee to negotiate with all the other self-driving cars on the road to get out the way, automatically.

Unfortunately, before this can happen we have to completely reinvent the way payments work, and leverage a recent, critical innovation in computer science known as the bitcoin blockchain. Credit cards and other payment systems are Jurassic and inflexible channels for the age of the Internet. For example, online fraud is widely reported to be outpacing growth in e-commerce. This should not be a surprise to anyone who has studied the security model. Centralised data storage, combined with a 90-day settlement period for credit card payments, creates honey pots that attract hackers. Last year, hundreds of financial institutions were compromised in increasingly large breaches of personal and financial data. Traditional centralised security models no longer work. In addition, credit cards take a base fee and 2–3% of every transaction. Sadly, over four billion people can’t even get credit cards and legacy-banking systems simply cannot scale to support an intelligent asset development where micro transactions will dominate the vast majority of volume.

The future financial system will be designed differently, levering on the blockchain as a core principle in risk mitigation. In this world, anyone on earth will be able to participate in creating economic value on the Internet, using a financial protocol that allows individuals and machines to manage their own funds. The blockchain is a game-changing innovation because now, for the first time in history, a bitcoin wallet holder can transact with any other bitcoin wallet holder on earth, without having to rely on an intermediary. A few thousand lines of computer code can now do what banks have done for thousands of years, not to mention forex markets, clearing houses and merchant processors (all of which drive friction and cost in transactions today).

The technology behind the blockchain has the potential to reshape not just the flow of capital but also the efficiencies of supply chains. As a stable, secure record of exchange, the blockchain can track not only the transaction but what went into a product and who handled it along the way. With blockchain all bitcoin transactions can include a small referenceable amount of data, which means in a world of internet-enabled devices, container ships, trains and trucks can record and capture any relevant details like location and elemental conditions and ensure that supplies are properly managed along their journeys. This data can then get captured and broadcasted to the bitcoin blockchain – the world’s largest and most secure distributed computing database. A system that can create true transparency helping everyone study the provenance of goods and raw materials spreadsheet in the sky.

FRICIONLESS AND TRANSPARENT
For intelligent assets to create value in the circular economy, we need frictionless payments as well as billions of internet devices negotiating with each other, unleashing market forces to bring down the costs of goods and services for all. Supply chains will be transparent and the quality of our food, healthcare and products will be improved. As an industry, we have a lot of technical work to accomplish, specifically focused on scaling transaction capacity. We also need to build better software and experiences that allow people to more easily get used to interfacing with digital currency. On public awareness, we need to do a much better job of educating policymakers, influencers and general consumers about this groundbreaking technology.

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QUESTIONS FOR BUSINESSES

1. How would the adoption of circular economy value drivers and the use of intelligent assets affect your industry? For example, if your industry shared pre-competitive data generated by intelligent assets, how much value could be created through increases in asset and resource productivity?

2. Could intelligent assets help you deploy new business models in accordance with circular economy value drivers?

3. Would the generation of detailed product information throughout the use cycle result in any design changes?

4. What value could you recover from assets you have sold in the last five years – and could information generated by those assets change this value?

5. Could data generated by your assets enable you to introduce (or improve) a reverse cycle program in your business (including reverse logistics, remanufacturing/refurbishing and recycling)?

6. What financial model changes are required for your company to move from selling products to providing performance contracts?

QUESTIONS FOR POLICYMAKERS AND THE PUBLIC SECTOR

1. What would a programme to support education, collaboration and innovation in the interplay between circular economy and intelligent assets look like?

2. Could you in any way support markets in overcoming the interoperability challenge for intelligent assets?

3. Could public procurement guidelines be designed to encourage circular business models enabled by intelligent assets?

4. Can your institution facilitate the sharing of big data between industry stakeholders while maintaining data privacy and security? Is there a need to oversee current legislation?

5. Could knowledge generated by intelligent assets enable your institution to develop incentive schemes for businesses and individuals to become more resource productive (e.g. reduce waste, improve waste disposal behaviour, reduce energy and water resource demand, improve transportation flows)?

6. How could innovation, and privacy and data protection, flourish at the same time?

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6. How could innovation, and privacy and data protection, flourish at the same time?
A converging theme in the opinion pieces featured in this report is the challenge of enabling open, yet secure data sharing that fosters innovation and generates trust between stakeholders. The most significant challenge for businesses is to successfully move towards more open innovation, gradually shifting from the traditionally protective approaches focused on centralising data to maintain control, while ensuring adequate trust and security.101 The greatest policy challenge is to create an environment where businesses are able to innovate openly while at the same time ensuring organisations’ and individuals’ integrity with a strong legal framework.

Employing both intelligent assets and circular economy principles requires a number of new capabilities for businesses to obtain a competitive advantage in the new economy emerging from the digital revolution. Below are some actions that – once a plan has been formulated – could help businesses capture the opportunities presented in this report.

Develop flexible business models. Within the emerging IoT landscape, businesses must model capable of swiftly adapting to rapidly changing environmental and economic variables, such as commodity prices, inventory levels, supply and demand patterns, will be future market leaders. The IoT enables real-time profitability optimisation, and businesses need to adapt their systems – leading to increased innovation and generating trust for those who are directly and indirectly linked through intelligent assets. To address this, and other challenges related to enabling progress in the circular economy–intelligent assets interplay, they could consider instruments in the six categories outlined below.102

Develop technical capabilities. Businesses will not only need the right sensing and interpretation technology but also the capabilities to filter, connect and make sense of the generated information in order to create mechanisms that support decision-making processes in the most beneficial way. Value is created from this information over several stages (i.e. data is created, communicated, aggregated, analysed and acted upon)103 and businesses and customers alike ideally need to be able to extract value from all stages to optimise asset and resource productivity and make processes more circular. The choice exists between developing such capabilities in-house and outsourcing them, leading to a number of different decision points for organisations, but also to the possible emergence of new service sectors.

Adapt financing models. Circular business models enabled by intelligent assets could disrupt several financial aspects of businesses, including capital structure, accounting and valuation. Better transparency of asset interactions could lead to more accurate valuation of those assets, and would influence the supplier–customer owner incentives. Future balance sheets could therefore look very different. Performance metrics and sharing models are just two examples of business models changing customers’ and suppliers’ needs for capital – which could in turn disrupt capital markets.

Develop collaboration platforms. Open innovation will not automatically lead to synergistic value creation that increases profits for everyone. The interoperability challenge is one that can only be overcome through the creation of new business models, which need to be enabled by intelligent assets and intelligent asset value drivers. For large businesses, internal collaborations may be just as critical to coordinate innovation.

ACTIONS FOR BUSINESSES

Successful policymaking involves a tailored approach to problem-solving and setting goals specific to a region, which is arguably also a requirement for capturing value resulting from the interplay between circular economy and intelligent assets. Many policymakers face the challenge of creating an appropriate regulatory environment around a technological innovation that effectively ensures stakeholder trust and security while encouraging innovation. Sophie Hackford at WIRED Consulting explains how technologies, such as blockchain, that allow tracking and stimulating them, are accelerating away from the capabilities of existing legal infrastructure to manage risks effectively, and that this development provokes altering the current regulatory environment to create a more effective regulatory system. Lessons learned from other fields, such as biotechnology or geoeengineering – where the creation of ‘guiding principles’ for stakeholders to abide by was preferred – could prove useful.104 On the other hand, sensitive issues such as data privacy and security require a robust legal framework with adequate enforcement mechanisms. The key challenge for policymakers lies in stimulating (open) innovation while ensuring data security and generating trust for those who are directly and indirectly linked through intelligent assets. To address this, and other challenges related to enabling progress in the circular economy–intelligent assets interplay, they could consider instruments in the six categories outlined below.105

ACTIONS FOR POLICYMAKERS AND THE PUBLIC SECTOR

Information and awareness. These policies aim to change the ingrained patterns of behaviour of both individuals and societies to encourage them with broad or narrowcast information campaigns, or changing the curriculum or educational approach in schools, universities and continuing education. Since both circular and IoT-related innovation requires the private and public sectors to cooperate across traditional sectoral and functional silos, an understanding of the economic potential and the necessary practicalities is crucial and often lacking. To improve individuals’ and societies’ ability to engage with technology, many countries have started national initiatives, such as the US ‘digital promise’, created to spur the research, development and adoption of breakthrough technologies in all areas.106 Similar programmes could be designed to create awareness of the limits of the linear economy and alternative, circular ways of doing business.

Collaboration platforms. These platforms can take the form of collaborations with some degree of government support, such as industrial symbiosis arrangements or R&D collaborations between academic and industry players. An important role of policymakers is to incentivise businesses to overcome interoperability hurdles by fostering cross-industry collaboration, including providing safe sharing environments (e.g. via blockchain) for multiple stakeholders to come together to solve existing problems. The demonstrator platforms set up by Digital Catapult United Kingdom are examples of a significant step towards establishing open innovation through the creation of ‘test beds’. These bring together businesses, universities and innovators to solve key challenges to growth in the IoT market while fostering circular practices.

Business support schemes. Government financial support such as grants, capital injections and financial guarantees all fall under this category, alongside the levers of technical support, advice, training and the demonstration of best practices. Possible solutions range from brokered traditional investment through public–private partnerships to using more innovative solutions including crowdfunding, as well as providing sufficient funding for research and education to support innovation from the circular economy–intelligent assets interplay. Finally, government can create investment stimuli for models created by pairing circular economy principles with intelligent assets by undertaking collaborative projects. An example of this is the Innovate UK – a government-funded body providing R&D funding for specific projects. Its mission statement is to fund, support and connect innovative businesses to accelerate sustainable economic growth. It has already funded IoT projects regarding both security in the IoT, and circular economy business models.107

Public procurement and infrastructure. The public sector can step in to provide purchasing power that is lacking in the private sector due to new business models – for example, enabling companies and citizens or market failures, and which prevent IoT-enabled circular economy activities taking off. An early example is ‘Copenhagen Connecting’ – an initiative by the Danish city of Copenhagen. It plans to use smart data in traffic lights and lighting to create a more efficient traffic system that will increase safety for all road users and reduce traffic. When fully implemented, the initiative is estimated to yield economic benefits of roughly USD 735 million.108

Regulatory frameworks. The application of government regulations, and the mandate or stimulate circular economy activities enabled by IoT technologies, or prohibit or discourage non-circular practices, can either change existing regulatory frameworks or create new legal frameworks. However, given differences in

102 Innovation like the blockchain technology present another alternative to conventional regulation as the system assures itself by nature.
106 See http://vivatech. inovate.gov.uk for fundings and initiatives on smart cities and IoT security and for wes- sibly, whilst circular business models.
110 See http://vivatech.inovate.gov.uk for fundings and initiatives on smart cities and IoT security and for wessibly, whilst circular business models.
Looking Ahead

Intelligent assets form a powerful disruptive trend affecting most industries. The technology is already a market reality and will continue to grow, yet whether this growth will effectively capture the value creation opportunities offered at the interplay with circular economy value drivers will be determined by whether public and private stakeholders manage to successfully design and implement the enabling conditions required to overcome the challenges discussed above.

Looking ahead with a broader perspective, one can envisage staggering benefits, though it remains an open question to what extent and how fast this potential will be harnessed. Below are just a few possible outcomes that could be realised if intelligent assets were to be further designed, developed and deployed in concert with circular principles.

Enable material backbones. In the study ‘Growth Within: A Circular Economy Vision for a Competitive Europe’, one key recommendation for Europe is to develop a ‘material backbone’ – a system to optimise the circulation of materials and minimise the need for virgin resources – to strengthen its competitiveness. Intelligent assets – in particular asset-tracking solutions – could be instrumental in realising that vision.

Optimise stocks and flows. The ability of intelligent assets to monitor the flows of both technical and biological materials means that the question of optimising stocks and flows – a cornerstone in achieving the circular economy – is no longer theoretical. It would be facilitated through combining an increased access to assets and multiplying the number of users per unit (e.g. through sharing platforms) with refining reverse logistic solutions enabling restoration through remanufacturing, and an increased transparency of the complex flow of residual and raw materials.

Reveal and quantify the cost of externalities. A major barrier for the transition towards the circular economy is the hidden cost of negative externalities. Technological intelligent asset-tracking detailed flows in, for example, food production systems, and in the future the extension to other applications, including the source of externalities, such as greenhouse gas emissions or ecosystem service destruction, in detail. This would not be a complete solution but a key step towards setting an accurate and fair price on these externalities.

As the global economy, and our living environment, become increasingly permeated by technology and intelligent assets, it is important for businesses and regulators to develop a more structured and system-based approach to the role they play in improving resource effectiveness, and with it people’s quality of life, while at the same time safeguarding personal privacy and security. A first step towards creating and capturing value through the interplay between intelligent assets and circular economy principles involves increased cooperation between stakeholders within and across sectors (as well as between public and private sectors). If companies and policymakers manage to identify and articulate the opportunities presented by the circular economy – and integrate them in their strategies or policies – the synergies created together with intelligent assets could be of common use for addressing several of the core challenges of designing an economy that is truly restorative and regenerative.

About the Ellen MacArthur Foundation

The Ellen MacArthur Foundation was established in 2010 with the aim of accelerating the transition to the circular economy. Since its creation the Foundation has emerged as a global thought leader, establishing circular economy on the agenda of decision makers across business, government and academia. The Foundation’s work focuses on four interlinking areas:

Education - Inspiring learners to re-think the future through the circular economy framework

The Foundation is creating a global teaching and learning platform built around the circular economy framework, working in both formal and informal education. With an emphasis on online learning, the Foundation provides cutting edge insights and content to support circular economy education and the systems thinking required to accelerate a transition. Our formal education work includes comprehensive Higher Education programmes with partners in Europe, the US, Sensing technology is part of the CE100 provides a unique forum for building and regenerative. Insight and Analysis - Providing robust evidence about the benefits of the transition

The Foundation works to quantify the economic potential of the circular model and to develop approaches for capturing this value. Our insight and analysis feed into a growing body of economic reports highlighting the rationale for an accelerated transition towards the circular economy, and exploring the potential benefits across different stakeholders and sectors. The Foundation believes the circular economy is an evolving framework, and continues to widen its understanding by working with international experts including key thinkers and leading academics.

Communications - Engaging a global audience around the circular economy

The Foundation communicates cutting edge ideas and insight through its circular economy research, reports, case studies and books disseminated through its publications arm. It uses new and relevant digital media to reach audiences who can accelerate the transition, globally. In addition, the Foundation aggregates, curates, and makes knowledge accessible through Circula	
technology, or discourage such types of taxes and government subsidies. They can be applied to the market to either encourage circular economy activities enabled by IoT technologies, or discourage non-circular activities. For example, getting rid of (sometimes) indirect subsidies for raw material extraction or fossil fuels could further incentivise performance models. As illustrated by the Ex2Tax Project, shifting the taxation structure from labour to natural resource use could further incentivise circular practices as well as potentially create hundreds of thousands of jobs.104

The speed between the development of new production and technology and associated security issues, it is practically impossible for policymakers to implement effective policy targeted at specific issues. Instead, policymakers should focus on creating a secure, enabling environment. One example is to allow the development of an IoT-enabled information infrastructure that could make it easier to differentiate between resources and ‘waste’ in cross-border trading, which would in turn help governments control resource flows and build material backbones. A second example is establishing data privacy and security frameworks to create trust and confidence in the IoT market. At the moment the IoT is such a new technology that no such data privacy regulations exist; however many governments have started addressing this issue, such as the US Federal Trade Commission, which urges companies to adopt best practices to address consumer privacy. 107

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