



CREATING A SUSTAINABLE FUTURE

How 12 disruptive technologies
can help organisations meet the
UN Sustainable Development Goals

2017

Bringing Ingenuity to Life
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Introduction

Technology innovation has been one of the great drivers of progress for humanity. From accessing clean water and manufacturing sustainably, to reducing poverty and ensuring health and well-being for all, we've turned to technology.

In an increasingly crowded and connected world however, the barriers to progress can appear impossibly difficult. And we now face a set of systemic challenges of a scale and complexity not seen before.

The UN Global Compact's 17 Sustainable Development Goals (SDGs) set an ambitious and transformative vision for peace and prosperity on a healthy planet. They are pledges to overcome some of the biggest challenges the world faces by 2030. Challenges like poverty, inequality and environmental degradation.

Achieving the SDGs will also create an estimated \$12 trillion a year in economic growth, 50 per cent of which will be in developing nations. But to get there, we urgently need to disrupt the status quo. Business as usual is not enough. We need breakthrough solutions.

Disruptive technologies have the potential to help.

As part of our work with the UN Global Compact, we've created executive briefs for 12 disruptive technologies that can help meet the SDGs.

All 12 technologies are mature enough to have a transformative impact in the short-term. That means they won't just help meet the SDGs, they'll also help companies grow in the markets of the future.

The executive briefs in this document will give you the understanding needed to start exploring how to use these disruptive technologies.

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Big Data
Blockchain

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Autonomous Road Vehicles
Additive Manufacturing

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TECHNOLOGY THAT IMITATES LIFE

Next Generation Robotics

Artificial Intelligence

New Realities



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Project Breakthrough

Disruptive Technology Executive Briefs

NEXT GENERATION ROBOTICS

Going beyond the factory floor

Robotics is a familiar technology for the vast majority of people but their perception of its applications and capabilities vary greatly. In its simplest form, a robot is a machine that performs an action (or series of actions) that include movement, based on instructions provided by either an operator or a piece of software.

Recently, the variety and range of applications for next-generation robotics have increased dramatically. These include those working with humans (sometimes called co-bots), interacting with humans (such as educational robots), assisting humans (surgical robots, exoskeletons), or adapting and integrating into human-made environments. We now see uses for robots across industrial manufacturing, the home and the battlefield.

The technology

New sensors (such as cameras, distance, force and proximity sensors) now enable robots to recognise and respond to their environment. The robots can also use software and algorithms (including artificial intelligence) to interpret the data collected and to control their movement. That movement is then enabled through actuators such as wheels, grippers and robotic arms.

The potential

Robots traditionally performed repetitive, pre-programmed movements in a structured environment using simple controls. Now there is an increasing need for them to adapt to less structured and more complex, changing environments. The new generation of robot designs make it easier and safer for humans to interact and work with them in these conditions, with the potential to bring dramatic changes to the world of work.

The barriers

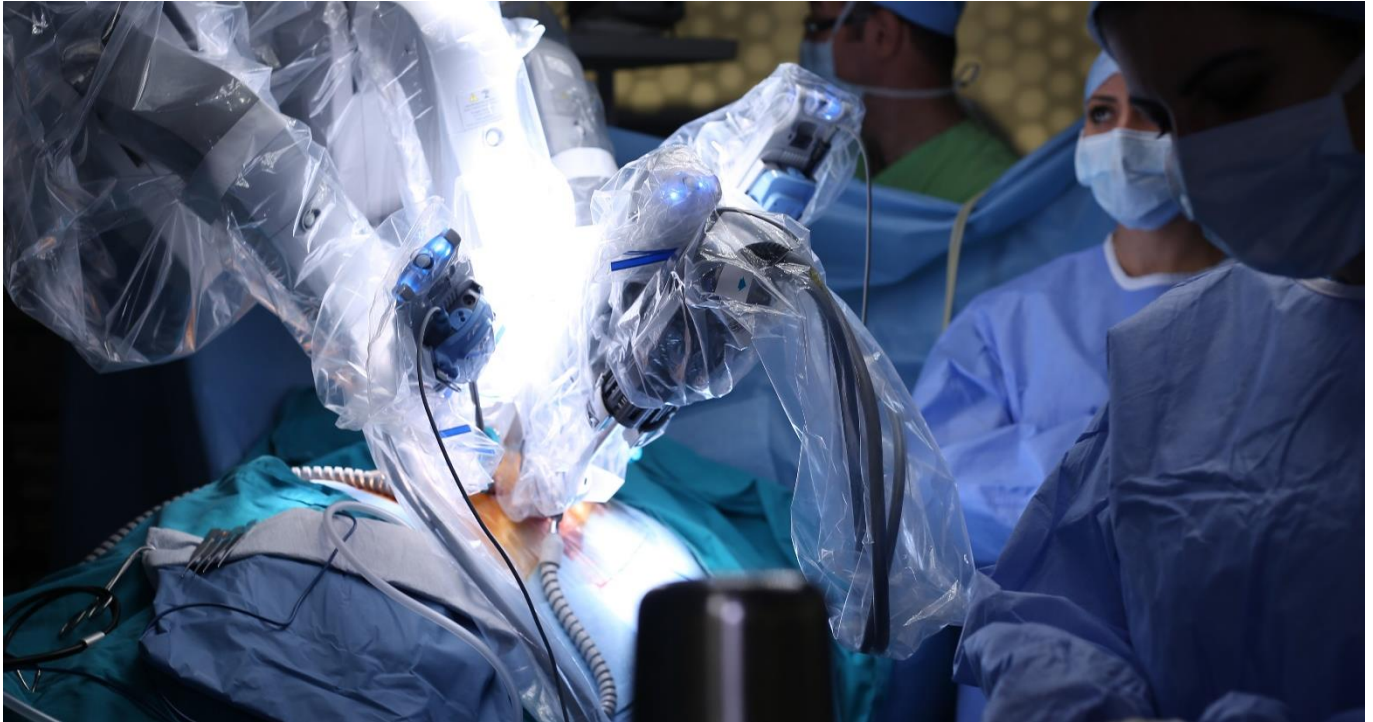
Automating more and more tasks using industrial robots can improve efficiency and lower production costs but are also able to reduce the number of human operators required. There are also safety and privacy concerns, with connected robots having the potential to be hacked and used to gather data or perform dangerous actions. Public perception of these factors will also be a key factor in the rate and level of uptake of this technology.



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Some Example Applications...



Hospital robots

Robots have an increasing presence in healthcare, such as surgical robots like Da Vinci or support robots used to deliver medical supplies around a hospital when needed. In addition, robots are also performing more routine tasks such as acting as guides, helping patients and visitors navigate large hospital estates, and freeing up valuable capacity for trained professionals.

Exoskeletons

The Phoenix exoskeleton has enabled people paralysed from the waist down to walk again. With the cost and weight of these systems reducing, we are likely to see exoskeletons increasingly used to both enable mobility and support work-based activities.

Manufacturing reinvented

Rethink Robotics have introduced the Baxter robot that is designed to work on a production line alongside humans. Human operators can re-program Baxter by moving its arms into desired configurations, much like teaching a child. Using such robots can reduce equipment costs for factories by allowing human-robot collaboration and minimising the changes needed to acquire and install the robot, as well as the costs associated with learning to operate and re-configure it.

Key Numbers

\$82.7 bn

Estimated market size in 2020

Source: Allied Market Research

20,000+

Patent applications filed annually

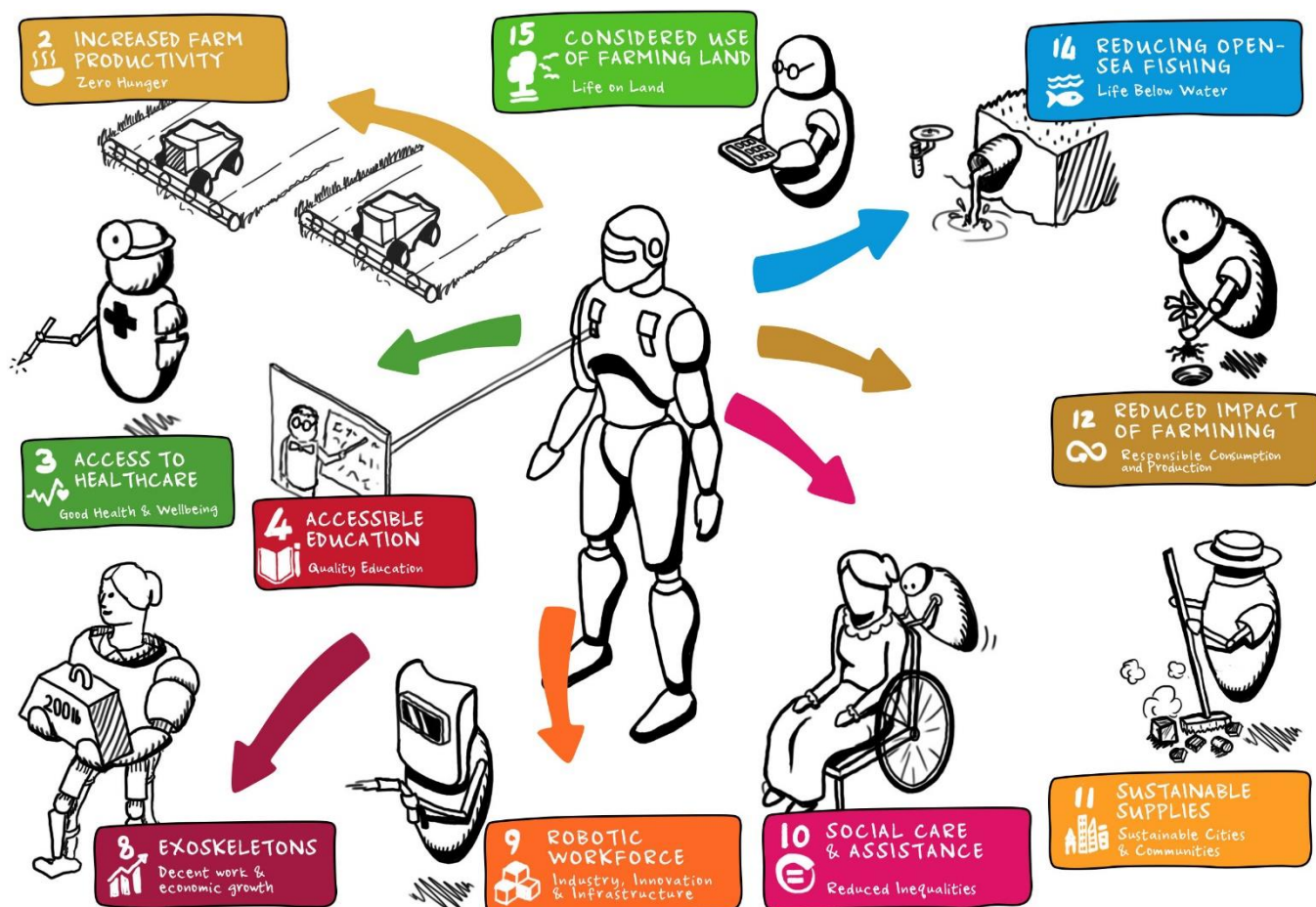
Source: Patsnap Insights

\$188 bn

Estimated spending in 2020

Source: Statista

Advancing the Sustainable Development Goals (SDGs)



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Next generation robotics have the potential to advance many of the SDGs. Below are some examples of areas of application across a wide variety of sectors.

■ SDG 2 Zero hunger

- Monitor fields, identify and remove weeds, and eventually eliminate the need for herbicides, making agriculture more cost-effective and sustainable.
- Improve farm productivity in areas where urbanisation has resulted in a reduction in the available workforce in rural areas.

■ SDG 3 Good health and well being

- Make high quality care and access to expert doctors a right for all, by using healthcare robots in remote or underprivileged locations. Assisted by next-generation robotics, procedures could be undertaken by less experienced staff, allowing individuals in remote or under-served locations to receive the same quality of care as those in major hospitals.
- Avoid injuries by automating tasks that are dangerous or harmful for humans to perform. Robots are already used in construction, search and rescue, ordnance disposal, mining and waste disposal, to avoid exposing human operators to dangerous, harmful or hazardous environments.

- Improve the quality of life of people with limited mobility through exoskeletons, to help with everything from picking up objects to walking. This type of robotics can also reduce secondary complications resulting from immobility, such as muscle wastage and sores.

■ SDG 4 Quality education

- Make education more accessible, even in remote locations where specialised teaching would be too expensive, or where trained educationalists are not available, or are in short supply.
- Provide specialist help for children with learning difficulties or autism through high quality, tailored educational tools which can adjust to individual difficulties and match learning style. Allow human specialists to reach a larger number of children with a range of learning difficulties.

■ SDG 8 Decent work and economic growth

- Transfer simple, repetitive tasks to robots, freeing up people to focus on more value-adding activities while increasing quality and safety. Jobs will become less dangerous, less repetitive and less physically demanding. Exoskeletons will open up highly physical roles to a wider workforce and reduce the likelihood of injury.

- Change the make-up of the workforce and nature of employment. As more tasks are automated, demand for manual labour will decrease, but demand for highly skilled engineering, programming roles and less specialised robot operators and maintainers will increase. The net effect on the overall number of jobs will become clear over time – it is likely to be uneven across geographies, as regions with better education and training gain at the expense of other areas as already observed in the decline of manufacturing locations across the world.

■ SDG 9 Partnerships for the goals

- Improve efficiency and effectiveness of production, whether it be in time, money or natural resources. Next generation robots can integrate into the production ecosystem smoothly and compared to full automation, offer valuable flexibility at a lower cost, requiring fewer changes to current operations while increasing flexibility, reducing human idle time and minimising cost.
- Allow less developed countries to automate at a lower cost, by reducing the costs of training and by acquiring and maintaining equipment. This can contribute to increased economic independence and enable countries to develop their own manufacturing base rather than relying on imports.
- Lower significantly the costs of customised products. Production line machines that are easy to reconfigure and re-program by non-experts, with reduced training time and investment requirements, will make mass-customisation feasible.

■ SDG 10 Reduced inequality

- Provide access to help and assistance for those who currently do not have it.

■ SDG 11 Sustainable cities and communities

- Enable more sustainable production and supply of services.

■ SDG 12 Responsible consumption and production

- Allow better monitoring of environmental impacts of farming operations and reduce the use of excess water as well as enable more efficient waste disposal, herbicide and fertiliser development.

■ SDG 14 Life below water

- Provide data relevant to pollution monitoring and support marine management through unmanned underwater vehicles.

■ SDG 15 Life on land

- Provide support in management of land and ecosystems.

Potential Negative Impacts and Barriers

There are fears about the potential for robots to replace humans, creating mass unemployment. It will be vital to address these concerns if they are to be widely accepted.

Human interaction and employment

Some of the earliest debates around next-generation robotics have been focused on the human labour that it replaces and the lack of human interaction it can cause. This will need careful management by all those involved in the roll out and implementation of this technology, tailored to the individual regions it affects to minimise short term impacts. In the longer term, the advent of next generation technologies is also going to bring with it a range of new industries and job creation, which, if managed correctly, has the potential to off set much of these impacts.

Ethical considerations

There are many ethical considerations when introducing robots into environments where they can make decisions that affect human lives, such as the use of autonomous robots in the military or robotic surgeons. Legislation to address these issues will need to be introduced and this is likely to be an area of extensive debate at both national and international levels over the next few years.

Public perception

Education to improve public understanding and perception of robots will be essential to ensure their smooth adoption in environments such as schools and hospitals, and to explain the capabilities and limitations of robot platforms.

Security

Cyber security is another important consideration, as more autonomous robots operate in safety-critical environments. There is a risk that someone could take control of the robot and do significant harm, undermining the public perception that robotics is a beneficial technology.

Technical Considerations

Basic tasks that we take for granted, such as climbing stairs or acting on variable instructions pose significant technical challenges which we will need to be overcome for robotics to reach its true potential.

Learning to get better

The learning algorithms that allow robots to seamlessly integrate into the environment present numerous computer vision and control challenges that are still being addressed. These will need to improve in both performance and cost to support their wider use.

Infrastructure

Information and infrastructure is currently tailored to human needs, with information presented in a human friendly format whereas robots need to be able to translate it to a robot friendly format.

The dalek conundrum

Robots will need to be able to operate in environments designed for humans including stairs, doors and lifts, presenting further mechanical and motion control challenges.

Dealing with surprises

Real world environments can be unpredictable and constantly changing. Anticipating all possible variations in real world environments is very challenging and until robots can learn to do so reliably, their applications will be constrained.

Trust and communication

Designing user interfaces that are intuitive for humans to use and facilitate human-robot interaction can be a challenge. Trusting them too much or too little can also present difficulties and mean that their interfaces are used ineffectively or not at all.

Dexterity

Manual dexterity needs to be improved to allow robots to handle delicate materials and different geometrical shapes.

Enabling New Business Models

Robotics has already revolutionised the world once. It is going to do it again.

Robots working closely alongside humans as an integrated part of the workforce will impact most, if not all, sectors of industry. They could potentially be used anywhere where physical tasks are performed, or where there is interaction with humans, in both developed and developing economies. In the same way as artificial intelligence will help humans and support the achievement of intellectual tasks, exoskeleton robots will enable humans to do more physical tasks.

Robots will allow services to be delivered in new and different ways to customers, products to be tailored to individual needs and to develop propositions to meet currently unmet customer requirements. Businesses will be able to operate faster, cheaper and more flexibly, with humans and robots working alongside each other. The flexibility of robots working with humans will reduce some barriers to entry and the ability to work across distances will allow businesses to serve locations that were previously uneconomical.

The impact will be felt on both mainstream businesses and how they operate, as well as creating opportunities for small-scale start-ups, and possibly as part of the tools that individuals own and bring to work to perform their jobs.

Robots will enable a number of the disruptive business model levers identified on the Project Breakthrough website. Specifically:

A more personalised product or service

Robots working with humans will make it easier to tailor and adapt products and interactions to individual consumers, and increase the geographical reach of experts.

A closed-loop process

Robots can reduce waste in the production-to-consumption process through better production techniques and control, and recovery and reuse of components and materials at the end of their life.

An agile and adaptive organisation

The combination of robots working with humans may offer greater flexibility than full automation. Entire product generations of robots can be updated remotely and instantly, rather than needing to be serviced or returned to the manufacturer.

More Examples...

Robokind are producing robots to help educate children with different needs and treat autism

<https://www.theguardian.com/lifeandstyle/2015/feb/01/how-robots-helping-children-with-autism>

Autonomous robot surgeon pits its skills against a human

<http://spectrum.ieee.org/the-human-os/robotics/medical-robots/autonomous-robot-surgeon-bests-human-surgeons-in-world-first>

Aviva looks to reskill staff if jobs are at risk of being done by robots

<http://www.insurancebusinessmag.com/uk/news/breaking-news/aviva-asks-16000-staff-if-their-jobs-can-be-done-by-robots-61106.aspx>

Project Breakthrough

Disruptive Technology Executive Briefs

ARTIFICIAL INTELLIGENCE

A more intelligent future

Artificial intelligence (AI) is expected to be one of the most pervasive disruptive technologies, touching every part of our lives and fundamentally changing the way we use and interact with technology. AI's ability to transform vast amounts of complex, ambiguous information into real insights has the potential to help solve some of the world's most enduring problems and to undertake tasks with greater efficiency and scale than a human could.

The technology

AI is the construction of computers, algorithms and robots that mimic the intelligence observed in humans, such as learning, problem solving and rationalising. Unlike traditional computing, AI can make decisions in a range of situations that have not been pre-programmed into it by a human.

Much of AI is about systems that can learn and evolve through experience, often to carry out specialised tasks such as driving, playing a strategy based game, or making investment decisions. This subset, also referred to as cognitive computing, needs to be trained by learning from experts.

Looking to the future, the focus is on creating an Artificial General Intelligence (AGI) that can apply itself to a broad range of tasks in a much less structured way.

The potential

As part of a wave of automation, we are seeing widespread and rapid adoption of early AI technologies that are transforming industries across every sector. This will have wide ranging implications for the global economy, countries and organisations, and will only accelerate as parallel technologies, such as the Internet of Things, unlock more opportunities.

The barriers

Although AI would be very different from human intelligence, high profile commentators such as Stephen Hawking and Elon Musk have pointed to the potential risks should its performance and capabilities dramatically exceed that of humans. AI also raises questions about how its decisions should reflect a moral/ethical code.

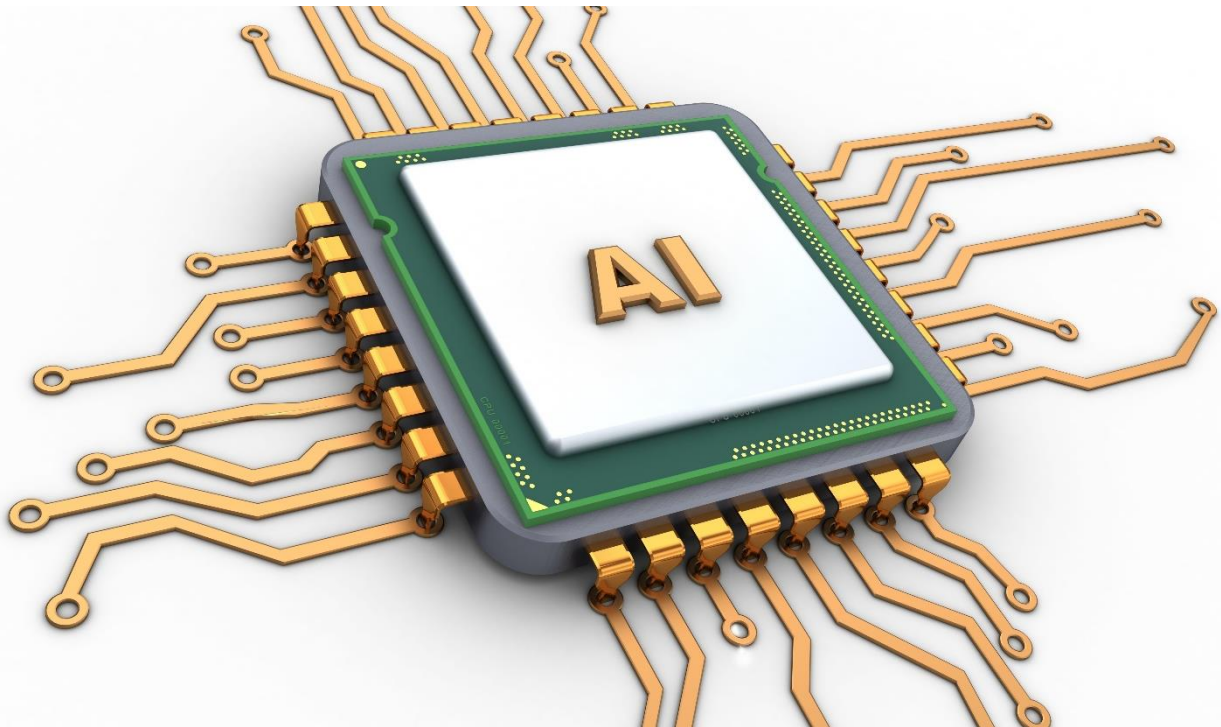
There is currently a significant debate and little consensus about when (and indeed whether) true AGI can be achieved, but many industry observers believe it is unlikely before 2030. However, given the current rapid evolution of such technologies, we may be at the early part of a dramatic increase in AI development.



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Some Example Applications...



Identifying poverty hotspots from satellite images

A team of computer scientists and satellite experts at Stanford University have created a self-updating world map to locate poverty. Analysing household survey data, and day and night time satellite images, the system looks for signs of poverty, such as intensity of nightlight, and finds correlations with roads, urban areas, farmlands and waterways. Initially focused on five African nations, the team plan to create a worldwide poverty map that will be publicly available online to support governments target their policies and programs more effectively .

Just-in-time water management

JEA (a Florida water company) is using artificial intelligence to reduce withdrawal of water from the area aquifer in Jacksonville, USA. Their system forecasts consumption, then monitors, regulates and adjusts supply in real-time, providing a just-in-time water supply.

This minimises well production during peak hours, optimises reservoir storage, and reduces the number of pump starts required, lowering energy consumption and maintenance costs. It means JEA can meet the growing demands of its customer base, reduce the need to dig new wells and preserve Florida's aquifer for the future.

Cognitive revolution for healthcare

STFC Hartree® Centre at Alder Hey Children's Hospital is harnessing the power and potential of IBM Watson's cognitive computing technology to personalise healthcare and enhance the patient experience. It has an enormous range of potential applications including quicker identification of clinical trends and monitoring admission patterns.

This project is creating a path to more personalised treatment, better health outcomes, increased patient satisfaction and significant cost savings.

Key Numbers

\$6.1 bn

Estimated AI market size in 2020

Source: Statista

\$47 bn

Estimated spending on AI technologies 2020

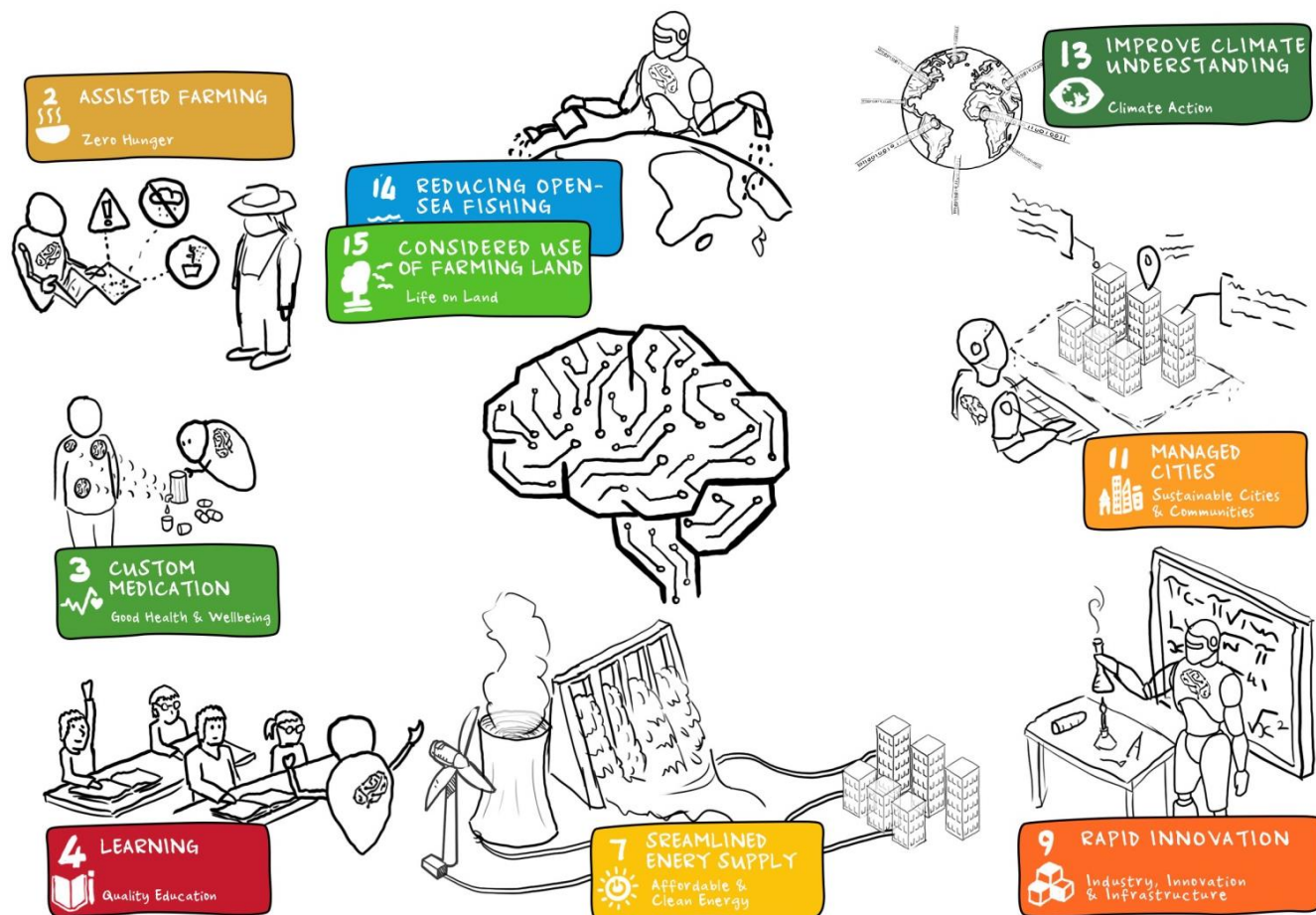
Source: IDC

283%

Increase in published patent applications involving AI 2010-2016

Source: Hoffman Warnick

Advancing the Sustainable Development Goals (SDGs)



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Artificial Intelligence has the potential to advance many of the SDGs. Below are some examples of areas of application across a wide variety of sectors.

■ SDG 2 Zero hunger

- Analyse seed genetic data to create crops that can thrive and adapt in changing conditions.
- Increase effectiveness of food supply chains through the use of AI technologies to drive insights that improve efficiency and reduce wastage.
- Support for farmers' decision making and increases in productivity.

■ SDG 3 Good health and wellbeing

- Mine healthcare records to improve quality of treatments and provide better and faster health services.
- Analysis of large-scale genetic data sets to help create new types of treatment and precision medicines customised for individuals.

- Provide expert assistance in diagnosis especially in repetitive tasks such as analysis of images and large bodies of research information.
- Provide immediate first line consultation to improve waiting times to see a doctor.
- Reduce pressure on frontline staff by using robots in healthcare.
- Speed up the development of new drugs allowing treatments to reach those who need them more quickly.

■ SDG 4 Quality education

- Improve learning outcomes through the analysis of data about individual learning, social and learning contexts, and personal interests.
- Provide virtual mentors for learners by integrating modelling, social simulation and knowledge representation.
- Provide lifelong learning companions that help the learner to adapt and build new skills throughout their lifetime.

■ SDG 7 Affordable and clean energy

- Optimise energy generation and reduce environmental impact through analysis of operational and environmental data.
- Help consumers to find the most affordable and clean energy deals by using AI agents.

■ SDG 9 Industry, innovation and infrastructure

- Help employees to make better decisions by providing insights based upon the analysis of complex data sets.
- Accelerate innovation cycles and improve time to market through the use of machine learning and predictive analytics.

■ SDG 11 Sustainable cities and communities

- Enable smarter and more efficient design of cities and communities, for example by discovering the correlations between design decisions and their impacts on peoples' daily lives.
- Empower citizens to make wiser choices for themselves and their collective communities.
- Orchestrate and optimise traffic flows and energy allocation within cities, as well as the use of wider physical and human resources to maximise benefits.

■ SDG 13 Climate action

- Improve actions to mitigate climate change through better modelling and analysis of large, complex data sets.

■ ■ SDG 14/15 Life on land/below water

- Generate insight to help to improve the sustainable management of land resources – soil, forests, biodiversity and allow greater understanding of the impact of land use choices through predictive analytics and machine learning.

Potential Negative Impacts and Barriers

As a less mature technology, the potential negative impacts of Artificial Intelligence are still being explored. However, science fiction and human imagination provide an insight into what we can expect.

Do as we say, not as we do

Organisations will need to put in place strong governance for AI activities to ensure that systems perform ethically and do not embed harmful assumptions that have unanticipated consequences, or discriminatory behaviours in their algorithms. Furthermore, AI will inevitably be deployed for criminal purposes, and in warfare, with implications for current legal and ethical frameworks.

Workforce considerations

The adoption of AI and the technologies of automation may lead to unemployment in many industries and professions. Society and organisations will need to respond to this. Concepts such as Universal Basic Income are being discussed by some as potential policy responses. Other options could be to make the technologies of automation a common good to ensure that benefits are felt fairly across society and not just by those at the top, and the creation of insurance schemes to protect against technological redundancy.

Organisations will need to plan how to integrate AI into their workforces and understand where it will be of greatest benefit and how it complements the human workforce. There is great potential for humans and AI to work together, for example the way that IBM's Watson enhances the diagnostic capabilities of medical professionals rather than just replacing them.

AI can also improve the effectiveness of individual workers by acting as a personal assistant e.g. a conversational robot advising a shop worker to help answer a customer's questions. It also has a role to play in innovation, enhancing the generation of ideas and creativity of humans across all sectors.

There will, however, be new demands on education systems to equip children with the right skills and qualities for a future in which many of today's jobs will not exist.

Equality of access

At present it is not entirely clear whether AI technologies will be fully democratised and accessible to anyone who wishes to use them, or whether there will be significant barriers to entry for those outside mainstream business. The business landscape could be dominated by a few small players who capture most of the value, or could open up platforms to enable innovation and value creation by start-ups and experimenters. As with many emerging technologies, the military are one of the early adopters, meaning those countries with larger defence budgets may benefit from early applications.

Technical Considerations

Whilst AI is now a commercial technology, there are still significant technical challenges to overcome in order to fulfil its potential.

Learning to learn

The use of the term intelligence often leads to misconceptions about the capabilities of AI and risk of anthropomorphism (assigning human-like traits and behaviours to non-human things). Much of the AI technology available today learns or optimises its activity to specific goals, and so is only capable of doing what it is told. Its capabilities reflect the training data and its quality, and the design of the AI processes. Typically there is still a need for human involvement to handle exceptions.

That means AI in its current form is narrow and specialised to work specific applications and the processes and programs it follows are non-transferable.

The Google Deepmind applications that triumphed against the best human players of the board game Go! could not beat even an average human player at chess.

The major change will come when AI starts to become truly intelligent and able to learn actions that it has not been taught. However, there is no agreement whether this technical milestone is achievable.

Unknown unknowns

Another technical challenge that will have to be overcome is the comprehension gap with what humans can themselves understand. The internal workings of AI systems are often not transparent and it can be difficult for humans to understand how AI learning systems have arrived at their conclusions. To combat this, designers and observers have discussed requiring a certain level of explanatory logic in AI systems, to allow for the checking of errors and for humans to learn and understand in parallel.

Enabling New Business Models

AI has the potential to solve problems that humans and current systems cannot

AI's capability to create new insight, to learn, and to automate tasks on a large scale has huge potential to transform industries and how businesses work, improving efficiency, effectiveness and speed.

AI can make business models more efficient by taking on responsibility for more routine work, which has well-defined goals, at lower cost. It can also augment human capabilities with expertise such as the way IBM's Watson's supports oncologists by providing analysis of a breadth of research that no human doctor could ever hope to read.

Specific applications could include:

- Advances and breakthroughs in medical research, material sciences and energy technologies
- Automated monitoring and analysis of the environment, satellite imagery
- Automation of vehicles reducing pollution and traffic deaths
- Intelligent automated supply chains - reducing waste and driving efficiency.

AI technologies are closely associated with data science and analytics and much of the impact on business models will come from new approaches to securing insight from large and often unstructured data. Increasingly sophisticated AI algorithms will often be able to function without human intervention allowing existing business models to be fine tuned and streamlined.

Many of these algorithms can already be found in investment banking and high frequency trading. Future examples where they could be applied include the optimisation and balancing of energy usage, both in consumer and industrial settings, and the potential for reduced waste and fuel usage.

Artificial intelligence will enable a number of the disruptive business model levers identified on the Project Breakthrough website, specifically:

A more personalised product or service

AI will allow the creation of highly personalised products and services, based on deep customer insight from multiple datasets, and learning of preferences over time.

A closed-loop process

AI will allow more effective and efficient production and consumption to be designed and managed, at a scale and complexity that is beyond existing approaches.

An agile and adaptive organisation

AI will allow organisations to make more sense of the data they have about their customers, markets and operations, and to anticipate how best to adapt and respond to changing needs.

More Examples...

Helping game keepers identify where poachers could strike

<https://news.nationalgeographic.com/2016/06/paws-artificial-intelligence-fights-poaching-ranger-patrols-wildlife-conservation/>

Helping refugees find trusted information using a smart phone

<https://www.theguardian.com/public-leaders-network/2016/oct/17/refugee-information-facebook-social-media-tech-help>

Building an AI Doctor to diagnose illnesses

<https://www.babylonhealth.com/>

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Disruptive Technology Executive Briefs

NEW REALITIES

Discovering the virtual world

New realities describes a collection of technologies that change how we view and interact with our own world and how we create immersive experiences in new worlds. The most well-known of these are virtual reality (VR – a completely digital environment) and augmented reality (AR – where digital images are superimposed on the real world). However, the evolution of the technology means that new areas such as mixed reality (MR) are also beginning to have a disruptive effect. MR is a sub-set of augmented reality where the real and virtual worlds merge to produce visualisations where physical and digital objects interact in real time.

The technology

The technology underpinning the realities themselves is not new but the computing power has only recently become available to make them truly commercially viable. New realities are typically accessed through head-mounted displays (HMDs) though, in the case of AR, these can be provided through a device with a camera and display screen, such as a tablet or phone.

The potential

The real excitement surrounding new realities is in their potential to succeed today's mobile devices and become the dominant medium through which people interact

with technology. It also has the potential to significantly improve technologies such as videoconferencing, telepresence and remote collaboration. While these are in use today, many have failed to live up to their initial hype.

VR and AR both enable new kinds of experiences and platforms for collaboration and interaction. In future it will be possible to carry out many of today's business and leisure activities inside virtual spaces. An early example from the commercial world is the use of VR by architects or property agents to provide consumers with virtual tours of buildings. AR technology is also being used in the manufacturing sector for product training and field engineering services, helping in the installation and maintenance of equipment.

The barriers

The current generation of HMDs are rather bulky and uncomfortable to wear for prolonged periods. There are also concerns about the psychological and health impacts that may arise from long exposure to highly immersive virtual environments. A further barrier to adoption is the cultural sensitivities around the use of HMDs in public places, as seen in the widespread rejection of GoogleGlass due to privacy fears.



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Some Example Applications...



AR in medicine

Two thirds of the world's population don't have access to safe surgery. Proximie is helping the lack of access to specialists in developing countries by providing a rich and interactive augmented reality platform to train, guide, and support surgeons. It allows specialist surgical training to be delivered globally, and is enabling specialist surgeons to provide expert support to guide procedures in conflict zones.

AR in maintenance and engineering

Israel relies on desalination for 80% of its drinking water. Keeping the equipment in the desalination plants running 24x7 is critical for Mekorot, the nation's water supplier, as the length of time from sea to tap is only three hours. Through the use of AR, Fieldbit have helped made Mekorot's field service engineers more efficient and effective. Field engineers now have access via smart glasses and a mobile app to experts and vendors anywhere in the world. They can see exactly what the

engineer is seeing and provide targeted guidance, sharing messages and superimposing markings and diagrams directly to the engineers field of view. This has improved the rate of first time fixes, enables more effective diagnostic and dispatch of replacement parts rates, increasing the overall speed of recovery and reducing equipment down-time. It is also enabling a resource library of protocols for complex fixes to be developed which is changing how they train and develop of engineers.

AR for workers with intellectual disabilities

Wireless Reach and the Vodafone Spain Foundation collaborated to provide customisable mobile AR applications for workers with intellectual disabilities. The applications included step-by-step training guides, multimedia tutoring materials and access to other work-related information. These helped them work successfully, increased their autonomy and advanced their careers.

Key Numbers

\$162 bn

Estimated market size by 2020 (AR and VR)

Source: Statista

5 bn

Estimated amount of AR applications on mobile devices in 2019

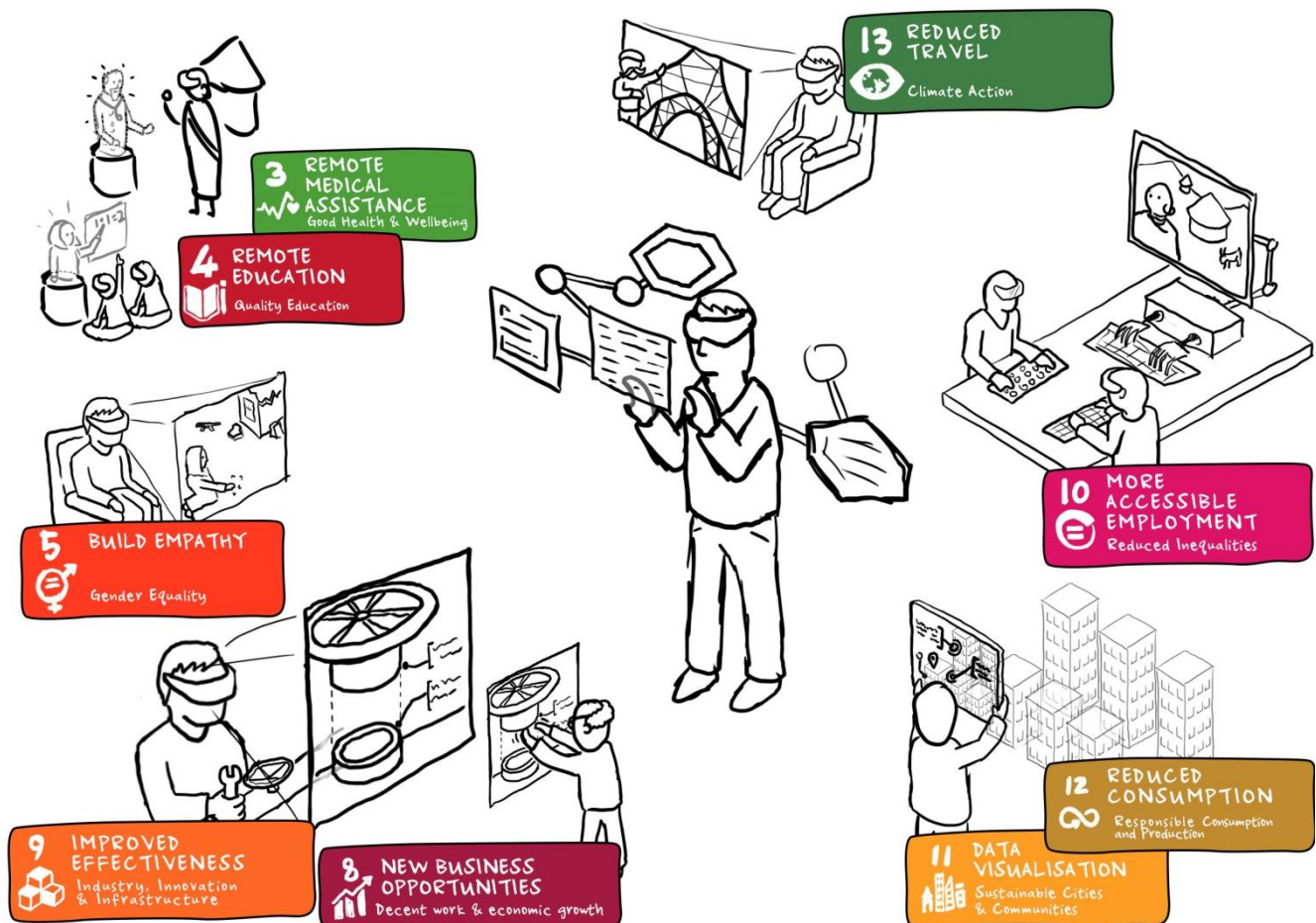
Source: Statista

760%

Increase in the number of AR/VR specific systems shipped between 2016 and 2020

Source: Statista

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New realities have the potential to advance many of the SDGs. Below are some examples of areas of application across a wide variety of sectors.

■ SDG 3 Good health and wellbeing

- Make virtual reality mental health treatments for disorders such as PTSD, anxiety and phobias accessible to the many.

■ SDG 4 Quality education

- Provide education and training remotely to learners in remote locations, in practical and immersive ways that lead to better outcomes.
- Allow access to education by leading experts irrespective of location.
- Enable on demand learning at the point and time of need.

■ SDG 5 Gender equality

- Promote equality and build empathy through creating shared immersive experiences and the ability to "see the world through another's eyes."

■ SDG 8 Decent work and economic growth

- Drive economic growth through effective collaboration regardless of location, bringing together the right skills and knowledge.
- Allow access to expertise and know-how to be shared regardless of location.
- Build empathy and trust across distances and cultures through rich telepresence experiences, opening up new markets.
- Create new business opportunities in the entertainment and leisure sectors.

■ SDG 9 Industry, innovation and infrastructure

- Provide rich virtual environments for remote working that allow effective team working and collaboration.
- Improve effectiveness and speed of design and development through shared visualisations of products and services.

■ SDG 10 Inequality

- Reduce the importance of proximity for certain types of economic activity and partially mitigate existing regional economic imbalances.

■ SDG 11 Sustainable cities and communities

- Reduce the overall need for travel by substituting physical presence for telepresence.
- Boost awareness and appreciation of the world's cultural and natural heritage through virtual tourism.
- Reduce the need for physical signage in cities and provide immediate dynamic information relating to the environment.
- Test responses and engagement with new urban designs in virtual reality before starting building.

■ SDG 12 Responsible consumption and production

- Enable cleaner factories through visualisation and instant feedback with AR.

■ SDG 13 Climate action

- Significantly impact climate change through a reduction in travel.
- Encourage better stewardship of the natural environment on land and sea through immersive campaigning and better education.
- Reduce the need to travel through the use of high quality and immersive VR and AR technologies in business and social / tourism contexts.

Potential Negative Impacts and Barriers

Just as the potential benefits for New Realities are still being explored, so too are the risks:

Health

Some potential health risks have been identified with the widespread mass market adoption of virtual reality. These include the risk of addiction and increased social isolation for those who choose highly realistic and immersive virtual experiences over participation in their society and communities. There are also some fears that prolonged use of VR could damage eyesight, and some users experience nausea and motion sickness.

Privacy

AR devices generally require always-on cameras and other sensors that can lead to privacy concerns. The backlash against the use of Google Glass in public places was evidence of this.

Access

High-end HMDs required for both VR and AR applications are currently quite costly and remain out of reach for a consumer mass market, although popular alternatives are HMDs that incorporate a phone or phablet such as Samsung's Galaxy Gear, or the low-cost Google Cardboard. As with many technologies, ensuring that it does not create significant divisions between rich and poor will be a key concern.

Fake news

The use of immersive experiences in journalism offers the potential to bring stories to life powerfully and allow experiences to be shared and to build empathy. However, it also has the potential for misuse, manipulation and as a tool for creating polarising propaganda.

Technical Considerations

Whilst advances in computing power have allowed new reality technologies to be viable commercially, there are still technical barriers to wide-spread adoption.

Size and comfort

Many of the augmented reality and virtual reality HMDs available today are quite bulky and can become uncomfortable if worn for prolonged periods. This is less of an issue for VR, where usage is often in benign environments such as home or office, but is crucial for AR where the focus is on use in a wide range of physical environments and workplaces. Creation of a convenient, non-bulky HMD that can be worn constantly remains a considerable technical challenge. Ensuring a big enough field of view is another technical difficulty in current

devices that are restricted to smart-phone sized screens. This is a particular issue for AR as when it is close to large objects they can only be partially viewed.

Computing power

Virtual reality, in particular, demands very high specification computer hardware to run (often a PC optimised for gaming) and the HMD is usually tethered to the computer, limiting movement. Most manufacturers are seeking to cut this physical link in future products and costs are likely to decline substantially over coming years, increasing access to higher end technology. Lower cost VR and AR technology has benefited from the innovation in processing chips and displays from the dramatic growth in smart phone evolution over the past five years.

Enabling New Business Models

New reality technologies have wide ranging impacts across sectors and value chains. This is particularly true in areas where remote collaboration is required and in education, visualisation and simulation.

VR in particular is already being used within business and industry and examples of applications include:

- Virtual tours of a business environment or workspace and the simulation of architectural designs that allows architects and builders to experience a building before is constructed
- VR and AR training for new and existing employees
- On-the-job expert support for remote and field force employees
- 360 degree views of a product for marketing
- Immersive simulations to gauge human performance, sentiment and to identify risk
- New forms of entertainment and leisure activities.

Many businesses have embraced VR as a cost effective way of developing a product or service. For example, it enables them to test a prototype without having to develop expensive physical versions. It is also a good way of detecting design problems at an early stage, when they can be rectified more cheaply than if they are uncovered later.

AR applications are also emerging in supply chain management. SAP has developed a warehouse operations systems that use smart glasses from Vuzix to provide real-time data about products and materials. While the impact may be small in the short term, the cumulative effect of reduced inefficiency could bring substantial overall improvements.

The relatively low cost of new reality technologies and computing power mean that there are opportunities for start-ups to come up with innovative applications and use cases, and bring these to a global market through internet enabled distribution platforms.

New realities will enable a number of the disruptive business models identified on the Project Breakthrough website, specifically:

A more personalised product or service

When coupled with other technologies such as AI, new realities will provide personalised experiences to meet the needs of individuals, whether that be for education and training, coaching and support, or entertainment.

A collaborative ecosystem

New reality technologies enable organisations to collaborate in virtual environments, regardless of location, and will enable team working.

An agile and adaptive organisation

New reality technologies will allow organisations to design new products and services more rapidly, and explore how consumers might engage with them.

More Examples...

Treating the global mental health crisis with virtual reality therapy

<https://techcrunch.com/2016/01/06/virtual-reality-therapy-treating-the-global-mental-health-crisis/>

Inspiring action to end polio for ever with VR films

https://www.inition.co.uk/case_study/virtual-reality-films-inspire-action-ending-polio-forever/

Bringing Augmented Reality to Heavy Industry

<http://www.engineering.com/AdvancedManufacturing/ArticleID/11264/DQRI-Smart-Helmet-Brings-Augmented-Reality-to-Heavy-Industry.aspx>

TECHNOLOGY THAT AFFECTS OUR WELL-BEING

Gene Editing

The Microbiome

Digital Agriculture



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GENE EDITING

Unlocking the power of biology

Gene editing changes the genetic material (DNA or RNA) of a living cell. It uses a range of different methods and techniques to add, subtract, or replace individual genetic bases and sequences. In medicine, the process of gene editing has enabled the in-depth study of diseases, allowing clinicians and researchers to understand their root causes. This focus on causes as well as on treatment is the most important aspect of gene editing.

While gene editing has primarily been seen as a medical technology, it also has exciting uses in many other fields including agriculture and biofuels where it can create strains of crops or algae that are more resistant to diseases.

Gene editing is a controversial technology as it impacts the building blocks of life, often raising public concerns. However, its increasing use cannot be ignored and awareness of its applications is essential if possible negative impacts are to be managed.

The technology

The leading technology, CRISPR (clustered regular interspaced short palindromic repeats) is a highly cost effective gene editing technology (estimated, by Professor James Haber, Brandeis University, to be 150 times cheaper than other leading technologies). It is

also easy to use requiring less training and education than other technologies. The use of CRISPR makes it possible to locate and edit specific spots on any DNA by disabling or knocking out genes, patching in a new gene, or replacing an existing gene.

The potential

In the short term, gene editing technology could be used to edit T-cells (white blood cells critical to the immune system) to better recognise cancer, or to edit immune cells to mimic a rare, naturally occurring immunity to HIV. This could turn these often terminal conditions to chronic or curable ones.

In the longer term, this work could identify and cure debilitating genetic disorders by editing these defects out of the patient's DNA entirely. This would mean they would never become ill from a known genetic cause.

The barriers

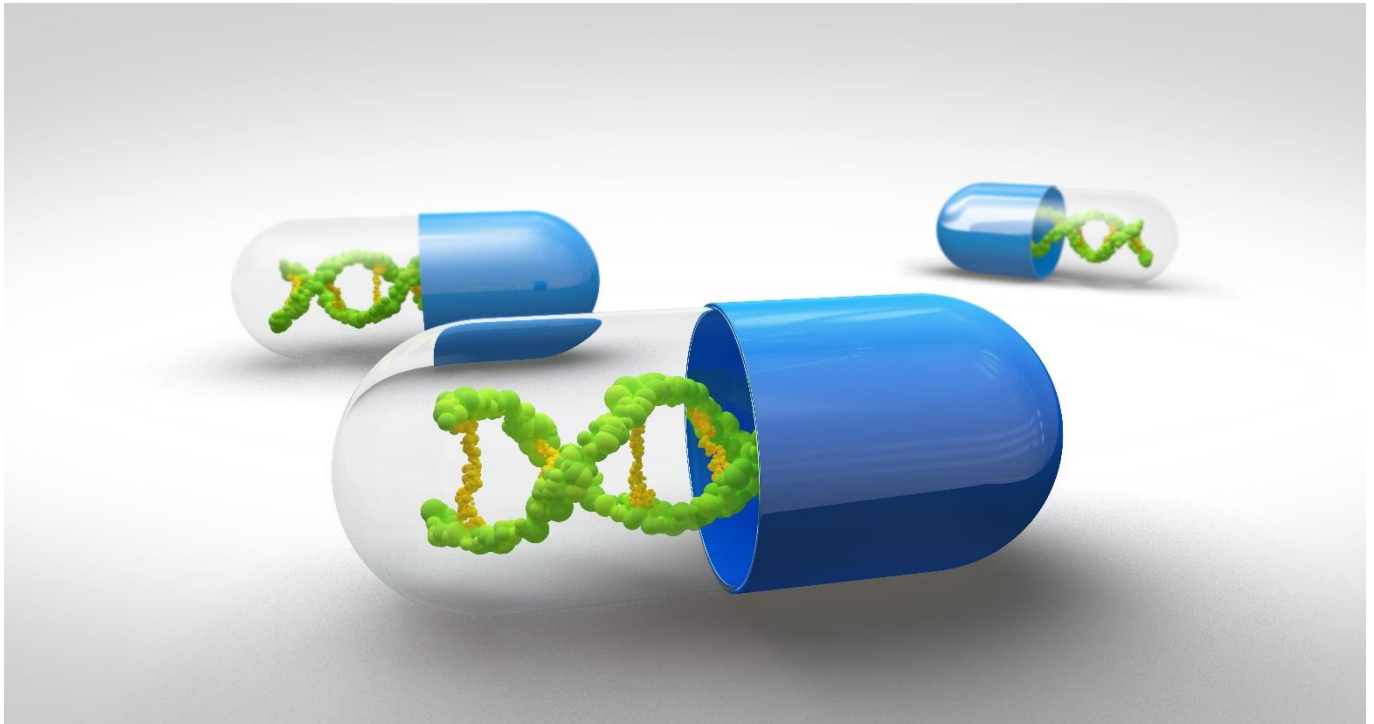
By directly editing DNA this technology has the ability to pass traits on to future generations, and the potential to cause irreversible harm to human health and the environment, whether as the result of intentional misuse or a lack of understanding. For this reason, risks need to be understood and mitigated in order to enable safe adoption and positive benefits.



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Some Example Applications...



New cures for diseases

One interesting example of the potential applications of gene editing comes from a series of experiments performed by the Salk Institute in California. In this study, scientists were able to partially restore the vision of blind rats suffering from the genetic condition retinitis pigmentosa. Genetic diseases in humans, such as cystic fibrosis or muscular dystrophy, could potentially be treated in much the same way.

Another factor which has excited scientists is the precision of gene editing. Unlike pharmaceutical or surgical treatments it focuses only on the affected genes, it does not affect healthy cells or tissue.

Agriculture

CRISPR has the potential to significantly impact agricultural productivity, to benefit of the developing world. In 2016 the first vegetables altered with CRISPR technology were eaten at Umea University, Sweden. The fact that no genetic material is added (unlike some traditional genetic modification techniques), and it is a far more targeted and accurate approach, means CRISPR offers a potential way to address many concerns in this area.

Biofuels and polymers

The University of California have adapted CRISPR technology to develop a yeast strain that enables the production of new precursors of biofuels and polymers. This could provide a more affordable, renewable source of fuel and specialty polymers.

Key Numbers

\$9.5 bn

Estimated market size in 2025

Source: Markets and Markets

\$24 bn

Size of advanced global biofuels market by 2024

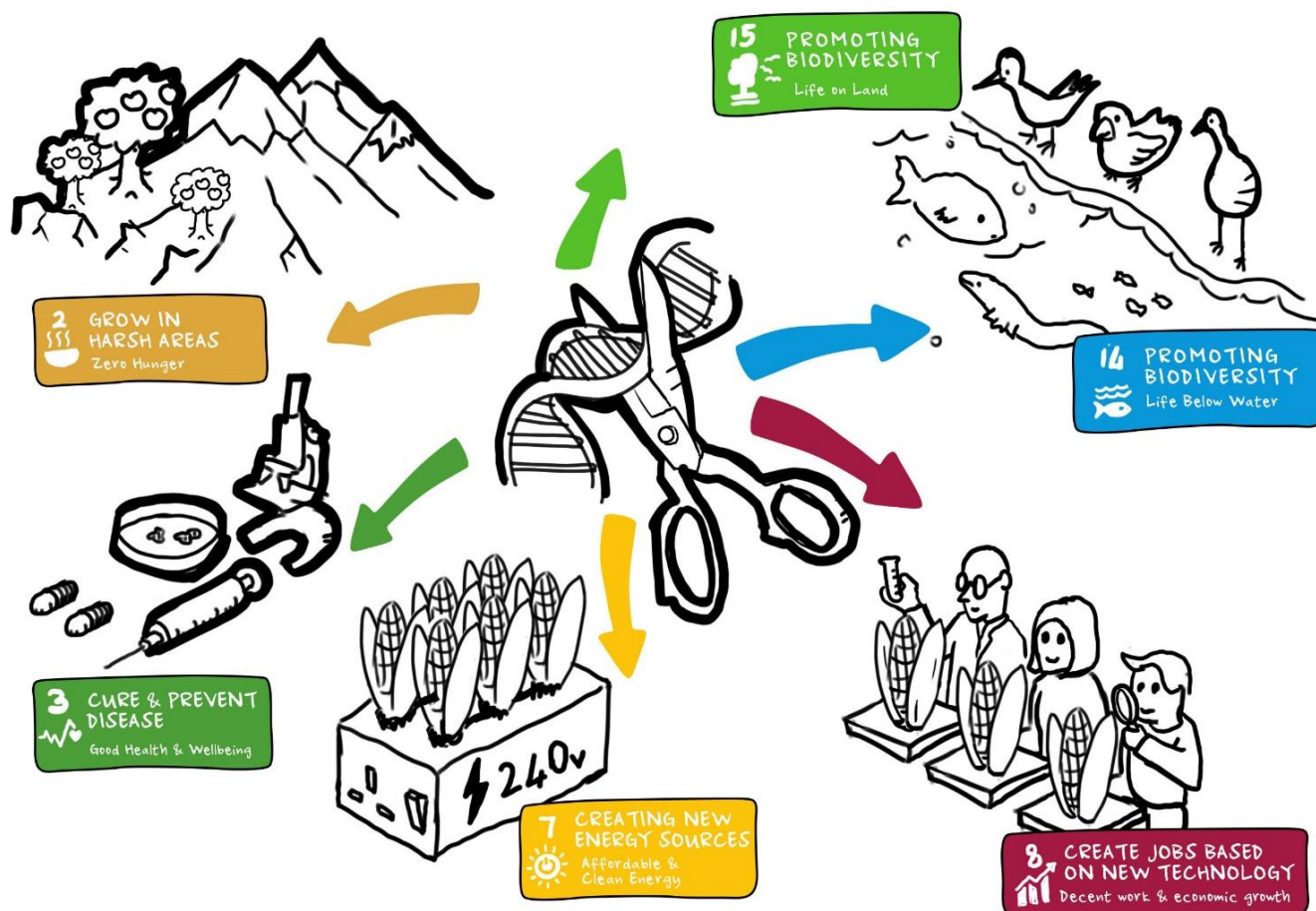
Source: Allied Market Research

\$1.3 bn+

Estimated start up financing in 2016

Source: CB Insights

Advancing the Sustainable Development Goals (SDGs)



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Gene editing has the potential to advance many of the SDGs. Below are some examples of areas of application across a wide variety of sectors.

■ SDG 2 Zero hunger

- Improve the ability of crops to grow in resource-limited areas.
- Manage the stock and productivity of livestock in a humane and ethical manner.

■ SDG 3 Good health and wellbeing

- Cure or prevent diseases rather than treat symptoms, which is the current focus of most modern medicine. This has the potential to fundamentally transform how care is delivered.
- Personalise care to patients. Within the wider movement towards providing genomic medicine, analysing an individual's genetic make-up can identify if a patient will respond well to a drug treatment, and allow focused interventions which minimise unpleasant or harmful side-effects.
- Use of gene editing to fight diseases associated with aging.

- Bring in a new class of treatments for debilitating diseases.
- Enable new advances in drug development by modifying more complex organisms to produce new proteins that can be used as medicine (for example insulin).

■ SDG 7 Affordable and clean energy

- Create new energy sources by enabling organisms to produce a biofuels such as bioethanol more efficiently. This will help reduce the reliance on non-sustainable or environmentally damaging energy sources such as fossil fuels.

■ SDG 8 Decent work and economic growth

- Create new jobs through a range of new start ups and products/service businesses based on this technology. As with any new industry, most economies are starting from a similar place, so the developing world has a great opportunity to enter this industry at a similar point to many developed countries.

■ SDG 14/15 Life on land/below water

- Support biodiversity in both areas.

Technical Considerations

Since the technology is in its early stages, there are still a number of technical challenges to be overcome to make it safe and viable. Some of these are outlined below.

Accuracy

In order to ensure that a gene editing treatment is successful, it requires the correct editing of a very specific gene or set of genes. If the mutation misses the intended target, it could lead to cancer or other serious health problems. Although CRISPR has been developed in order to minimise these effects, even low levels of unintended change can have significant detrimental effects.

Delivery mechanism / immune response

The gene editing enzymes need to be delivered to the correct cellular location in the body whilst also avoiding immune responses and disruption to DNA. A number of techniques are being developed to do this but the human immune system makes it difficult for doctors and researchers to successfully deliver the gene editing enzyme to the proper location without being destroyed.

Scale up

Given the specificity of these potential treatments, off-the-shelf solutions may be less efficient. This means more effort will be needed to test each individual treatment option before it can be used. This creates significant hurdles for large scale production before widespread adoption is possible.

Enabling New Business Models

Gene editing can vastly increase efficiency as well as create new markets and opportunities.

Gene editing will have an impact across the healthcare value chain, from innovative approaches to the development of drugs and novel treatments, to re-evaluation of clinical trials, and disruption of the traditional prescription infrastructure to deliver personalised treatment options. It will also raise questions about where treatment is delivered - hospitals or outpatient facilities - and by whom - doctors or highly trained gene editors.

The ability to cure diseases rather than just treat symptoms will disrupt the business models of the healthcare and the pharmaceutical industry. A reduced need for long term treatment of diseases will lower demand for traditional drugs. The need to recoup the R&D costs of developing fast-acting cures will then have a lasting impact on commercialisation approaches, pricing strategies and how insurance companies reimburse treatment.

This potentially challenges the traditional structure of pharmaceutical companies. The ease-of-use and low-costs associated with treatment techniques as a result of gene editing could lower barriers to entry, and lead to the rise of 'garage biotech' where amateur scientists

develop innovative, complex potential therapies. There will also be new business opportunities for providers able to meet the need for cells with specific mutations and other adjacent services required for complex treatments using gene editing.

Gene editing will enable a number of the disruptive business model levers identified on the Project Breakthrough website, specifically:

A more personalised product or service

Gene editing will allow treatment to be personalised to individuals, based on their genetic make-up. This potential will have implications for how treatments are developed, approved and distributed. For example, since off-the-shelf solutions will not work, pharmacies as we know them will no longer be necessary unless they adapt to meet the need to deliver personalised treatment options.

Usage based pricing

The ability to cure or prevent rather than manage symptoms may make outcome based pricing a more attractive and effective mechanism for both providers and purchasers, rather than the current volume based models.

More Examples...

Using CRISPR Technology
to modify crops

<https://www.pioneer.com/home/site/about/news-media/news-releases/template.CONTENT/guid.95ED9999-5719-1E79-8DA3-CE9A62C58CA2>

Gene Editing successfully
used on girl with leukemia

<https://www.newscientist.com/article/dn28454-gene-editing-saves-life-of-girl-dying-from-leukaemia-in-world-first/>

CRISPR used to create
oil producing yeast

<https://www.sciencedaily.com/releases/2016/01/160126162324.htm>

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THE MICROBIOME

Our microscopic allies

The human microbiome is all the genetic material from the microbes - bacteria, fungi, protozoa and viruses - that live on and inside the human body. The microbiome benefits human health through vitamin production, provision of nutrients and educating and training our immune system.

The idea of using bugs instead of drugs and chemicals is not new, with probiotic yoghurts common place. However, ongoing research is just starting to unlock the potential of this treatment, with startling results being seen across chronic diseases and mental health.

The bacteria, known as microbiota, also play a critical role in animal and plant health and ecosystems. The microbiota of the soil can help create disease resistance in plants and allow them to extract more nutrients from the soil.

The technology

The Human Microbiome Project, which has sequenced 300 individuals' microbiomes, has brought real insights into what they do and how they can affect human disease and health.

Improvements in DNA sequencing technology can identify the indicators of a healthy microbiota. Deviations can then be tracked to understand an individual's risk of disease at different points in their life. This means personalised treatment through precise modification of an individual's microbiota may soon be achievable.

The potential

Looking to the future, the microbiota will increasingly be used to tackle and prevent many diseases including those in crops and chronic human illnesses. The role of the microbiota in health is leading to new insights into diseases and providing ways to uncover new targets for drugs and ways to use bacteria to treat infection.

The barriers

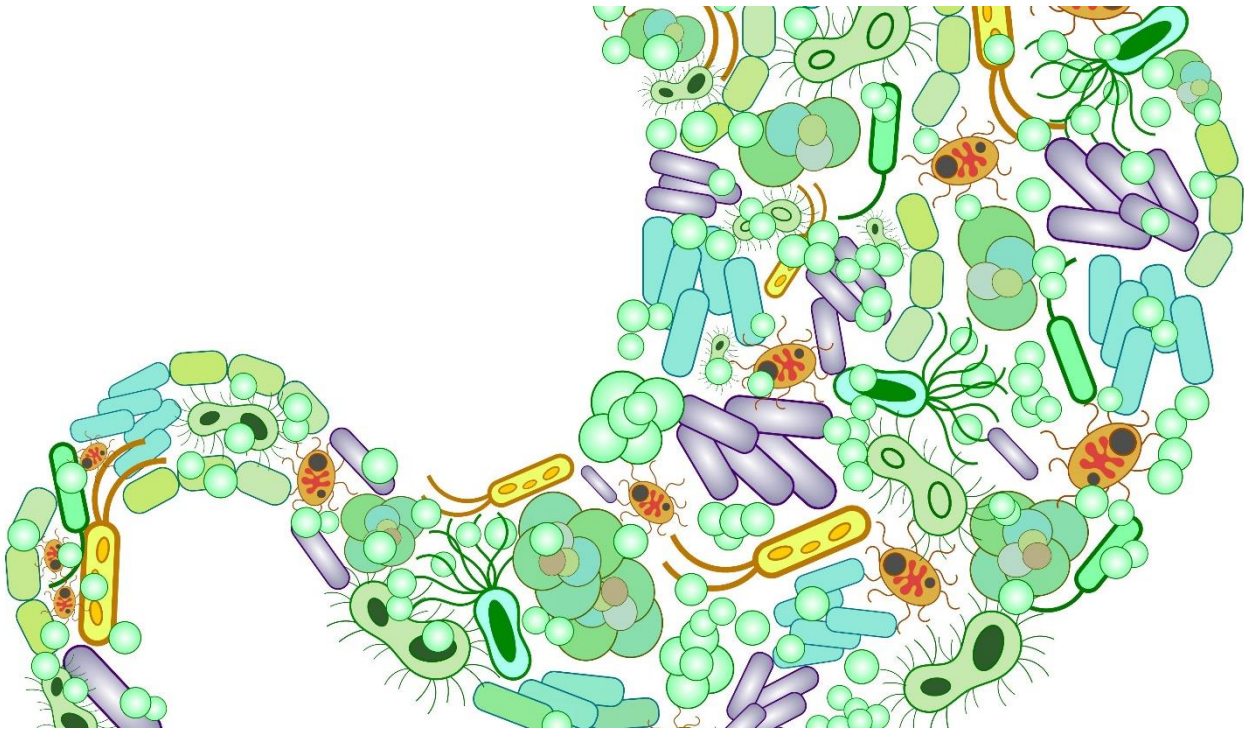
With an ever growing antibacterial culture, we are isolating ourselves from the good microbes as well as the bad. In some cases this is leading to their extinction and we do not yet understand the impact. That means education and public perception will be key to ensuring the potential of the microbiome is realised.



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Some Example Applications...



Bugs as drugs

The Wellcome Trust Sanger Institute is working to create a pill full of bacteria that will restore a healthy gut microbiota where the balance between healthy and unhealthy bacteria has been disrupted. One example is where unhealthy levels of have grown. When *C. difficile* bacteria levels increase this is an example of where serious health problems can occur. It is very difficult to treat with antibiotics and the pill will provide a simple and accessible way to put micro-organisms into intestine of a sick patient that can combat the infection. The approach of replacing gut bacteria has shown to be successful in more than 90% of examples, in some cases saving lives.

Agriculture and climate change

Research into soil microbiota has shown how some species can enhance plant defences against infection. However, other species can cause problems and Rothamsted Research found one strain of bacteria removed nitrogen from the soil. This depleted the nutrients needed for plant growth and created greenhouse gases. That underlines the need to develop a clear understanding of the impact of soil microbiota.

Mental health

The American College of Neuropsychopharmacology has acknowledged the strong scientific link between gut bacteria and mental health. This is opening up a whole new avenue of potential treatments to help conditions such as bipolar disorder.

Key Numbers

\$71.7bn

Estimated market size in 2023/4 for Pro/Prebiotics

Source: Global Market Insights/Grandview Research

2321

Microbiome patent applications (2011-16)

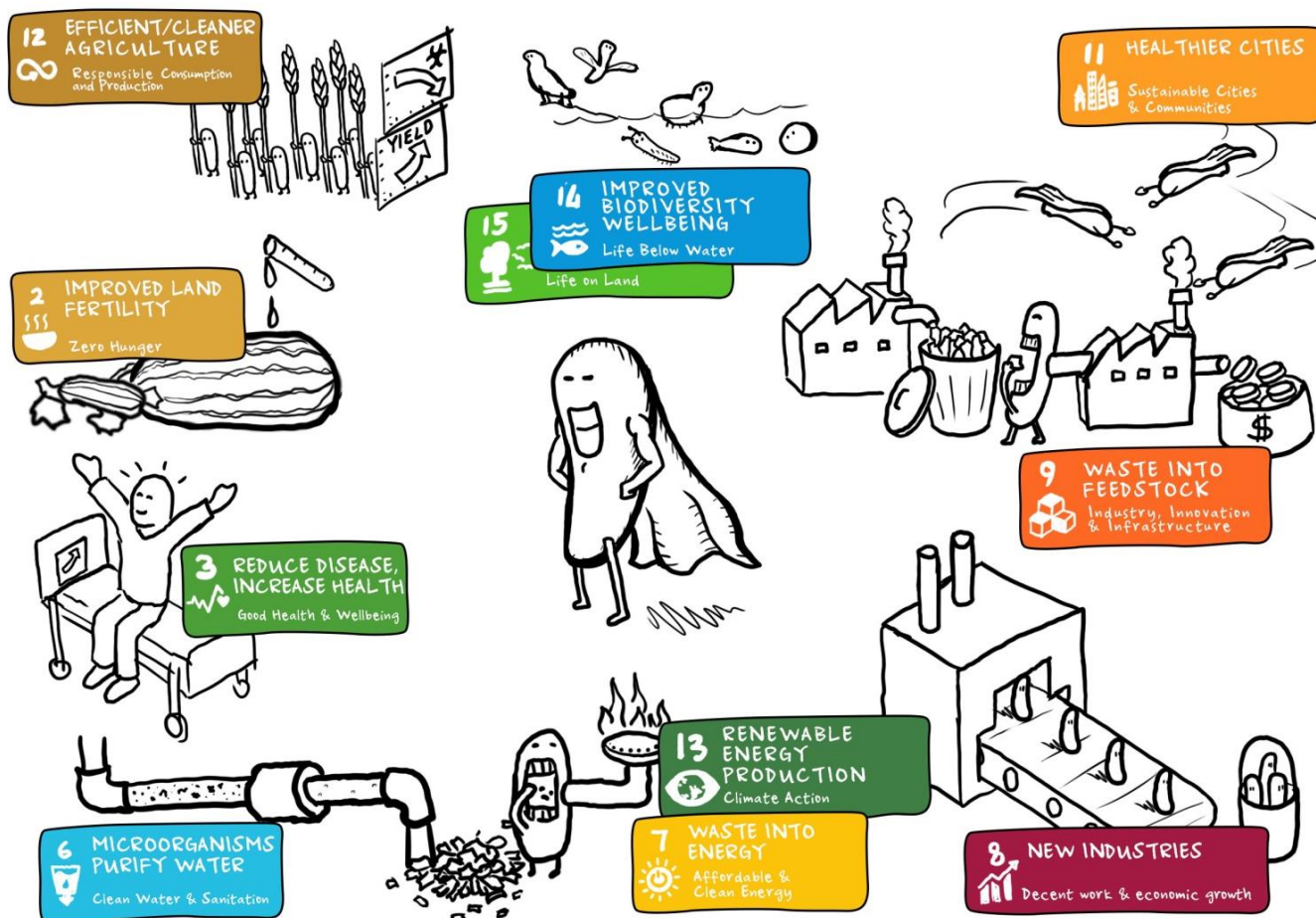
Source: Frost and Sullivan

106

Ongoing projects from discovery to clinical trials

Source: Intellisness

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The microbiome has the potential to advance many of the SDGs. Below are some examples of areas of application across a wide variety of sectors.

■ SDG 2 Zero hunger

- Improve the nutritional value of food and reduce the susceptibility of crops to disease, enhancing yields.
- Improve the fertility of land, including nitrogen fixation, to convert it into arable land in a variety of environments.
- Improve an individual's microbiota so they can get more nutrients from the food they consume.

■ SDG 3 Good health and wellbeing

- Optimise a person's microbiota to reduce their risk of illness including infectious and chronic diseases.
- Use the microbiota to help identify new biological targets for the discovery of new therapies, new antibiotics and other anti-microbial molecules that bacteria use.
- Use 'bugs as drugs'.

■ SDG 6 Clean water and sanitation

- Micro-organisms to purify the water in rivers, streams and lakes.

- Reduced nutrient run off from agriculture through using biofertilisers to reduce pollution.

■ SDG 7 Affordable and clean energy

- Biofuels from non food products such as abundant but underused lignocellulose (biomass) and greenhouse gases e.g. carbon monoxide and carbon dioxide.

■ SDG 8 Decent work and economic growth

- New technologies across a range of industries to create new jobs and new businesses.
- Make new or improved industries. One example, would be helping to create arable land and energy production opportunities in countries that are resource poor.

■ SDG 9 Industry, innovation and infrastructure

- Innovation to overcome the significant technical challenges in understanding and implementing this technology.
- Products that will create new and advanced industries including in healthcare and chemicals.
- Sustainable industries that use waste and unwanted products from one part of the economy and convert them into useful products e.g. the use of greenhouse gases to create biofuels; the reduction in fossil-fuel based agricultural chemicals in favour of beneficial micro-organisms.

■ SDG 11 Sustainable cities and communities

- Exposure to a wider more diverse microbiota than typically exists in urban areas as this may link with human health and disease.
- Urban farms that use micro-organisms to enable crops and plants to grow.

■ SDG 12 Responsible consumption and production

- Agrichemical industry using fewer chemicals, reducing waste, nutrient run-off, pollution and clean-up.
- Conversion of waste products and underused products to useful products such as biofuels.

■ SDG 13 Climate action

- Improved soil microbiotas using micro-organisms that do not give off greenhouse gases.
- Reduced use of fossil fuels for chemical and energy industries, using micro-organisms to produce biofuels.
- Use of micro-organisms to reduce waste greenhouse gases and make useful products.

■ ■ SDG14/15 Life above land/below water

- Reduced pollution with new bio products and manufacturing methods, and increased ability to clean up water.
- Use of microbiota to preserve biodiversity and wellbeing of many other species.

Potential Negative Impacts and Barriers

Society has become increasingly concerned about germs and this attitude is having an impact on the use of microbiota:

The anti-bacterial balance

The increasing use of hygiene products such as anti-bacterial hand wash is reducing our everyday exposure to microbes. It is now thought that everyday exposure to different microbial species is important for normal development of the immune system. Without this, the risk of allergic disease is thought to increase - this is known as the hygiene hypothesis.

Microscopic extinctions

The hygiene hypothesis also suggests that changes to the environment and our lifestyle means some species of the microbiota are being eliminated from the environment. Many of these species have co-evolved with humans and it is not yet known what the longer term implications of their disappearance will be for the environment and human health.

Uncontrolled antibiotics

Over-prescription of antibiotics also has a significant impact on our microbiota. However in many societies antibiotics are demanded by patients even for viral infections.

Regulation

Regulation may need to change. Already in the US the FDA has banned certain ingredients in anti-microbial hand gels as they are linked with allergies in children. This will lead to new product development that is more microbiota friendly.

Public acceptance

A change in attitudes towards germs, antibiotics and using waste products as medicine will be one of the most difficult barriers to overcome. Not all microbes are beneficial and providing the right advice and education to help transform attitudes is crucial.

Technical Considerations

Whilst great progress has been made using genome sequencing to identify the individual species making up the microbiota, there is still a lot of work to do understand the functions and health implications both of individual microbes and of the ecosystem of co-habiting microbes:

The 'unculturable'

In order to study the bacteria in our microbiota, it is important to be able to grow or culture the bacteria in the laboratory. This presents many difficulties with many bacteria being perceived as 'unculturable'. However, a number of techniques are being developed which are beginning to tackle this challenge.

The lack of a common baseline

Due to the scale and complexity of the microbiota and because of the unexpected variability between individuals, studies to determine the role of the microbiota in health and disease are challenging.

The circular micro-economy

Species within the microbial ecosystem interact with each other. Certain bacteria produce substances as a waste product which go on to feed other bacteria, creating a mutual dependence within the system. That means understanding the role each species plays in isolation does not give the true picture. The complexity of the system requires powerful analytics, using systems biology and big data to derive more accurate insights.

Safe sampling

Sampling some parts of the microbiota is challenging. For example, a biopsy is needed to understand the microbiota of the small intestine. This is an invasive procedure and carries a risk of internal bleeding. It also can produce inaccurate results as the microbiota varies throughout the intestine.

Other disruptive technologies

In some cases a micro-organism's metabolism may need to be re-engineered for some purposes e.g. advanced biofuels. Other disruptive technologies, such as Gene Editing, will be needed to do this posing a number of technical challenges that need to be overcome.

Enabling New Business Models

An increasing understanding of the role of the microbiota in human health will impact pharmaceutical and biotech companies across the value chain.

The areas likely to see the biggest impact are drug discovery and drug development and manufacture. In addition, new diagnostics approaches will be needed for some microbiota treatments. There will also need to be new ways to provide drugs to patients.

These developments will have an impact on regulatory authorities and healthcare services, particularly through more personalised and precision medicine.

In the agricultural sector, biofertilisers could have a disruptive influence on the agrichemicals business through a reduced need for fertiliser and pesticides. It could also disrupt agricultural practices and increase the amount of land available for growing crops and change the types of crops that can be grown in these areas. This will open up new opportunities for farmers and for start-ups in agricultural technology.

The microbiota offers huge potential for both big businesses and small start-ups to use data from large government projects such as the Human Microbiome Project.

The microbiome will enable a number of the disruptive business model levers identified on the Project Breakthrough website, specifically:

A more personalised product or service

Tailored therapeutics based on an individual's microbiota and genetic profile.

A closed-loop process

Biofertilisers can multiply organically and produce waste products beneficial for the ecosystem, as well as removing or reducing the need for consumption of agrichemicals and disposal of their waste products. The human microbiota can also produce essential vitamins required by the host, reducing the need for the use of supplements.

More Examples...

Analysing people's microbiota to make personalised dietary recommendations

<http://personalnutrition.org/AboutGutTests.aspx>

Biofertilisers function as key players in sustainable agriculture

<https://www.scientificamerican.com/article/microbes-added-to-seeds-could-boost-crop-production/>

Understanding the role of the lung microbiome in respiratory disease

<http://www.gsk.com/en-gb/behind-the-science/innovation/take-a-deep-breath-your-lung-microbiome-will-appreciate-it/>

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DIGITAL AGRICULTURE

Feeding the future

Digital agriculture is the use of new and advanced technologies, integrated into one system, to enable farmers and other stakeholders within the agriculture value chain to improve food production.

Most of today's farmers make decisions such as how much fertiliser to apply based on a combination of rough measurements, experience and recommendations. Once a course of action is decided, it is implemented but the results are normally not seen until harvest time.

In contrast, a digital agriculture system gathers data more frequently and accurately, often combined with external sources (such as weather information). The resulting combined data is analysed and interpreted so the farmer can make more informed and appropriate decisions. These decisions can then be quickly implemented with greater accuracy through robotics and advanced machinery, and farmers can get real-time feedback on the impact their actions.

The technology

Technologies used include sensors, communication networks, Unmanned Aviation Systems (UAS), Artificial Intelligence (AI), robotics and other advanced machinery and often draws on the principles of the

Internet of Things. Each one of these brings something valuable to farming from data collection, through to management and processing, as well as guidance and direction. This integrated system offers new insights that enhance the ability to make decisions and subsequently implement them.

The potential

Digital agriculture has the potential to make agriculture more productive, more consistent and to use time and resources more efficiently. This brings critical advantages for farmers and wider social benefits around the world. It also enables organisations to share information across traditional industry boundaries to open up new, disruptive opportunities.

The barriers

Digital agriculture has the potential to transform the way we produce the world's food but the approach is still very new, costs are high and the details of the long term benefits are rarely available. That means to secure its widespread adoption will require collaboration and consensus across the value chain on how to overcome these challenges.



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Some Example Applications...



Aquaculture

Factors such as contamination from pollutants (washed from the land into the water by rain) and disease have varying impacts on yield. The farming of oysters is one such example of this. The technology company, The Yield, has partnered with Bosch to help Tasmanian oyster farmers manage these challenges using sensors, predictive analytics and a clear user interface. This enables more accurate predictions about when water contaminants are too high or an outbreak of disease is likely so that farmers are able to take proactive steps to reduce oyster loss.

Potatoes and reducing water use

PepsiCo has successfully reduced water input to their potato crop by 26% over the past ten years. One way they have done this is through locating sources of waste

water for re-use in irrigation. They also monitor soil moisture, link this to weather forecasts and set more efficient irrigation levels. This can improve sustainability and water availability in countries at risk from drought.

Lettuces that help kidney disease sufferers

For people with kidney disease, too much potassium in the diet – such as from high-potassium vegetables – is unhealthy. This is a growing issue in countries like Japan where 10% of the population suffer from chronic kidney disease. Fujitsu teamed up with Microsoft and others to grow lettuces with less than 80% of the potassium content of traditionally grown lettuce through carefully controlling growing conditions. This work has both enriched diets and demonstrated how sensors, analytics and data visualisation can create a system to improve agricultural practices.

Key Numbers

\$15 bn

Estimated digital agriculture market size in 2021

Source: Digitising Agriculture, PA Consulting

80%

Of agriculture companies surveyed expect a competitive advantage from digitising agriculture

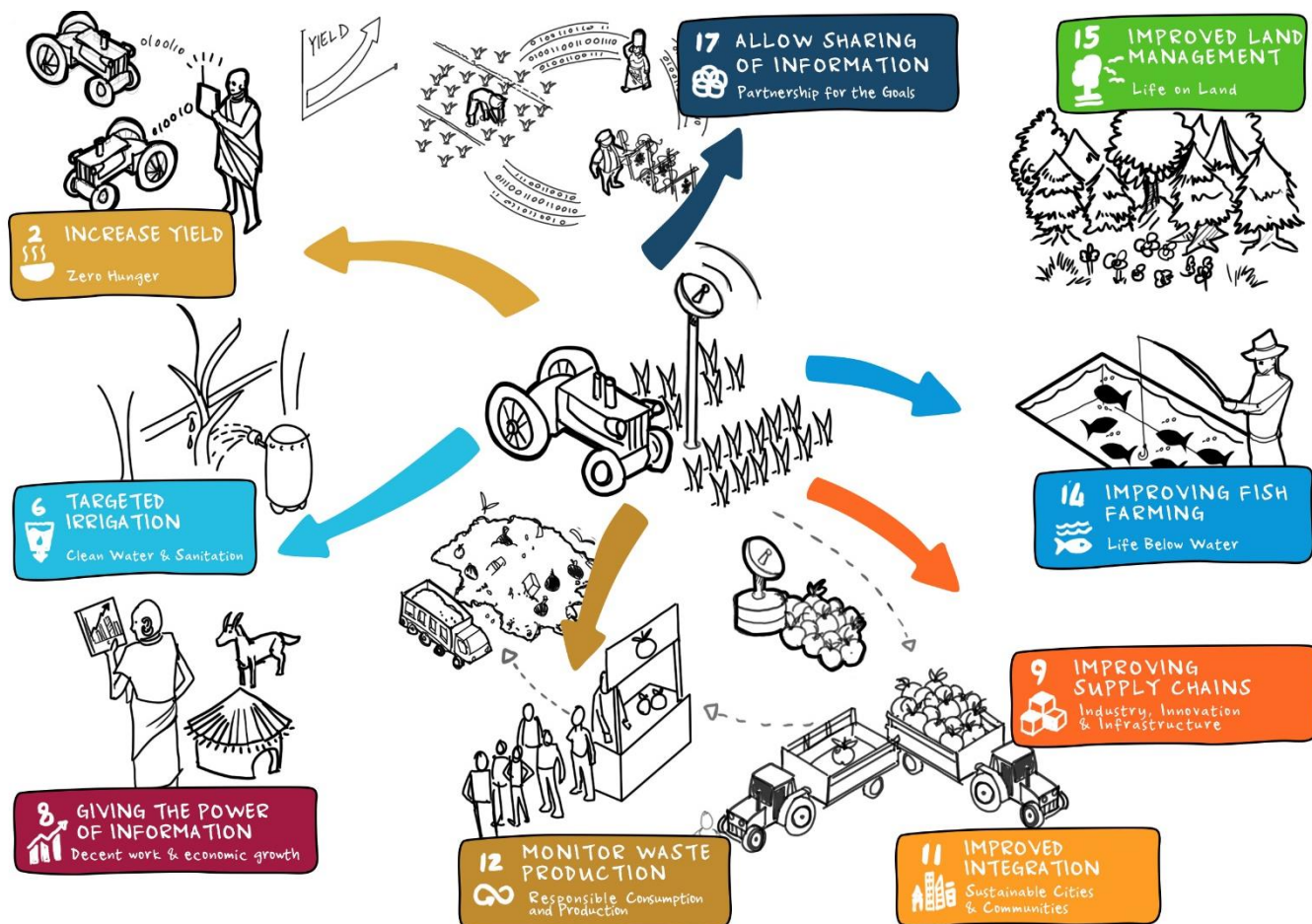
Source: Digitising Agriculture, PA Consulting

60%

Increase in food supply required to feed the predicted world population in 2050

Source: Food and Agriculture Organisation (FAO), UN

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Digital agriculture has the potential to advance many of the SDGs. Below are some examples of areas of application across a wide variety of sectors.

■ SDG 2 Zero hunger

- Make better farming decisions by supplementing local knowledge developed over generations with real-time, detailed, environmental data.
- Increase yield per acre and reduce production loss to help improve food security and increase the food output, required to keep up with population growth.
- Improve transparency and sharing of information. By providing quantitative data on factors that have been difficult until now to measure and interpret, farmers will be able to improve their economic models. Financiers and insurers can also better understand risk to protect farmers financially.

■ SDG 6 Availability and sustainable management of water

- Waste less water through a better understanding of soil moisture, crop health and weather forecasting – provide only as much water to the plants as needed.
- Reduce chemical use and run-off into local water supplies.

■ SDG 8 Decent work and economic growth

- Give more power to those working in agriculture and support related innovations such as up-to-date agricultural pricing and trading – particularly the ability to facilitate trade without using intermediaries.

■ SDG 9 Industry, innovation and infrastructure

- Improve resilience and effectiveness of food / farming supply chains through better integrated systems and information sharing.

■ SDG 11 Sustainable cities and communities

- Enable more sustainable city growth through better waste management as a result of improved integration across the food value chain.

■ SDG 12 Responsible consumption and production

- Provide information which allows consumers to be more responsible.
- Reduce waste through better decision making across the supply chain, using predictions of harvest yields and quality to improve planning.
- Reduce waste in storage through improved planning and by linking agricultural sensors with transport management systems to reduce food spoilage.
- Reduce the chemicals used, and improve long-term soil management through better planned crop rotations.

■ ■ SDG 14/15 Life on land/below water

- Allow increased freshwater fishing by improving water quality with aquaculture technology.
- Reduce chemical run-off contaminating oceans.
- Promote more sustainable land ecosystems through a more considered use of farming land and approach to forestry.

■ SDG 17 Partnerships for the goals

- Allow companies to partner to increase the impact on all the SDGs through improved availability of information.

Potential Negative Impacts and Barriers

As digital agriculture develops, it will be critical to make the technology available to as many farmers as possible and to implement it in ways that minimises negative impacts on those who work in the sector:

Data and Intellectual Property (IP)

The more collaborative, such as sharing of data, the more sophisticated and beneficial the solutions will become. However, there is no clear consensus on how to protect data or IP rights and there is less incentive for already successful parties to develop collaborative technologies that might help their competitors.

Access to data could evolve so that it reinforces inequalities rather than drives collaboration. It is possible that closed platforms and data (rather than open source technology and open data) could create economic barriers that prevent competition and potentially stop the benefits being available to developing markets. Ensuring that information is used in a positive way will be a significant challenge in an area that is not yet widely understood.

Employment impacts

Agriculture and its associated industries remain one of the world's largest sources of employment. Due to the potential of this technology to reduce labour intensity and generate labour savings on farms, the implementation of digital agriculture could cause economic disruption in areas where many people work in the industry.

Security

As with other industries that are becoming increasingly reliant on digital systems, there exists a key security challenge. If agricultural systems are reliant on technology that is not secure enough, an opportunity for large-scale, coordinated agricultural warfare could arise. Hacking control systems to damage crop growth, contaminating feed and water supplies, and manipulating data to conceal issues could all be used to damage yields and threaten the ability of people to feed themselves.

Case for change

Case studies showing the effects of digital approaches on mainstream crops are still uncommon – especially those showing the long term benefits. This makes it difficult to develop business cases that show consistent benefits. Although this is changing, in the short term it may inhibit farmers' willingness to deploy technologies and possibly restrict the ability of individuals to secure investment.

Development costs

Despite falling costs, the initial outlay for development and adoption in large agricultural settings could be prohibitively high, and discourage usage and innovation. Technology must be understood, sourced, deployed, connected and monitored to create an effective system and this one-time cost, especially in an area that is not yet widely understood or proven, may be a significant barrier for some years to come.

Technical Considerations

As digital agriculture is a complex system of technologies, it is essential to clearly define the design and manage the integration of the disruptive technologies that underpin it.

User centric design

It is often difficult for technology companies to understand the farmers' exact needs and to assess how good is 'good enough' for everyday use. In the short term, this may lead to advances which fail to address the key areas of need or deliver over-performing systems which are unnecessarily expensive. Closer links to farmers and other key stakeholders and continuous communication with end-users will help to ensure that the most value is gained from innovation.

Technology integration

The integrated systems of digital agriculture often rely on a number of early-stage, emerging technologies – for example autonomous robotics. The progress in implementing digital agriculture solutions in many areas will be heavily linked to the development of these underpinning technologies.

Connectivity

Integration of digital agriculture systems will require reliable connectivity between fields, data centres, end users and other parts of the supply chain. Reliable connectivity of some form will be necessary to aid ease of adoption but is often lacking in many parts of the rural world.

Enabling New Business Models

Digital agriculture can vastly increase efficiency as well as create new markets and opportunities.

Unlike much of today's farm equipment that is both large and expensive, the continued decline in technology costs and the reduction in the size of devices means that digital agriculture should be substantially more accessible to populations in developing economies. This means the benefits can be felt across the globe and in countries that are simultaneously the most reliant on agriculture yet the most challenging to farm.

Digital agriculture will empower customers by providing information on food history and safety at the point of purchase. It will transform farming through better decision making, more precise management, and automated action through the use of robots and advanced machinery. At its most disruptive, digital agriculture will integrate systems across the supply chain to allow better information sharing between providers, distributors, retailers, consumers and supporting industries.

New companies are already offering products and services based on digital agriculture technologies. However, it is recognised that hardware alone is no longer enough; the key is to integrate this hardware into systems which capture the right data, use algorithms to make that data usable, and direct the use of agricultural hardware. While currently many individual solutions exist, in the future businesses will join these up to create new disruptive approaches.

Digital agriculture will both affect existing business models in the sector and create new opportunities. The greater focus on the end user enabled by some of the technologies, and a continued reduction in price will allow experimentation and enable small-scale local providers to be more innovative and explore new applications. Existing businesses are likely to be disrupted by the desire of consumers to be closer to the farmer and in doing so, remove cost in the process of getting food from farm to fork.

However, no single company seems to have all the capabilities across digital agriculture. This means successful companies will be able to identify their core capabilities and work to build relationships in those areas where they do not have the right skills.

Digital agriculture will enable a number of the disruptive business model levers identified on the Project Breakthrough website, specifically:

A more personalised product or service

Digital agriculture technologies may create demand for personalised services where products are tailored to the requirements of individual farms.

A closed-loop process

Digital agriculture technologies will enable a reduction in chemical usage, a reduction in waste and spoilage, and better matching of demand to supply.

A collaborative ecosystem

Digital agriculture will enable better collaboration across the food supply chain. It will also create opportunities for providers of digital agriculture products and services to the industry.

More Examples...

Fujitsu enrich diets of kidney disease patients by reducing potassium in lettuces

<http://www.iotjournal.com/articles/view?12992>

PepsiCo significantly reduces water use by recycling waste water and only irrigating when needed

<https://www.environmentalleader.com/2016/09/how-pepsico-saved-80-million-by-cutting-water-use-26/>

Urban Farmers are using technology to bring farming to where people live

<http://www.dutchnews.nl/features/2016/04/89233/>

TECHNOLOGY THAT MAKES CONNECTIONS

Internet Of Things

Big Data

Blockchain



United Nations
Global Compact



Project Breakthrough

Disruptive Technology Executive Briefs

INTERNET OF THINGS

Connecting the world

The Internet of Things (IoT) is set to transform our lives just as profoundly as mobile communications and the World Wide Web have done in recent years.

We are just beginning to see the benefits that IoT brings from having a better understanding of the world around us. The combination of connected sensors and cloud computing platforms means virtually any physical object can be connected to the internet. This will support our ability to make decisions, as 'things' around us respond and react to anticipate opportunities or hazards and take action - to be 'smarter'.

The technology

Advances in technology are providing us with smaller, cheaper and more accurate sensors that can measure any aspect of our environment. These sensors, embedded into everyday objects, are then connected by global communications systems to the cloud. This allows data to be stored in diverse and decentralised ways and provides a powerful means to process this information, draw insights and make things happen.

The potential

Today there are early examples of how IoT is transforming our environment, yet its full potential is still to be realised. In energy production, manufacturing, transportation and in our home lives,

the benefits of sensing, communicating, and computing are being discovered. Domestic appliances that 'know' when they need servicing and can schedule a visit from the service engineer. Doctors who receive vital signs information from their patients 24/7 not just when they see the patient. Farmers that can receive up-to-date information about the best time to harvest using sensors in their fields.

And with simple IoT solutions being built by schoolchildren using systems that cost less than \$10, the pace of adoption, and discovery of new applications, is only going to increase.

The barriers

Privacy is a key concern in the IoT. As we enable this global network of billions of sensors, so the potential to abuse the information gathered about the environment, individuals and organisations grows. We must have the confidence to understand the privacy boundaries within which these systems operate – and reassure users that they are empowered, not threatened, by them.

Today, however, the biggest hurdle to overcome is access. With over half the world's population still not connected to the internet, we have lots to do to make IoT deliver benefit to everyone.



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Some Example Applications...



Making cities smarter

IoT has the potential to transform entire cities by solving everyday problems. Widely deployed sensors, network connections and data processing capabilities provide a way to deal with traffic congestion and reduce noise, crime and pollution. For example, sensors have been deployed on lamp posts to detect gunshots and notify the police even faster than a person is able to. Traffic lights can adjust to the flow of traffic and relay this information to other areas, to provide alternative routes and smoother travel.

Cleanspace

Each year millions of deaths worldwide are attributed to air pollution. Drayson Technologies believes that people should have the tools to know what is in the air they breathe and, empowered with this information, be able to reduce their own exposure to air pollution. The company developed CleanSpace™, a portable personal air pollution sensor and app that gives real-time personal

data on pollution exposure and motivates non-polluting transport choices in return for rewards.

Accessible healthcare

In a world where access to healthcare is not evenly distributed, the IoT has the potential to address this. Brighter have partnered with Telia and Ericsson to develop a connected blood glucose meter and insulin injection system to be used in patients' homes. Currently only available in the Swedish market, these kinds of connected medical devices have huge potential to transform healthcare globally, extending the reach and capacity of health practitioners in areas where they are limited – such as in the developing world.

Connected construction

JCB's Livelink telematics system connects construction equipment, such as excavators, to provide real time health monitoring. This helps maintain equipment at maximum availability and offers valuable insights into their use improving efficiency of operations.

Key Numbers

\$11tn

Impact on global economy by 2025

Source: PA Consulting

4.5mn

Employment in the sector by 2020

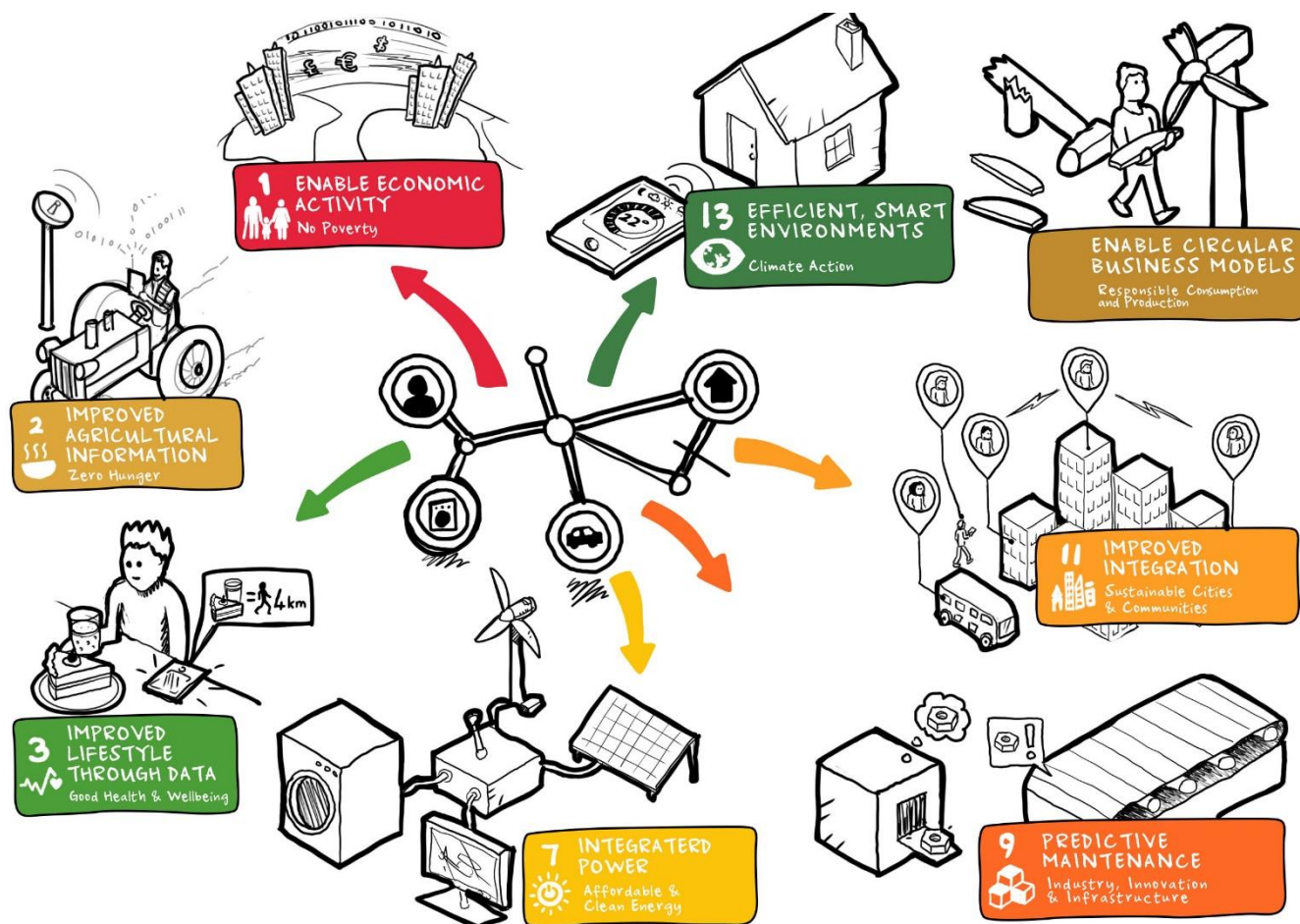
Source: Cisco

38.5bn

Connected devices by 2020

Source: Statista

Advancing the Sustainable Development Goals (SDGs)



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IoT has the potential to advance many of the SDGs. Below are some examples of areas of applications across a wide variety of sectors.

■ SDG 1 No poverty

- Tackle fuel poverty through better awareness of consumption and helping people make smarter decisions.
- Improve social housing through monitoring conditions in smart buildings.

■ SDG 2 Zero hunger

- Increase yield and improve food security by using IoT to monitor soil and weather conditions, crop health, pest activity and crop treatment.
- Decrease food wastage through using insights gained from connecting different parts of the supply chain.

■ SDG 3 Good health and wellbeing

- Use wearable devices and smart clothing to provide individuals with immediate access to information that highlights the impact of their behaviour and lifestyle choices, and motivates them to adopt and sustain positive lifestyles.

■ SDG 7 Affordable and clean energy

- Improve monitoring, control and integration of power sources. For example, increasing efficiency in renewable energy sources through improved management of their variable output.

■ SDG 9 Industry, innovation and infrastructure

- Create opportunities for new and innovative products and service models.
- Track and manage assets remotely and in real-time, allowing a more efficient use of people.
- Predict when parts will fail using sensors so they can be replaced before this happens, reducing down time.
- Help employees make better decisions about the tasks they are doing by providing relevant real-time information.
- Automate repetitive and predictable processes through smart IoT systems.

■ SDG 11 Sustainable cities and communities

- Transform city infrastructure through intelligent buildings and transport infrastructure, air quality monitoring, smart energy and water networks.
- Share information between widely dispersed groups of individuals through technologies such as shared activity trackers, which help people to stay connected and feel part of a broader community.

■ SDG 12 Responsible consumption and production

- Reduce waste from manufacturing, and from shorter and more responsive supply chains.

- Track the provenance of products and their constituent components across the supply chain and their lifetime, so that products are more easily reused and recycled, supporting circular economy models.

■ SDG 13 Climate action

- Monitor ecosystems and the natural environment using webs of connected sensors.
- Improve energy efficiency through smart devices that can provide a low cost way for people to conserve energy by monitoring home temperatures, varying temperature by room and controlling temperature when out of the house.

Potential Negative Impacts and Barriers

Access to the internet in developing countries will be the key factor limiting the global potential of IoT.

Sharing the benefits

Less than half of the world's population (3.5bn people – source Statista) have access to the internet. There is enormous potential to use IoT to improve sustainability and growth in the developing world but this will be limited by the rate of people becoming connected. Until internet connectivity is pervasive worldwide, IoT will largely be a first world phenomenon.

Security

Managing a diverse network of connected devices and sensors creates significant security challenges and it is critical that devices are designed with security in mind and IoT connections are secured end-to-end. The risks were made abundantly clear in October 2016 when a Distributed Denial of Service attack infected a large number of poorly secured connected consumer devices with a virus.

In another interesting example, British Prime Minister Theresa May was reported to have banned government ministers from wearing smart watches to meetings amid fears that they could be hacked and turned into listening devices.

Increased electronics demand

As smart, connected devices become more pervasive the demand for electronic components and their raw materials will rise. Aside from the need to ensure this ever increasing demand is sourced in a responsible way, this will have an impact on waste. Although largely covered by existing legislation in the developed world it will be important to ensure that more hazardous products are not heading to landfill sites in developing countries. The advent of biodegradable electronics will have a big mitigating impact on this.

Technical Considerations

The IoT will create new and diverse challenges for both manufacturers and consumers, and these will need to be overcome as they adapt to that change.

Interoperability

Integrating different solutions from a range of manufacturers is a challenge. Today we have many networks of things but a lack of standards is limiting the potential for greater interoperability. This means that a level of commonality that makes the technologies interchangeable will be key to mass consumer adoption.

Manufacturer responsibility

Traditional business models work on an assumption that the manufacturers' responsibility stops when customers take ownership of the product. Issues relating to guarantees, warranty and replacement parts are the only reason for subsequent contact. With IoT however, manufacturers need to maintain ongoing connections and services, provide support and advice, and manage upgrades, all of which creates new business activities around collecting and aggregating data. This requires more engagement with customers and, while creating potential new sources of revenue, it can also increase costs for organisations and take them into unfamiliar areas.

Data overload

A dramatic increase in connected objects will generate huge amounts of data that needs to be processed to generate insight – collection alone will not lead to improvements in services. It is what we do with the data that will make a real difference and there will be a need to ensure that users have the capability to process and analyse these new volumes of data.

Enabling New Business Models

The IoT is going to challenge many current business models as well as opening up a number of new ones.

As a broad enabling technology, IoT can have an impact across many sectors. The increasing availability of sensors, connectivity, and cloud-based computing makes it possible to gather a wide variety of data. This can then be used to generate actionable, real-time information and intelligence in a way that is significantly more cost effective than previous methods.

Established businesses may typically start connecting their existing products, manufacturing lines and assets. IoT provides an opportunity to measure and automate what is going on in a business. This provides greater degrees of control than traditional information gathering techniques which rely on manual input. When combined with big data analytics and data visualisation this can provide valuable new insights into efficiency and productivity.

Machine learning can go further and help detect anomalies, predict usage patterns, and optimise maintenance scheduling and other improvement opportunities. This means manufacturers will be better able to monitor, control, improve and automate their operations in ways that were previously unimaginable.

IoT will help organisations gain a better understanding of customers, their needs and behaviour, from data about how they use products. This will allow product performance to be improved, and additional valuable services to be provided. It will also deepen their relationships with those customers by engaging them through their products after they have bought them, creating new business opportunities.

An even greater potential for IoT comes from monitoring the environment through the use of widely deployed networks or sensors that gather data such as indicators of climate change, levels of pollution, population movement and soil health.

In many industries, IoT is disrupting traditional business models causing companies to ask the fundamental question "what business am I in?" This is creating opportunities for start-ups, and for technology companies with expertise in capturing, managing and exploiting information to enter new sectors.

It also means competition can now come from unforeseen directions, examples include Google entering the domestic heating market through NEST and Apple entering the automotive market. As a result, businesses need to look more broadly when considering their options for the future, and form partnerships more extensively.

IoT will enable a number of the disruptive business model levers identified on the Project Breakthrough Website, specifically:

A more personalised product or service

IoT can capture information and insights on individual customers and their preferences, and tailor services and their delivery to individuals.

A closed-loop process

IoT will allow products and components to be tracked across the supply chain and their lifetime, enabling reuse and recycling.

Asset sharing

IoT will allow the monitoring and tracking of usage of assets, which is essential to asset sharing business models.

Usage based pricing

By monitoring asset status and health, IoT can provide the information needed for usage-based pricing.

More Examples...

Connected off grid
energy supply in Africa

<http://www.vodafone.com/business/why-africa-is-feeling-the-power-of-iot-2016-03-07>

Tesla's over the air
software updates

<https://www.wired.com/insights/2014/02/teslas-air-fix-best-example-yet-internet-things/>

Changing a business
model through IoT

<http://www.paconsulting.com/our-experience/rentokil-launching-an-internet-of-things-cloud-platform-to-handle-24-million-messages-a-day/>

Project Breakthrough

Disruptive Technology Executive Briefs

BIG DATA

Creating insight from the connected world

One of the major trends of our time is the exponential increase in data. The internet, social media and connected devices are just some of the sources of immense amounts of data which can be used to answer questions about almost every aspect of our lives and industries. Big Data is the ability to capture and analyse this data to create meaningful insights or actionable information. It can be used to answer questions, identify trends, spot anomalies or explore the information in more detail through processing both structured and unstructured data such as text, imagery and video.

The technology

Big Data relies on computers which can spread the storage and analysis of data across many low cost servers, often hosted in the cloud. There are many ways to analyse this data, ranging from traditional statistical techniques for testing hypotheses to novel approaches identifying objects in images or video data. Often Big Data solutions bring sets of data together in innovative ways to create unexpected answers and insights. These techniques are now more readily available and can be used in ways that make the most of new computing technology.

As well as the computational techniques required to manage this data there have been many advances in analysis and visualisation of the data. These have created new ways of showing information on standard web browsers opening up analysis and understanding to anyone with a personal computer or tablet.

The potential

As more aspects of our lives become monitored and connected, it is difficult to imagine an area where Big Data will not make an impact. For example, utility companies are using their measurement and finance data to better predict maintenance routines. Financial institutions can predict risk and monitor fraud more accurately and retailers have used it very successfully to predict customer behaviour. We are all only beginning to fully understand the applications of Big Data techniques and its ability to improve our wellbeing, communities and planet.

The barriers

The major risk with Big Data is the power it gives organisations to monitor multiple aspects of our lives and potentially try to control them. This ranges from the mild irritant of targeted advertising to mass surveillance programmes.



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Some Example Applications...



Condition based monitoring

Aviation is one of the most safety-conscious industries, where companies are consistently striving to improve the performance of expensive assets. Both Rolls Royce and General Electric's aviation business closely monitor the performance of their engines on behalf of their customers, both in real time to check they are working properly and also using historic analysis to improve performance. Each engine can generate terabytes of sensor data every day, so preparing and analysing these high volumes to generate insights is a Big Data challenge. By getting it right manufacturers and their service teams can identify faults before they occur, understand the root cause of problems and improve manufacturing techniques to avoid problems re-occurring in the future.

Predictive policing

The Los Angeles and Santa Cruz police decided to take a more data driven approach to reducing crime. In conjunction with a company called PredPol they collected crime statistics and applied a mathematical model previously utilised for earthquake detection. The resulting tool predicts likely locations for crimes enabling police forces to better deploy their officers. Several forces around the world claim to have seen a measurable improvement in crime prevention as a result of this or similar tools.

Logistics optimisation

UPS delivers 17m packages and documents every day, shipping over 4 billion items per year using tens of thousands of vehicles. It uses Big Data techniques in a number of ways, one of which is optimising its fleet. On-truck measurements and advanced algorithms help with route planning, engine emissions and predictive maintenance. Since starting the programme, the company has saved almost 40 million gallons of fuel and avoided driving over 350 million miles.

Key Numbers

80%

Percentage of data which is unstructured

Source: IBM

40

The number of Petabytes of data Walmart processes in a day

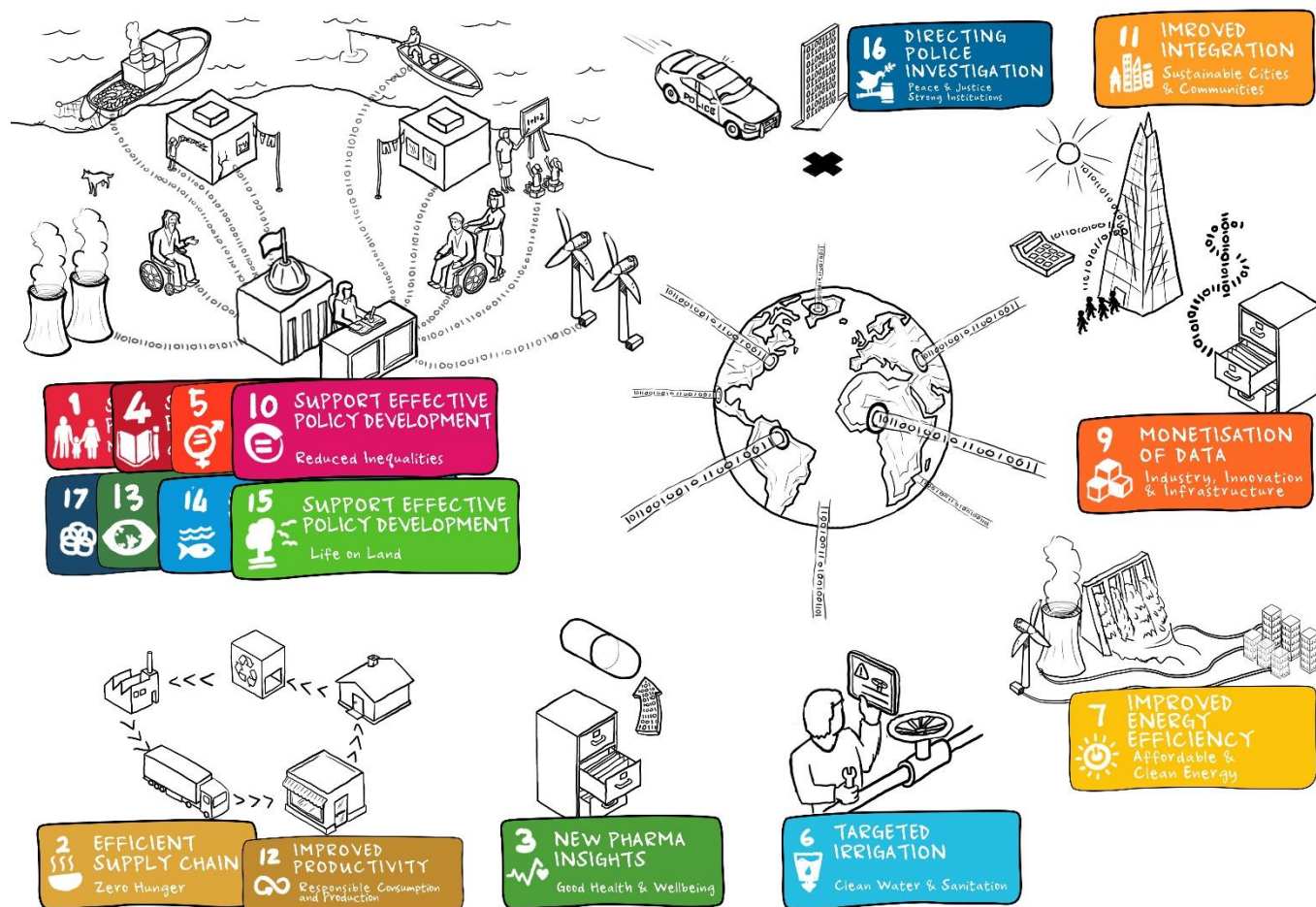
Source: Datafloq

9 billion

The number of connected devices in 2016 (excluding computers, phones)

Source: IDC

Advancing the Sustainable Development Goals (SDGs)



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Big Data has the potential to advance many of the SDGs. Below are some examples of areas of application across a wide variety of sectors.

■ SDG 1 No poverty

- Analysis of data sources including open data sources such as social media feeds to understand the impact of policies on poverty.

■ SDG 2 Zero hunger

- Provide insights to increase farm productivity and enable more sustainable farming
- Improve supply chain management and reduce food wastage.

■ SDG 3 Good health and wellbeing

- Already being used by pharmaceutical companies to look for new insights in their significant stores of data
- Enable other technologies such as gene editing.

■ SDG 4 Quality education

- Already being used in the US to analyse teaching/education data, to understand where it is most effective and update approaches accordingly.

■ SDG 5 Gender equality

- Support more effective policy development, through using Big Data analytics to provide insights that were not previously possible.

■ SDG 6 Clean water and sanitation

- Sensor data enables the preventative maintenance of water networks, reducing costly leakages.

■ SDG 7 Affordable and clean energy

- Big Data has the potential to drive significant efficiencies through enabling preventative maintenance and better demand forecasting.

■ SDG 9 Industry, innovation and Infrastructure

- Big Data is already being used in most sectors to monitor performance, improve marketing and identify efficiencies
- The value of data is being increasingly understood and monetised creating significant sources of wealth
- For infrastructure, Big Data can be an important part of condition based monitoring when combined with sensor data

■ SDG 10 Reduced inequalities

- Analysis of data feeds such as social media to identify factors that contribute to areas of wealth and poverty and inform policy makers accordingly.
- Alternative means of assessing key statistics where government supplied data is unreliable

■ SDG 11 Sustainable cities and communities

- Already a key enabler of smart cities. Companies are starting to monitor all their buildings, collecting and analysing it using Big Data tools.

■ SDG 12 Responsible consumption and production

- Industry is already adopting Big Data approaches to improve productivity.

■ SDG 13 Climate action

- Support more effective policy development, through using Big Data analytics to provide insights that were not previously possible.

■ SDG14/15 Life above land/below water

- Support more effective policy development, through using Big Data analytics to provide insights that were not previously possible.

■ SDG16 Peace, justice and strong institutions

- Big Data analytics are already being used to predict where crimes may occur, so that law enforcement can be proactively deployed
- Can be used to help solve crimes when they occur.

■ SDG 17 Partnership for the goals

- By sharing different and diverse data sets, new insights become apparent, driving stronger understanding.

Potential Negative Impacts and Barriers

For a new technology to gain acceptance it must be safe and reliable but, just as important, it must be supported by the right legal and regulatory framework or there is a risk of a public backlash that will limit its use.

Data usage and privacy

As more opportunities become available to bring data together, careful consideration needs to be given to the legal, ethical and reputational implications of doing so. For example this could include government departments sharing data but also companies using social media to make risk or commercial decisions (e.g. increasing a person's insurance premium due to their social media behaviour). Data privacy laws will need to keep pace, both at a local and global level.

In some cases the statistical techniques common in Big Data have led to accusations of racial profiling or of disadvantaging poorer sections of the community.

Challenges of rapid change

The Big Data industry is fast growing and changing rapidly. Many startups meet niche needs but launch and close every day. As a result, there are growing product differences and selecting a set of providers to build a system that meets particular requirements could cause problems if the software changes or the suppliers disappear. To address this a group of interested parties and vendors have created the Open Data Platform initiative to enable a common computer code and interchangeability for certain Big Data technologies.

Skill shortages

As demand for people with data science and Big Data skills and experience is growing dramatically, businesses will see a marked increase in salary demands for high performing staff. This can be minimised by retraining existing staff or fixing prices with providers (e.g. outsourcing or agencies). As with previous analytics and visualisation trends, some will opt to use user friendly self service tools for analytics tasks. Whilst these are initially more expensive they simplify the use of Big Data techniques, reducing dependency on expensive resources.

Big Data fatigue

There has been much hype surrounding Big Data and whilst there have been significant investments many projects have not brought the benefits organisations wanted to see. The focus has often been on the technology rather than delivering business insight that can improve data-driven decision making, a big part of this is knowing what questions to ask.

Many companies are still developing their capabilities as the products mature, people develop and lessons are learned. This can lead to delay and frustrate many business who can then view Big Data's promise as just hype.

This can be tackled by taking small steps to demonstrate the incremental value of Big Data. These can include short term cloud computing based pilots that allow for faster response times and a more agile approach. It is always important to ensure the team developing this capability is comprised of both Big Data scientists and subject matter experts who can interpret and tune the insight being generated.

Technical Considerations

Big Data is one of the more established of the breakthrough technologies and so many of the early technical challenges have been addressed – however, as it continues to gain popularity, additional areas will need to be addressed.

The rate of development is rapid and constant as new gaps are identified by niche players that then add to the products available. It can be hard for suppliers to keep their versions up to date and supportable - proprietary versions often significantly lag open source solutions.

Many of the emerging solutions, particularly with leading edge capabilities, currently rely heavily on very technical developers that can use a wide variety of

computer languages and syntaxes. This can lead to a shortage of resources and in turn higher salaries.

Some of the new technology, such as Hadoop, are ideally suited to cloud computing giving companies rapid access to relatively cheap and flexible new capacity.

Security is another important and legitimate concern for many businesses and it is important that Big Data uses well established guidelines for securing internet applications. Big Data applications are often hosted on platforms provided by the US companies such as Google and Amazon. In many cases customers and the wider public have shown concerns that data hosted on these platforms can be accessed inappropriately by these companies. Whilst these fears are unfounded it is important to be aware that these perceptions exist.

Enabling New Business Models

Big Data is transforming business

In 2014, Wired magazine said 'Data is the new oil of the digital economy.' Since then the dramatic increase in the amount of data being captured has continued. This gives businesses deeper and finer insight into customers, sophisticated intelligence about the environment they operate in, and new ways to control their internal operations. For many organisations Big Data has improved both the quality and time taken to make business decisions. This enables them to respond in real-time to customer requests and to take more innovative approaches. For example, it is making loan applications quicker and easier or enabling retail companies to combine social media, weather, finance and logistics data to optimise stock distribution.

The potential of Big Data touches all industries, from supply to demand, and increasingly across value chains and industries. Many of the large technology companies that have emerged recently have Big Data at the heart of their business model. Google successfully monetised their search systems and massive infrastructure through sponsored adverts and the ability to match advertisers and consumers. Uber and Airbnb in the transport and accommodation sectors leverage high volumes of usage data to analyse employee and customer behaviour to improve customer satisfaction and increase sales.

Some of these companies have also been at the forefront of forging new business models providing Big Data services. These include Amazon and their Elastic Compute service, or Google's BigQuery cloud data analytics platform. Other new business models have

emerged whose purpose is to create value from very deep analysis of raw data. For example there are many firms able to analyse website viewing so that each site maximises its chance to make a sale.

By providing easy access to the tools and infrastructure needed, the large technology companies have opened up the world of Big Data to start-ups and innovators. This has also disrupted established organisations who no longer need to invest large amounts of capital to build data centers filled with highly sophisticated machines, but instead can use cloud based solutions and flexible analysis tools to provide powerful capabilities.

Big Data will enable a number of the disruptive business model levers identified on the Project Breakthrough website, specifically:

Personalised product and service

Big Data is a key technology in enabling services which are individually tailored to the user or to their current activity. Big Data techniques can identify what data is relevant to a given user in their current context.

Closed loop process

Big Data allows consumption and supply patterns to be better understood and controlled, improving efficiency, and reducing wastage.

Asset sharing

Big Data allows sophisticated insight into demand and supply to better match and promote asset sharing.

More Examples...

GE Expands into industrial analytics

<https://sloanreview.mit.edu/case-study/ge-big-bet-on-data-and-analytics/>

Pirelli use Big Data to improve manufacturing and resource use

<http://business.pirelli.com/global/en-ww/how-pirelli-is-becoming-data-driven>

When Big Data and satellites collide

<https://www.planet.com/pulse/descartes/>

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BLOCKCHAIN

Building trust in a complex world

Blockchain is perhaps one of the most exciting and talked about, yet least understood, technologies of recent years.

It is best described as a new kind of database and internet infrastructure which enables sharing, collaboration and builds trust in transactions. Developed by Satoshi Nakamoto in 2008 and first implemented in the Bitcoin cryptocurrency, blockchain removes the need for a single trusted institution, such as a bank or a legal firm, to oversee and verify transactions. Instead, those involved agree on a set of information to be stored (such as legal agreements, financial transactions, health records) and then the transparency of the blockchain technology means they can be confident that this data will remain available for as long as it is required. This then provides a digital, tamper proof record of the transaction.

The technology

Blockchain is a distributed database or ledger that stores records of transactions in blocks. Each new block has a unique encrypted fingerprint and is linked to the previous block. This ensures the blockchain cannot be changed retrospectively. As new blocks are written, the updated blockchain is continually replicated across other copies. The process also ensures that conflicts (where more than one block is created at the same time) do not arise across the multiple copies of the ledger.

The potential

Netscape co-founder Marc Andreessen said blockchain "gives us, for the first time, a way for one internet user to transfer a unique piece of digital property to another internet user, such that the transfer is guaranteed to be safe and secure, everyone knows that the transfer has taken place, and nobody can challenge the legitimacy of the transfer. The consequences of this breakthrough are hard to overstate."

Currently the most common blockchain applications are cryptocurrencies. But blockchain offers a trusted, tamper-proof way of recording transactions for any digital asset. It could transform property and land rights, medical records, intellectual property, identity, and validation of provenance and ownership of goods and assets.

The risks

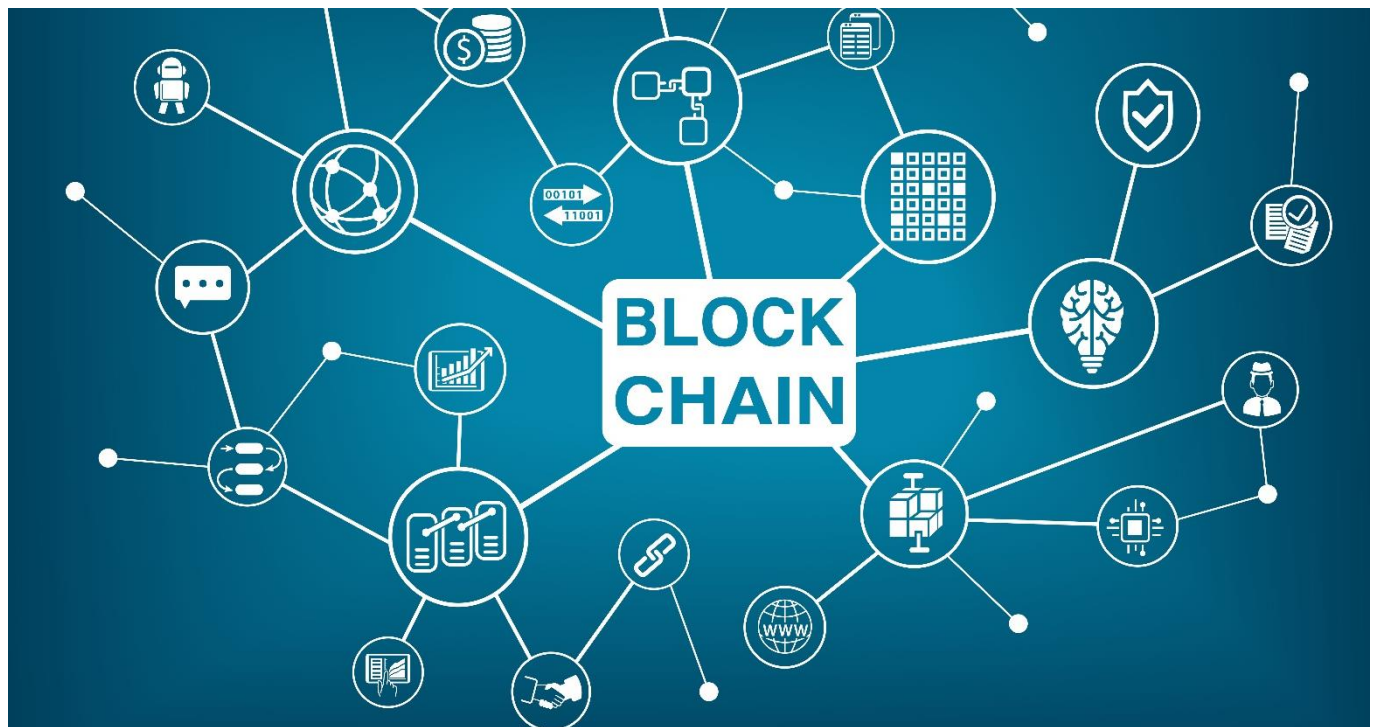
Like all immature technology, blockchain still needs further development to deliver on its promise. In particular, given its potential to provide secure and tamper-proof records, the security of the associated applications and infrastructure will be critical. The regulatory and legal framework will also need to evolve to reflect the issues raised by blockchain.



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Some Example Applications...



Managing the land registry with blockchain

The republic of Georgia is piloting a blockchain solution to validate property transactions. Developed in partnership with Bitfury, the national government are planning to expand the service into registration, purchase and sale of land titles. They are one of a number of governments, including Honduras and Sweden, exploring how blockchain can help provide a transparent and secure way of managing property and land rights.

Identity management for refugees

With an estimated 20% of the world's population not having a legal identity, proof of identity is a significant barrier, particularly for refugees, to accessing financial and government services. BanQu has piloted a blockchain based scheme in the Dadaab refugee camp in Kenya, helping displaced Somalis create economic identities. Additionally, initiatives such as ID2020 are bringing together technology companies, development

agencies, and think tanks to help the one billion individuals without a legal identity, seeking to develop a solution by 2020 using technologies such as blockchain, and have it implemented by 2030.

International money transfers in Africa

Based in Nairobi, BitPesa provides international payment services between Africa and the rest of the world. Using Bitcoin, the most popular blockchain based cryptocurrency, BitPesa provides a cheaper alternative to international money transfers, enabling import and export from African countries, and the remittance of money from abroad.

Supply chain transparency

Connecting fisherman, global retailer and consumer, a pilot by British tech company Provenance has successfully tracked tuna fish through South East Asian supply chains - proving blockchain's role in improving transparency and sustainable practices in the sector.

Key Numbers

\$2.3 bn

Estimated market size
in 2021

Source: Statista

\$135 mn

Estimated value of transactions on the Bitcoin blockchain

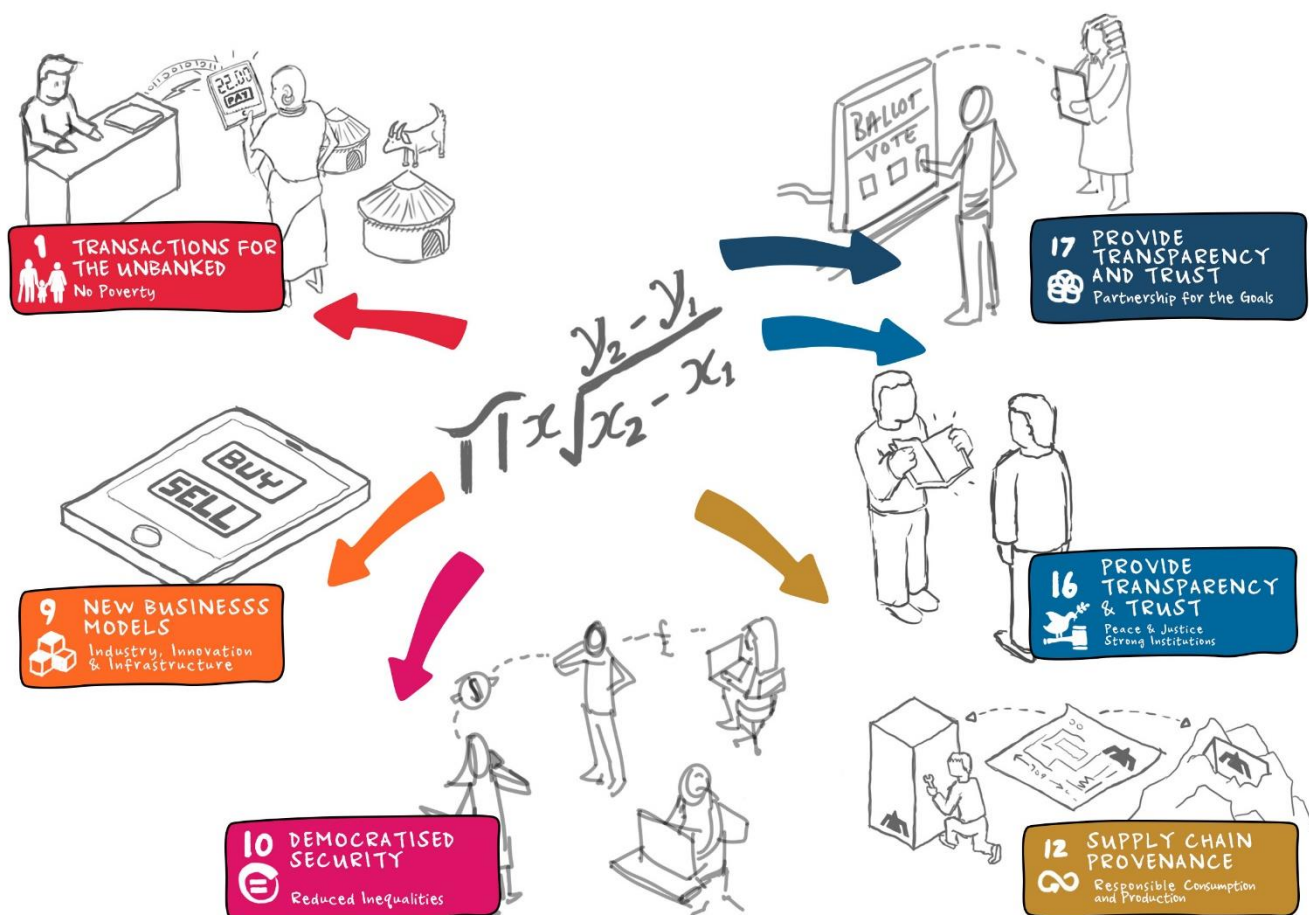
Source: Blockchain Info

34 mn

Number of blockchain wallet users worldwide

Source: Statista

Advancing the Sustainable Development Goals (SDGs)



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Blockchain has the potential to advance many of the SDGs. Below are some examples of areas of application across a wide variety of sectors.

■ SDG 1 No poverty

- Rapidly open up the ability to trade and enable transactions for the world's unbanked. Blockchain and cryptocurrency-based initiatives such as BitPesa and CariCoin are already gaining traction.

■ SDG 9 Industry innovation and infrastructure

- Create an infrastructure to build trust, reduce friction and increase transparency and efficiency across supply chains.
- Remove friction from value chains.
- Improve the efficiency, and reduce the cost, of transactions.
- Enable traceability of the provenance of products across the supply chain.

■ SDG 10 Reduced inequalities

- Giving those without access to banking an opportunity to trade.
- Enable new webs of value exchange between all the connected Internet of Things devices.

■ SDG 12 Responsible production and consumption

- Reduce waste from manufacturing, and from shorter and more responsive supply chains.
- Track the provenance of products and their constituent components across the supply chain and their lifetime, so that they can be more easily reused and recycled, supporting circular economy models.

■ SDG16 Peace, justice and strong institutions

- Provide transparency and trust.
- Transform democracy by providing a mechanism for establishing identity, and casting votes.
- Provide open and trusted mechanisms for processes such as registering property and assets, paying taxes, and accessing state welfare.

■ SDG17 Partnership for the goals

- Provide transparency and trust.

Potential Negative Impacts and Barriers

Blockchain could revolutionise how business is done across many sectors, but this revolution will only happen if costs can be reduced, a supply of skilled expertise can be found and risks are managed effectively.

Impact on existing centralised trust systems

A shift from a centralised trust system could lead to a loss of income/work for those organisations such as banks, the legal profession and governments.

Technical skill shortages

Highly skilled blockchain expertise is in short supply but it is possible for organisations to begin to experiment with blockchain using existing open blockchain platforms such as Ethereum, Factom or even the Bitcoin blockchain without significant capital outlay. There is also a wealth of start-up activity providing opportunities for partnership, acquisition or other ventures.

Co-option

It is possible that established organisations may wish to co-opt blockchain technologies within their existing business models. For example R3 is a distributed

database company that leads a consortium of more than 70 of the world's biggest financial institutions in research and development of blockchain usage in the financial system.

Regulatory and legal regime

There is considerable regulatory and legal ambiguity around Distributed Autonomous Organisations (where a virtual organisation operates autonomously following rules determined in smart contract software without requiring human managerial direction) and how blockchain technology fits more widely within regulatory regimes and legal frameworks.

Energy consumption

The cryptographic underpinning that makes blockchain secure requires significant computing power to solve mathematical problems, particularly for the Bitcoin protocol. Whilst measuring energy consumption is difficult, some estimates of the amount of power required for this activity are extremely high, and this demand will continue to grow. However, alternative, more energy efficient mechanisms are now being developed.

Technical Considerations

Like all immature technology, blockchain still needs further development to make it a rapid, reliable and affordable system.

Performance

Resolving issues such as transactional speed and throughput, the verification process, security, and data block limits will be crucial to the mainstream adoption of blockchain.

Computing power

Blockchains that use 'proof of work' (solving complex mathematical problems) as a mechanism for authenticating transactions require a lot of energy due to the computing power needed. This cost is coming down and efficiency is improving but it is not yet at a point where it has mass market viability.

Integration

Blockchain applications can be challenging to integrate with existing systems and will often demand complete replacement, making it costly and time consuming and this can delay its adoption.

Interoperability

There are many approaches to blockchain adoption with multiple choices of models and technology –public, private, hybrid, etc. Different systems and implementations can have varying levels of security, privacy and control and the market as a whole will need to work to gain widespread trust in the options.

Governance

Governance and ownership of technical standards will also be an important issue. The challenge can be seen in the fact that, to date, developers have been unable to agree changes to the underlying technology of Bitcoin to improve performance and throughput.

Trust

The fundamental blockchain architecture puts trust and security at its heart. But implementation will only be as good as the smart contracts, software code, networks and infrastructure they run on. The DAO, a blockchain based venture capital fund which raised \$150 million in 2016 was drained of \$50 million of funds by an investor who gamed the smart contract.

As the value and importance of applications underpinned by blockchain increases, there will be more attempts to find ways of compromising them and a need to defend the system against these attacks.

Enabling New Business Models

There has been considerable hype around the disruptive impact of blockchain technologies on business models with some commentators describing it as being as disruptive as the internet itself.

Blockchains have the potential to be applied in many sectors wherever there are transactions and record-keeping. The key benefit lies in the way transparency reinforces trust in all transactions. This can be cheaper and more accurate than using centralised institutions and its transparency can also remove conflicts of interest from ownership. It also can dramatically reduce the high initial cost/benefit ratio for participants in transactions, and its naturally distributed design frees a central organisation from costly and error-prone administrative duties.

Blockchain is an open and accessible technology that can be used to drive innovation by both incumbents and startups. Different models exist, depending on whether the blockchain is publicly accessible, private, or a hybrid of the two. Public blockchains are being offered on a pay-as-you-go basis, which reduces infrastructure costs. Its tendency to use openly available technology also reduces the need for new entrants to build trust with customers.

The greatest potential impact will be on those who act as trusted authorities today e.g. banks and law firms. Interestingly, the financial services industry has been a driver of blockchain innovation, often using private blockchains to increase the efficiency of internal transactions.

The open source nature of some blockchains make this technology easily accessible as a platform for innovation. This means the advantages can be felt by consumers and citizens across the world and not just in advanced economies or highly technical industries.

Another possible business model is the Distributed Autonomous Organisation (DAO). This is where a virtual organisation operates autonomously following rules determined in smart contract software, without requiring human managerial direction.

Blockchain will enable a number of the disruptive business model levers identified in the Project Breakthrough website, specifically:

A closed-loop process

Blockchain can enforce the transparency, security, authenticity, and auditability necessary to make tracing the chain of custody and attributes of products possible, which in turn enables reuse, refurbishment and recycling.

Asset sharing

Blockchain can potentially create a (currently missing) trusted universal infrastructure where assets and their use can be transparently and securely tracked.

Usage based pricing

Blockchain can enable usage based pricing by providing a verifiable record of transactions.

Collaborative ecosystem

Blockchain has great potential as a technology for connecting and sharing information and verifying transactions across value and supply chains.

More Examples...

Walmart & IBM apply blockchain for supply chain traceability

<http://www.computerworlduk.com/iot/walmart-picks-ibm-bring-traceability-food-with-blockchain-3654841/>

Factom – an open source blockchain platform for data authenticity and trust

<http://www.akasig.org/2016/07/28/blockchains-for-social-good/>

PointNurse – connecting patients and medical practitioners on the blockchain

www.pointnurse.com

TECHNOLOGY THAT AFFECTS HOW WE MOVE AND MAKE THINGS

Unmanned Air Systems

Autonomous Road Vehicles

Additive Manufacturing



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Global Compact



Project Breakthrough

Disruptive Technology Executive Briefs

UNMANNED AVIATION SYSTEMS (UAS)

Opening the skies to all

Unmanned Aviation Systems (UAS) are fixed wing or multi-rotor aircraft without an onboard human pilot that move autonomously or semi-autonomously. They can range from small hobbyist quadcopters to large, fixed wing aircraft.

The technology

UAS technologies are not new but their integration into a commercially viable system has provided real transformation in the tasks they can perform.

Technologies include the use of sensors to monitor the environment and collect data, as well as autopilots and flight stabilisation software that simplify remote-controlled flight. They also use software algorithms to interpret the data and plan autonomous flight.

The potential

UAS can be used in a range of applications including delivery, inspection, farming, surveillance, monitoring, search and rescue, filming, logistics, law enforcement and photography. Their potential to fly in conditions that humans can't (or won't!), their ability to travel further without human intervention, and the lowering in costs resulting from these factors means there are a multitude of potential applications to consider.

The barriers

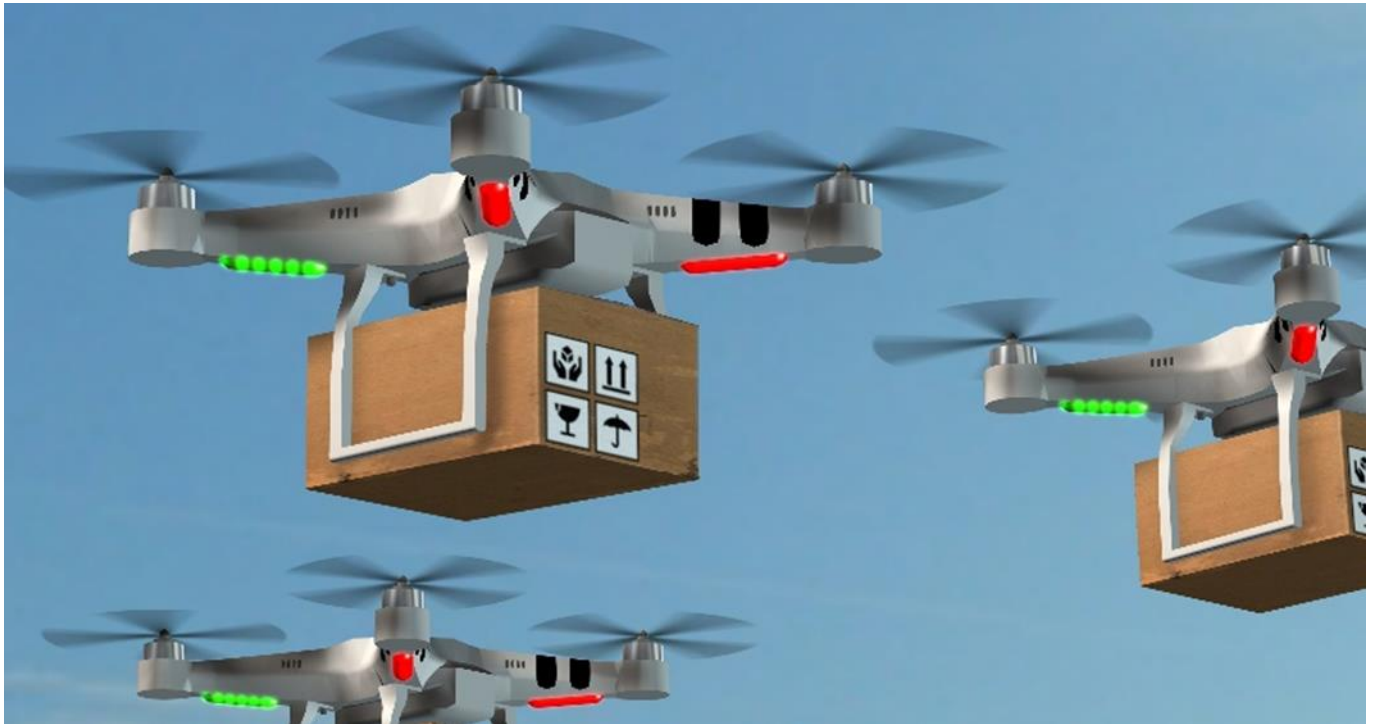
Widespread adoption is being limited by safety and security concerns, such as UAS being used illegally or recklessly. With reports of drugs being flown across borders and into prisons, as well as the already acknowledged concerns over air traffic incidents, responses to challenges like these will need to be developed and implemented before the technology can go truly mainstream.



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Some Example Applications...



Delivery

One of the most immediate commercial applications for UAS is home delivery. By using UAS, companies can minimise the time between ordering and delivery, improving the customer experience and providing more options for time-sensitive products such as foods or medicines. Amazon is one of the higher profile examples of a company that is pursuing this development.

By avoiding traditional delivery routes, UAS have the potential to significantly reduce road congestion (and associated pollution) as well as open up previously hard-to-reach areas to services that are currently not available or are not commercially viable. As the technology improves and the supporting factors such as regulation are clarified, the range of products that can be delivered in this way could grow considerably.

Monitoring

Aerial inspection company, Cyberhawk Innovations, use Remotely Operated UAVs (ROAVs) to inspect structures that are difficult or dangerous for humans to reach, such as wind turbine blades. This can be done more regularly, at a lower cost, providing higher resolution images and without the risk of having human workers work at dangerous heights. This provides the opportunity for early intervention to rectify problems and save operational costs.

Agriculture

UAS, with near infrared sensors, have been trialed in Sri Lanka to monitor farmers' fields and provide information on their crops, such as the optimum time to harvest.

Key Numbers

\$13.4 bn

Estimated market size in 2022

Source: Statista

7 mn

UASs estimated to be in the US in 2023

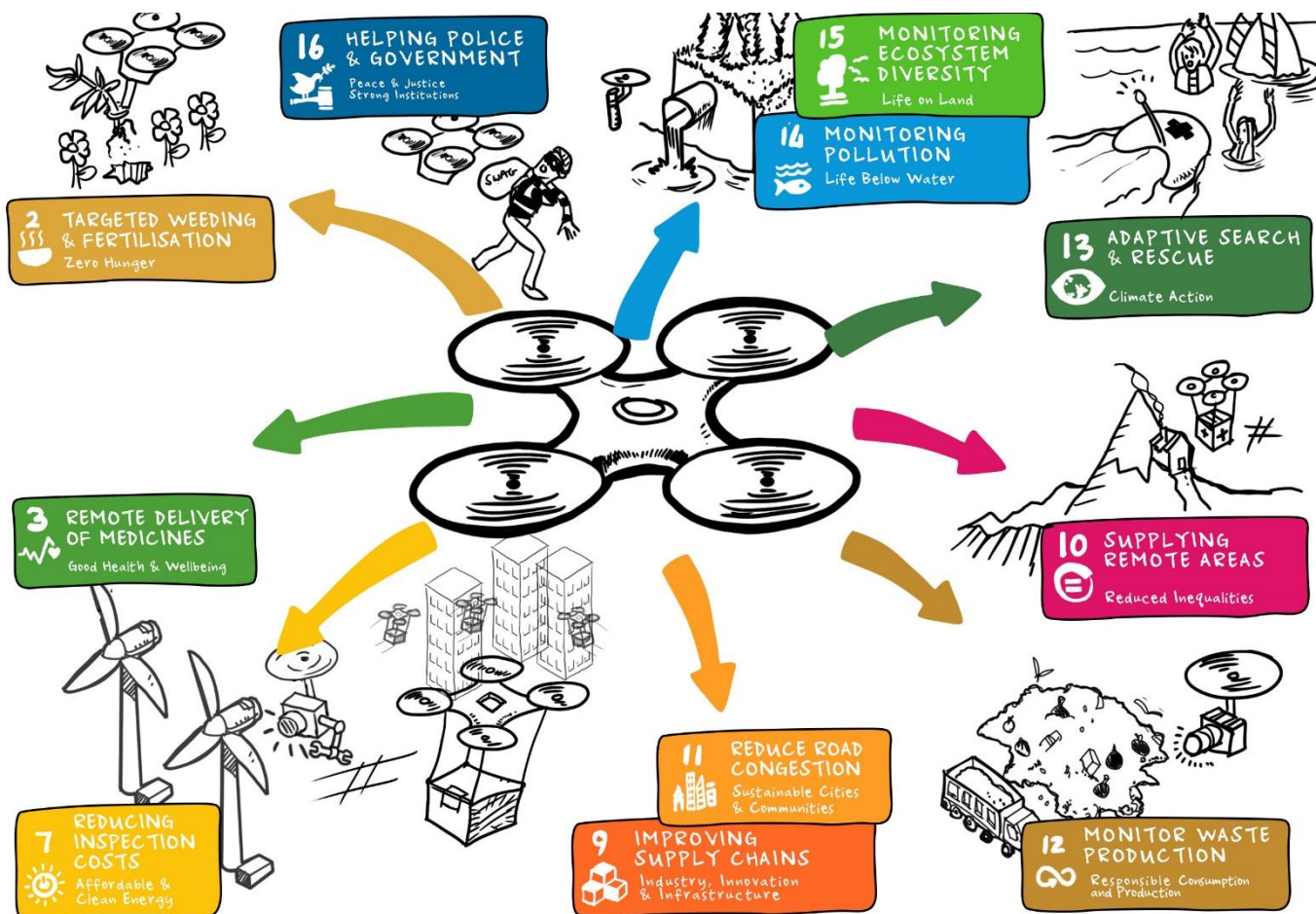
Source: FAA

\$3.9 bn

Estimated R&D investment in 2020

Source: Statista

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Unmanned Aviation Systems have the potential to advance many of the SDGs. Below are some examples of areas of application across a wide variety of sectors.

■ SDG 2 Zero hunger

- Provide data to increase farm productivity and enable more sustainable farming.
- UAS can be used to identify weeds and deliver herbicide only when needed, and eventually could be used to locate and remove individual weeds, removing the need for herbicides altogether.

■ SDG 3 Good health and wellbeing

- Deliver medical or nutritional supplies to remote areas.
- Explore environments that are dangerous for humans to explore, and detect the presence of hazardous Volatile Organic Compounds.
- Explore large areas quickly in rescue missions, for example in the aftermath of a natural disaster or searching for those lost at sea. UAS can fly in groups to rapidly cover large areas, an operation which can be costly, challenging and dangerous for manned aircraft.

■ SDG 7 Affordable and clean energy

- Reduce inspection and maintenance costs of renewable energy infrastructure such as solar cells and wind farms.

■ SDG 9 Industry, innovation and infrastructure

- Safely and continuously monitor structures or infrastructure that is hazardous or costly to reach. For example, inspect power lines using drones with onboard video cameras instead of using humans to climb them.
- Reduce costs of maintenance and monitoring of large infrastructure more generally by deploying swarms of autonomous UAS.
- Improve factory efficiency by using drones to monitor, move and deliver tools and inventory efficiently and autonomously.
- Deliver goods quickly and efficiently, which will also reduce road traffic and congestion.
- Research is also looking at ways of using UAS to construct temporary infrastructure such as bridges.

■ SDG 10 Reduced inequalities

- Deliver supplies, medicine or disaster relief to remote locations at a lower cost, to areas that cannot be reached otherwise, or where quick delivery is required.
- Allow for wider communications network coverage, by using UAS carrying communications nodes to extend signal reach into remote areas.

■ SDG 11 Sustainable cities and communities

- Reduce congestion and related emissions from road transportation and provide easier access to isolated areas by using UAS to deliver goods.

■ SDG 12 Responsible consumption and production

- Monitor waste production through regular autonomous inspections.

■ SDG 13 Climate action

- Monitor pollutants and climate.
- Provide adaptive search and rescue capacity to help with climate change-induced disasters.
- Decrease overall carbon emissions through more efficient logistics.

■ ■ SDG14/15 Life above land/below water

- Monitor pollutants and ecosystem diversity.
- Monitor wildlife.

■ SDG16 Peace, justice and strong institutions

- Monitoring and surveillance to support law enforcement.

Potential Negative Impacts and Barriers

For a new technology to gain acceptance it must be safe and reliable but, just as important, it must be supported by the right legal and regulatory framework or there is a risk of a public backlash that will limit its use.

Privacy

Developing ways to manage intrusions into privacy, through legitimate or illegitimate collection of data, will be crucial to ensure that UAS are not misused.

Security

The potential to hack UAS is a major concern. As with many connected devices, UAS are often not designed with security as a key consideration. This leaves them vulnerable to breaches and opens the door for either a legitimate application to be hijacked (for example, stealing data that has been legitimately collected) or an illegitimate application to be performed (such as taking control of UAS and trying to use it to disrupt air traffic).

Legislation

Autonomous outdoor operation is either illegal in many places, heavily constrained or more worryingly, is not specifically legislated for. Without rapid intervention to address this, there is a risk that the technology could be used for negative activity resulting in demands to control its use. The insurance aspects of autonomous drones operating outdoors in public airspace will also need to be defined and could affect commercial use of drones for inspection and delivery.

Current regulations and legislation already greatly limit the areas in which UAS can operate and can also make the process to acquire an appropriate license lengthy and costly.

Criminal activity

The availability and lack of ownership registration for drones creates risks of crime. Drones have been reported as being used to fly narcotics over prison walls and borders. Even if the drones are captured, there is no data on who purchased or operates it. This, combined with the low cost of acquisition, makes these a very appealing way to smuggle contraband with minimal risk of capture or prosecution.

There have also been examples of UAS being modified from a legal or benign purpose to an illegal purpose, such as the reports of a handgun being attached to a UAS with a small modification to allow it to be fired by the UAS operator.

Weather

Being able to operate in difficult weather conditions such as rain, snow and high winds is a critical requirement and will be a great challenge for lighter UAS in particular. Unless UAS can rapidly become usable in all conditions (or at least the majority of those currently navigable by vehicles), their application will be limited.

Public acceptance

If not properly addressed, all of the above factors could contribute to some public mistrust of drones which will hinder their adoption and development. There is also benefit in showing that the breadth of UAS capability is broader than military operations (an area 'drones' are often associated with) and highlight their multiple civilian applications.

Technical Considerations

UAS have a huge range of potential commercial applications but for these to be viable they will need further technical development so they can fly for longer and in all conditions.

Battery life

Many of the lighter, more agile and versatile UAS have limited battery life meaning that, depending on load, flight time can be as little as 10 minutes. Whilst this may be adequate for some commercial purposes over short distances, until a longer range can be developed the commercial applications may be limited.

Autonomous flight

Fully autonomous flight requires an understanding of constantly changing obstacles and environments and the ability to reliably navigate in GPS-deprived environments. Urban areas have numerous tall buildings, commercial aircraft and other features such as power lines. Rural environments suffer from a lack of connectivity and contain features such as trees and wildlife. Managing these challenges will require further technical developments.

Communications

On-board processing power can be constrained. A good quality communications link to a base station is therefore often required – this again reduces operational range and will limit the number of commercial applications until it can be resolved.

Interface design

Intuitive user interface design is important for human users to be able to gain control of autonomous UAS if required and to be able to easily control UAS swarms. If UAS can only be operated with a significant amount of training, their ability to disrupt current approaches will be substantially constrained.

Other emerging technologies

Satellite technology and large distributed sensors networks (potentially made from biodegradable electronics) could also carry out many of the monitoring and communication roles that UAS offer. One of these technologies could become more prevalent, reducing the likelihood of widespread adoption of UAS.

Enabling New Business Models

Unmanned flight eliminates the need to design an aircraft around a human pilot.

UAS open up a whole set of new freedoms in design and operation, allowing vehicles to operate at higher speeds, in more hazardous environments and for longer durations.

They have the potential to affect many sectors, including transportation, agriculture, entertainment and security. They will also have an impact across the value chain from exploration, production and distribution, to maintenance and servicing. The opportunities are likely to be in geographies and regions where distance and physical access can be a challenge.

UAS will allow customers to be served in new ways. They will enable more effective and cheaper ways of monitoring and collecting data, maintaining and servicing infrastructure and assets, and of distributing supplies. Aviation capability can now be made available at a much lower cost, as the absence of a human pilot enables craft to be smaller and also more fuel efficient. This will also substantially reduce the risk of human errors, often attributed to fatigue.

Today small drones can be purchased off the shelf for as little as a few hundred dollars and immediately put to use. Making such technologies affordable to a much

wider market has the potential to bring significant innovation in areas such as logistics, communication and monitoring.

UAS will enable a number of the disruptive business model levers identified in the Business Model section of the Project Breakthrough website, specifically:

A more personalised product or service

By collecting information, UAS will be able to personalise maintenance and servicing. They will also enable more flexible and tailored logistics and distribution to meet customer needs.

A closed-loop process

By monitoring production processes, waste, and resource usage, UAS will enable a closed-loop process within and across businesses.

An agile and adaptive organisation

The flexibility offered by UAS will allow monitoring and data collection to be adapted to meet changing circumstances. The ability to act as low cost, easily deployable, communications nodes will also aid this. They can enable more agile distribution for supplies as they can be routed as required, and are not constrained by surface infrastructure.

More Examples...

Drones to deliver medical supplies
in humanitarian missions

<https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1462760058735-442>

UAVs and drones
for agriculture

<https://www.theguardian.com/global-development/2015/dec/26/drones-farming-crop-problems-uavs>

Drones build rope bridge

<https://www.youtube.com/watch?list=PL0vyE01Abq2nBsh9R-RekNtao3G-ptmCH&v=CCDIuZUfETc>

Project Breakthrough

Disruptive Technology Executive Briefs

ADDITIVE MANUFACTURING

The rise of the makers

At its simplest, additive manufacturing is the process of building up a three dimensional object layer by layer from a digital file, adding material only where it is needed. This contrasts with traditional manufacturing methods that start with a raw material that is then reduced to its desired size and shape. The full applications of this technology are being seen as it moves from prototypes to full-scale industrial production, in areas ranging from food, to aerospace and healthcare.

The technology

Additive manufacturing (or 3D printing) has developed from a number of technologies that emerged over the past 20 years, including software, automation, materials science and post-processing. The technology is now available through off-the-shelf printers and is increasingly being integrated with conventional production technologies for industrial applications.

The potential

Additive manufacturing can reduce waste, challenge global supply chains (through localised manufacturing) and offers flexibility in the manufacturing process. Although the equipment required can still be quite expensive, new business models, such as Fab Labs, are increasing its accessibility. With the business case for using additive manufacturing in small scale and customised production already clear, we can expect to see rapid expansion of the technology's applications in both industrial and consumer uses.

The barriers

Slow print times, the quality of surface finish and high raw material costs (materials are often specific to brands of printers) will impede adoption in mass production environments. However, in certain areas, such as food, the choice and accessibility of materials makes its use more attractive.

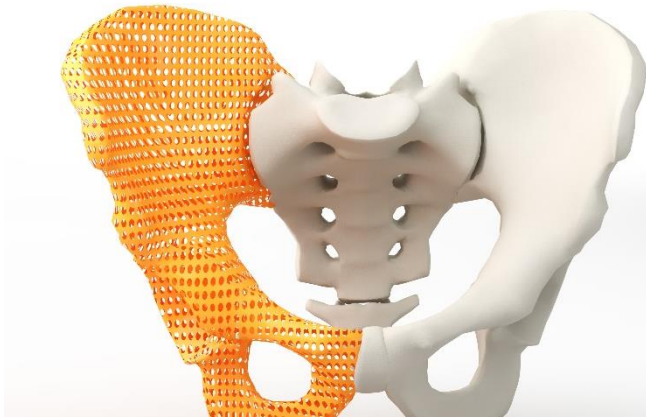
Concerns over how the technology could be used for illegal activity, such as 3D printing of guns, as well as fears over potential unemployment resulting from the disruption of current business models have captured headlines and are likely to remain issues as the technology develops.



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Some Example Applications...



Medical implants

Despite the fact that everyone is unique, medical products, such as, artificial joints have for a long time only been available in standard shapes and sizes, with minimal customisation. Additive manufacturing can provide far greater personalisation of products. Renishaw used their additive manufacturing technology to recreate parts of a motorcycle crash victim's skull – allowing for reconstructive surgery that would not have otherwise been possible.

Flying high

GE is developing its biggest ever engine using 19 3D-printed fuel nozzles that spray fuel inside the combustion chamber. The conventional nozzles they replaced had more than a dozen welded parts but the new nozzles do not need these. This has helped reduce the engine's weight by 25%, increase fuel efficiency, and make it quieter.

Bioprinting

Organovo Inc. have demonstrated that it is possible to print models of human organs and tissues, such as liver, kidney and skin.

Plastic waste used as feedstock

Indian company Protoprint have partnered with a Pune based waste picker co-operative to set up a low cost 3D printer filament production facility. They are able to offer a price an order of magnitude higher to the pickers for the collected waste HDPE, and still make a profit of 600%.

The 3D home

In 2016, Apis Cor 3D printed a 38 square metre home in 24hrs for \$10,000. Though this was just the walls, and windows, roof and insulation still needed to be added, it demonstrated the breadth of potential this technology can have.

Key Numbers

\$21 bn

Estimated additive manufacturing market size in 2020

Source: Statista

6.7 mn

Estimated global shipments of 3D printers in 2020

Source: Statista

30,000+

Number of 3D printing patent applications to date

Source: 3D Printing Industry

Advancing the Sustainable Development Goals (SDGs)



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Additive manufacturing has the potential to advance many of the SDGs. Below are some examples of areas of application across a wide variety of sectors.

■ SDG 1 No poverty

- Reduce the cost of making or buying advanced products and components.
- Enable cheaper and easier repair, through production of spare parts – even when they might have been discontinued.

■ SDG 2 Zero hunger

- Reduce the quantity of food that is wasted during production, helping to lower costs and increase availability.

■ SDG 3 Good health and well-being

- Provide access to customised medical devices and prosthetics, improving quality and comfort for users while reducing cost.
- Manufacture body parts that currently rely primarily on donors, such as internal organs.

■ SDG 8 Decent work and economic growth

- Increase global resource efficiency in consumption and production.
- Support increases in economic productivity.
 - Enable new, localised production - with access to the required feedstocks (such as plastics) a whole product range can be manufactured in dispersed sites, reducing shipping and logistics costs, and allowing products to get to places where they would not normally be available.

■ SDG 9 Industry, innovation and infrastructure

- Improve the share of Gross Domestic Product that comes from industry by allowing more economies access to the tools and capabilities to manufacture complex products.
- Increase access for small scale producers through the lower capital cost of manufacturing complex products.
- More flexible manufacturing as there is no need for expensive moulds, multiple/different production lines or time consuming tool changes.
- Innovation through precise placing of ingredients allows the production of new forms, intricate designs, and targeting of functionality and active ingredients.

■ SDG 11 Sustainable cities and communities

- More localised production would reduce transport needs and the resulting congestion/pollution.
- The printing of buildings can assist in both the rapid construction of dwellings when needed, but also in producing structures (or aspects of structures) that were not previously possible.

■ SDG 12 Responsible consumption and production

- By adding, rather than reducing / removing, additive manufacturing reduces the amount of waste during production.

Potential Negative Impacts and Barriers

As additive manufacturing proliferates, its accessibility and affordability pose risks and benefits in equal measure:

Illicit goods

The widely publicised manufacture of a 3D printed gun demonstrated the ability of additive manufacturing to produce firearms. While it is already possible to make a rudimentary firearm with many tools available from a local hardware store, additive manufacturing removes the skill required - making it easier and more accessible and raising concerns about its misuse.

Intellectual property

Safeguarding the intellectual property of additive manufacturing designs may become a key legal battleground. As the designs will be digital, they can be shared and this means they can be more easily copied. This may allow rapid distribution, but authors may not receive recognition for their design. How this is addressed may aid, or inhibit, the transformative power of additive manufacturing.

Access

Ethical concerns will play a key role in relation to the availability of additive manufacturing. The ability to bioprint new organs or body parts can bring huge benefits but its usage and availability risks widening the gap between the medical options available to the rich and poor.

Case for change

If localised production becomes the norm, this will disrupt traditional manufacturing industries and their supply networks. This would be a shift rather than a replacement, although the short term effects could be disruptive, resulting in potential job reductions.

Development costs

While 3D printing can appear cheap for low volume items, because of the reduced set up costs, at present it is not economical for high volume production. The cost of some materials (especially plastic and metal powders) is a lot more expensive than material stock for conventional manufacturing. However, in food production there is increasing research into ways additive manufacturing can produce items quicker and more economically than the traditional approaches.

Technical Considerations

There are still some technical barriers to overcome before additive manufacturing can be adopted on a large scale .

Materials science

Materials science is key to the new developments in printing. Currently materials require varying levels of pre-treatment to prepare them for the printing process. This is often expensive and proprietary technology. The feedstocks also have varying levels of sustainability/recyclability which need to be addressed. Investing in research and technology to increase the range of materials (included recycled materials as a feedstock) and their availability whilst reducing their cost will be key to more wider adoption.

Production speed

In most additive manufacturing applications, both print time and the time required for post processing (completing surface finishes) are not as fast as for traditional manufacturing techniques. This is not an issue for small volume, specialist components. However, focussing on technologies to overcome this will be the key to unlocking the full potential of this technology.

Design challenges

Today's products are not designed with additive manufacturing in mind. For complex parts it is often down to the skill of a designer to set the printer to maximise the chance of success. Increasingly advanced software is being developed to overcome this, though there is plenty of scope for continued development.

Enabling New Business Models

Additive manufacturing has the potential to impact manufacturing and distribution across a range of sectors, particularly where small-run applications and customisation is valuable

Much as digital computers unleashed a wave of innovation in the 1970s which is still felt today, additive manufacturing could lead to similar disruption to business models. The breadth of materials, and range of scales it can use means it has potential to disrupt a large number of established sectors e.g. food, consumer products, pharmaceuticals, industrial, healthcare, infrastructure, and transport. It also avoids the need to hold spare inventory, reducing warehousing costs, and overstocking. The impacts will be felt across value chains from extraction to servicing including:

- More efficient production to reduce demand for raw materials
- Democratising product design
- Development of new transformative products through rapid prototyping and new functionality
- New flexible production techniques, responsive to local needs. Local flexible production capabilities (fabrication labs)
- Reduced need for global distribution and supply chains due to local production
- Servicing through local repair and refurbishment.

Additive manufacturing potentially changes the economies of scale equation, affecting incumbent businesses, and creating opportunities for small-scale providers which could better serve niche and local markets.

Additive manufacturing will enable a number of the disruptive business model levers identified on the Project Breakthrough website, specifically:

A more personalised product or service

Additive manufacturing enables businesses to design, produce and offer unique personalised products in cost effective ways.

A closed-loop process

Additive manufacturing produces less waste by its very nature, it is additive rather than reductive. By enabling local production and use of local feed-stocks such as plastics, it helps accelerate the shift towards closed-loop production and consumption.

Agility

The inherent flexibility in additive manufacturing equipment means that organisations can rapidly prototype during development, and then reconfigure existing equipment to manufacture new products.

More Examples...

NASA funds 3D food printer

<http://inhabitat.com/nasa-funded-food-3d-printer-gets-its-first-prototype-3d-prints-an-entire-pizza/>

3D printing used in construction

<http://www.economist.com/news/science-and-technology/21722820-think-spiderweb-floors-denser-skyscrapers-and-ultra-thin-bridges-3d-printing-and>

Daimler uses 3D printing for spare parts

<http://fortune.com/2016/07/13/daimler-trucks-3d-printing-spare/>

Project Breakthrough

Disruptive Technology Executive Briefs

AUTONOMOUS ROAD VEHICLES

Revolutionising travel and logistics

Over the last five years, the automotive sector has made significant advances towards fully autonomous vehicles. This will impact cars and trucks, but also all types of road vehicle from buses to refuse collection. It will offer huge advantages. Eliminating vehicle collisions (making our roads much safer), optimising the movement of vehicles (reducing congestion and leading to greater efficiency), and freeing up drivers' time (to do other things rather than driving) – to name just a few. Pilots are underway and over a 30 - 40 year timescale it will have a significant impact on our lives.

The technology

Technologies being developed enable the full transfer of driving function from the driver to vehicle systems. Manufacturers are testing, on public roads, vehicles with greater levels of autonomy, including those with full self-driving capability. This capability is dependent on vehicle systems being able to analyse, in real-time, large volumes of complex data, make appropriate decisions and draw together many existing and developing technologies into an integrated system. It is this integration where much of the technical complexity lies, both in ensuring that the constituent technologies are sufficiently mature and that they will work together seamlessly. It is not just the technologies on board the vehicle but those embedded into the road infrastructure that need to be considered.

The potential

The autonomous road vehicles revolution will change the way we think and interact with the sector. It is opening up new business opportunities, such as the provision of healthcare as you commute. It will change ownership models, with people opting to buy mobility when they need it – allowing vehicle assets to be used more and therefore transport costs to be reduced. It will also pose interesting challenges for town planners – if vehicles are in use much longer what can valuable parking space be used for?

Current activity is focused on the developed world. However, the developing world has huge potential for this technology and the ability to potentially jump ahead in some cases.

The barriers

The eco-system in which autonomous road vehicles will exist is incredibly complex. Successful deployment is dependent on more than the technology. Regulation, insurance and commercial models are just some of the areas that need to come together – and are arguably where the real complexity lies.

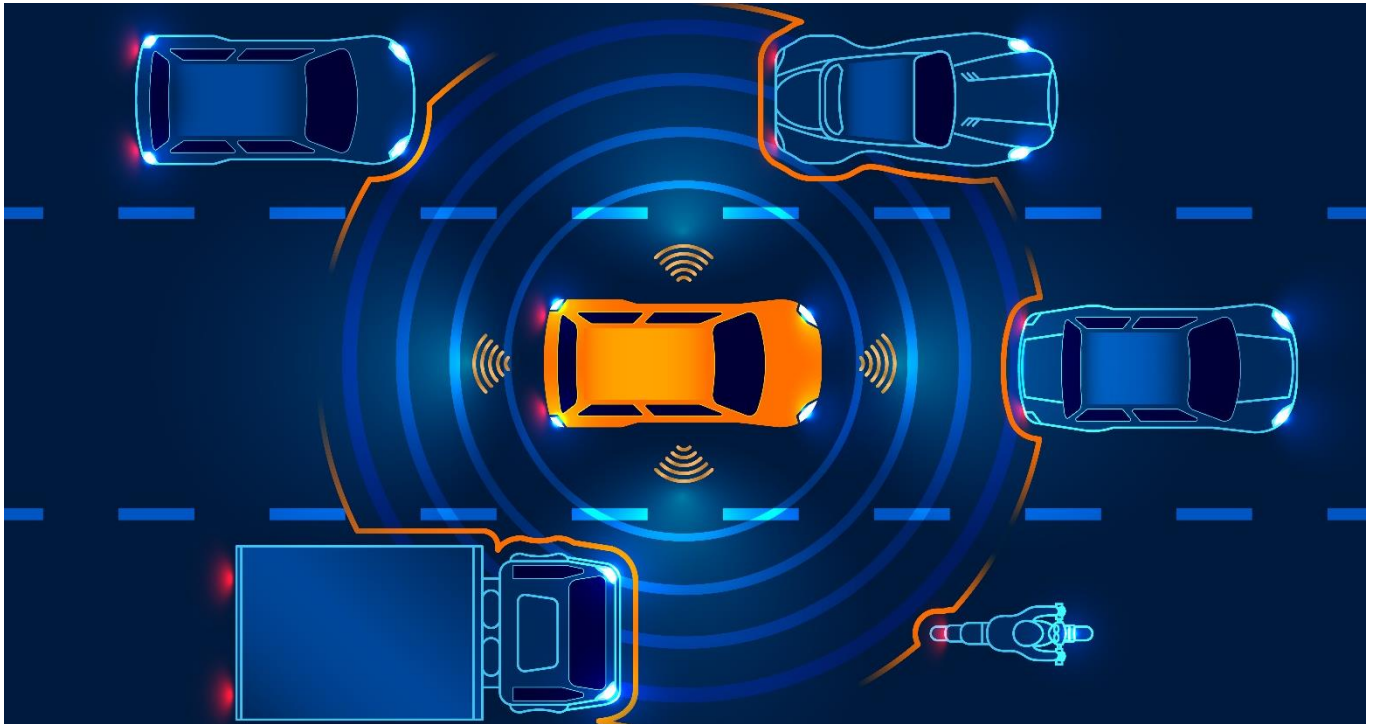
The impacts on employment will need to be actively addressed to minimise negative affects and avoid public resistance.



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Some Example Applications...



Driverless cars

Perhaps the best known examples of autonomous vehicles have been the driverless cars being tested by Uber. In September 2016, Uber started conducting a trial in the city of Pittsburgh (USA) using a fleet of cars laden with lasers, cameras and other sensors to enable it to drive with no one holding the steering wheel. These vehicles were deployed on the roads to pick up Uber passengers and drive them to their destination.

Driverless bus

In 2016, Helsinki trialled a self-driving bus, in one of the first tests of its kind. Since then other cities, such as Las Vegas and London, have followed suit, with more expected to follow.

Freight platooning

MAN and DB Schenker are planning European platooning trials in 2018. Platooning is where a number of vehicles are connected together and control is handed to the lead driver. Platooning has the potential to be one of the first examples of partial autonomy we see on the roads.

Autonomous waste collection

The city of Gothenburg in Sweden is trialling an autonomous refuse collection truck throughout 2017. This reduces collection times by removing the need for operators to constantly jump on and off the vehicle.

Key Numbers

\$42 bn

Estimated autonomous vehicle market size (all levels/types)

Source: Statista

2309

Autonomous vehicle patents filed by leading automotive and digital companies in the last 6 years

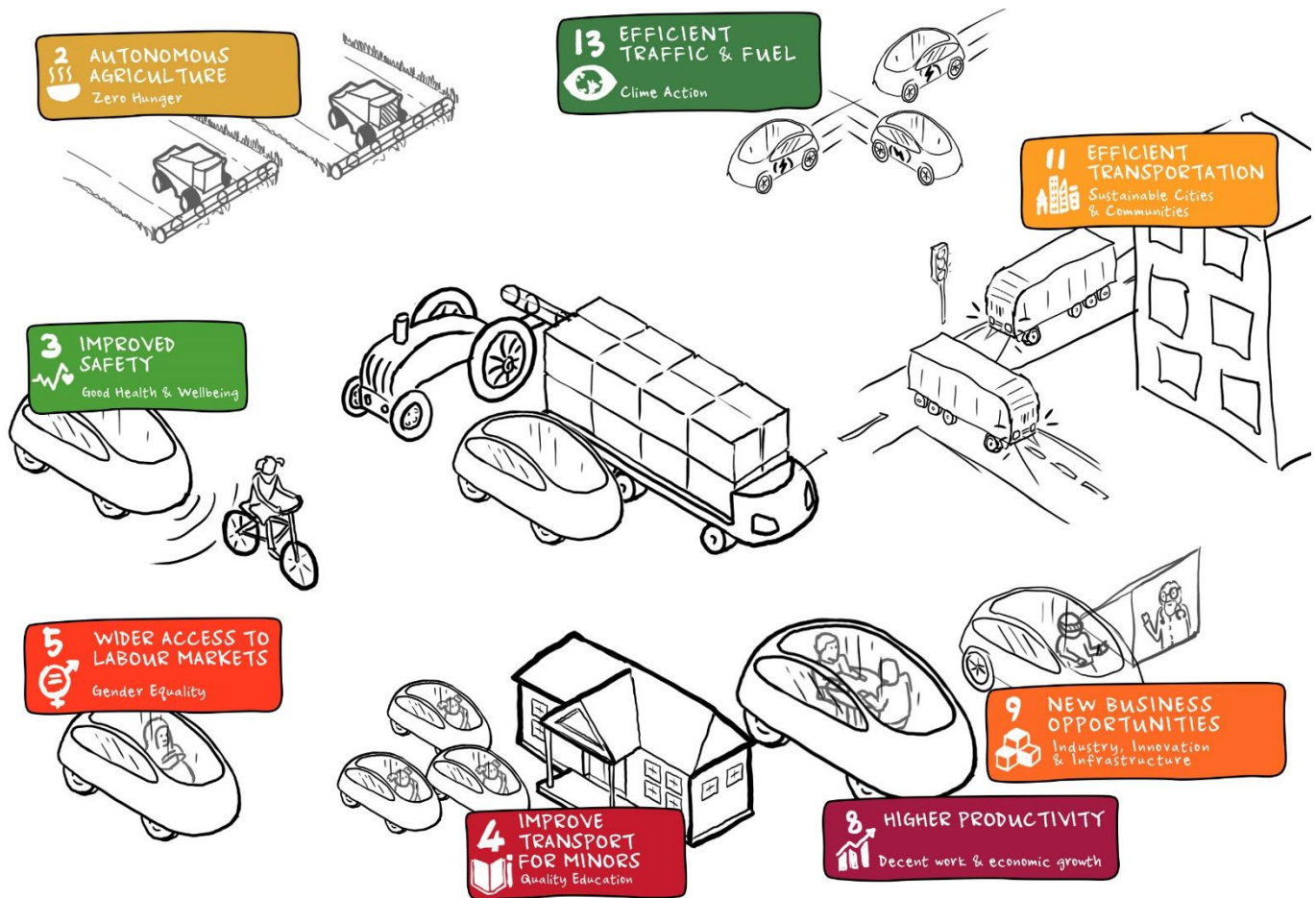
Source: Statista

91.5 mn

Estimated number of driver assistance systems to be on the roads by 2020

Source: Statista

Advancing the Sustainable Development Goals (SDGs)



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Autonomous vehicles have the potential to advance many of the SDGs. Below are some examples of areas of applications across a wide variety of sectors.

■ SDG 2 Zero hunger

- Reduce agriculture costs through autonomous vehicle provision.
- Provide vehicle access to farmers who might not have had it previously.

■ SDG 3 Good health and wellbeing

- Contribute to reductions in deaths from road traffic accidents through improved road safety.
- Contribute to reduced automotive emissions and improved air quality and health.

■ SDG 4 Quality education

- Increase access to education through provision of automated transport, changing the balance of how schooling is delivered and increasing quality for all.

■ SDG 5 Gender equality

- Empower a wider female workforce through removing the need to drive to access labor markets.

■ SDG 8 Decent work and economic growth

- Higher levels of economic productivity through greater efficiencies in labour-intensive sectors involving transportation.

■ SDG 9 Industry, innovation and infrastructure

- Introduction of technologies that enable reduction in carbon footprint through greater efficiencies.
- Efficient use of people by removing the limiting conditions surrounding certain roles.
- Opportunities for new and innovative products and service models.

■ SDG 11 Sustainable cities and Communities

- Improved road safety through fewer road collisions and deaths.
- The opening up of parking space for other uses
- Affordable transportation systems of goods and people through increased efficiencies.
- Improved transportation access for the elderly and disabled.

■ SDG 13 Climate action

- Contribute to improving the climate through the combined effects of air quality improvements and reduced fossil fuel usage.

Potential Negative Impacts and Barriers

When thinking of autonomous vehicles, people often focus on the car and the technology behind it. However, much of the complexity lies in bringing together all of the other supporting parts of the system, from insurance to commercial models. There are also significant challenges in balancing the positive and negative impacts, with improved safety and a reduced environmental impact on one side against loss of employment on the other.

Employment

Autonomous vehicles promise cheaper transport of people and goods due to reduced labor costs but this must be considered against the impact on jobs.

Sharing the roads

Safety is a leading benefit of autonomous vehicles due to their ability to monitor the environment and react to incidents far more quickly than human drivers. They also reduce erratic behavior by drivers or the risk of driving under the influence of alcohol or drugs. But there are major uncertainties about how these vehicles will safely integrate with non-autonomous vehicles, and some studies predict they will initially worsen congestion in a mixed fleet. The safe operation of partially autonomous vehicles is also challenging, particularly when the vehicle requires the driver to take back control.

Rebound effect

Autonomous vehicles will make transport cheaper, as such, many experts think this could result in more journeys being made. However, given the efficiency

gains this is still likely to result in a net positive environmental impact.

Liability and regulations

The question of liability when the vehicle is being driven by an autonomous system has led some automotive manufacturers to accept responsibility for any system error that has led to an incident, fueling a whole new model for insurance. National and international regulations will also be required to ensure the safety and road worthiness of vehicles.

Ethics

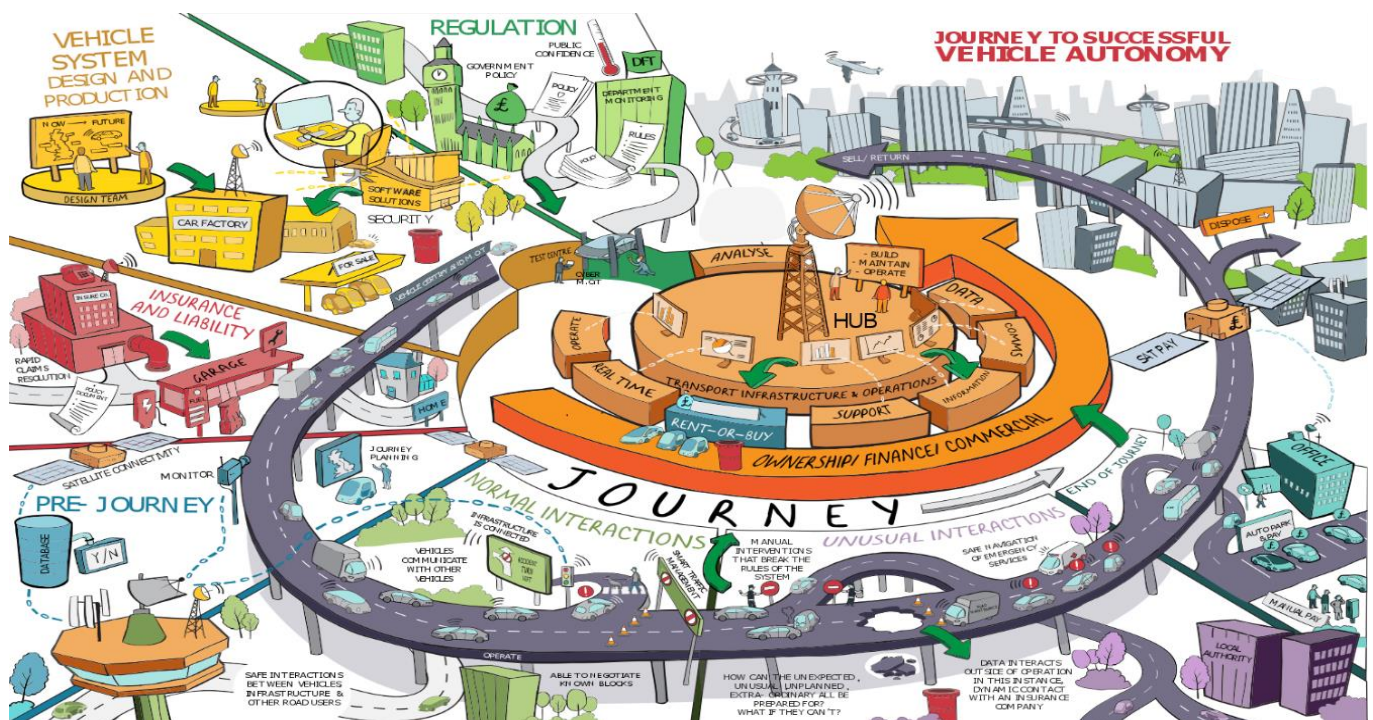
Autonomous systems will need to be able to make very difficult decisions which would traditionally be managed by a human's value system. An example might be whether they system will have to reflect whether it is better to hit a pedestrian or brake heavily causing the vehicle behind to hit the autonomous vehicle potentially injuring the "driver".

International cooperation

A truly autonomous travel experience will require inter-governmental agreement on a long term vision and identification of programs of action to establish a common framework to realise its benefits and allow autonomous vehicles to operate seamlessly across international borders.

Business Case

The true costs for autonomous road vehicles and likely benefits are predicated on assumptions. If any of these assumptions turn out to be false their business case could be impacted, either slowing or pausing the roll out of this technology.



Technical Considerations

The advent of autonomous vehicles brings with it new and diverse challenges for both manufacturers and consumers, and these will need to be overcome as they adapt to them.

Disengagement

Disengagement is the process where a human driver intervenes in the normal autonomous operation of the car to prevent an accident. Autonomous system manufacturers are investing significant resources in overcoming the challenges of this kind of intervention through a combination of hardware and software as early research shows that drivers take a substantial amount of time (seconds) to readjust to driving again bringing consequent safety risks.

Testing

For the technology to be proved an increasing amount of testing in ever more complex environments will need to be conducted. Though some countries are more mature in their testing legislation than others, all will need to develop and grow their testing regulations in order to facilitate the growth of this technology.

Security

Just as theft of modern vehicles with keyless entry technology has increased, autonomous vehicles bring with them their own security challenges. If the network or vehicle security were to be breached, control of the vehicle could be gained by a third party. Ensuring security in such a highly technical environment across national borders will also prove difficult unless certain international standards for the necessary security measures are developed.

Road Infrastructure

Without clearly defined standards and emerging autonomous vehicle technologies, the technology that will enable the road infrastructure to adapt to autonomous vehicles has not yet been defined. The changes to existing infrastructure, such as traffic signals or road layout, could be significant and would require extensive design work to ensure it is suitable for both autonomous and non-autonomous vehicles (in the interim), as well as other users such as pedestrians and cyclists.

Enabling New Business Models

Autonomous vehicles open the door to mobility as a service

Autonomous vehicles have the potential to transform the efficiency and effectiveness of transport and logistics. Removing the need for a human driver coupled with new mobility service models may change the current model of car ownership and radically improve the utilisation of vehicles (it is estimated that cars are idle for 92% of time). In logistics, autonomous vehicles will not be limited by the legislative and physical constraints on how long human drivers can safely drive for, and may also benefit from smarter routing and offer ways to reduce the costs of the final stages of delivery of goods to a customer.

Current manufacturers of vehicles are already well aware of the impact of non-traditional new entrants. Technology companies such as Google and Apple experimenting with autonomous vehicles and Tesla producing new electric vehicles threaten to take market share. Equally, companies like Uber or Lyft are changing the competitive dynamics of the taxi business.

The business model for vehicle ownership will develop. Manufacturers will need to decide whether to provide mobility services, act as fleet owners, transport service

providers or continue to sell vehicles to individuals. However, in the short term, the impact of autonomous vehicles is likely to be seen more in urban areas, where increased population densities make the economic benefits more attractive.

Autonomous vehicles will enable a number of the disruptive business model levers identified in the Business Model section of the Project Breakthrough website, specifically:

A more personalised product or service

By enabling transport as a service, autonomous vehicles will allow personalisation of meeting transportation needs, rather than being tied to a personally owned vehicle.

Asset sharing

By removing the need for a human driver, autonomous vehicles may de-personalise transport ownership and enable asset sharing.

Usage-based pricing

Providing transport as a service rather than through vehicle ownership will require usage-based pricing provided by autonomous vehicles.

More Examples...

Embark trial trucks that drive autonomously between cities

<https://finance.yahoo.com/news/embark-unveils-self-driving-truck-130000503.html>

Apple's plans for an autonomous car are starting to become public

<https://www.ft.com/content/5c643f94-b983-11e6-8b45-b8b81dd5d080>

Helsinki trials self-driving buses

<https://www.theguardian.com/technology/2016/aug/18/self-driving-buses-helsinki>

The Disruptive Technology Executive Briefs were produced for UN Nations Global Compact, cross sector technology, innovation and business design expertise.

The briefs are intended as an easy to digest introduction to disruptive technologies, to help organisations understand how they could advance the Sustainable Development Goals and business performance.

These overviews explore key features, examples of applications, potential positive and negative impacts, and how they may enable the new business models.



United Nations Global Compact

The United Nations Global Compact is a call to companies everywhere to align their operations and strategies with ten universally accepted principles in the areas of human rights, labour, environment and anti-corruption, and to take action in support of UN goals and issues embodied in the Sustainable Development Goals.

The UN Global Compact is a leadership platform for the development, implementation and disclosure of responsible corporate practices. It is the largest corporate sustainability initiative in the world, with more than 9,000 companies and 3,000 non-business signatories globally.



Project Breakthrough

Project Breakthrough – a collaboration between UN Global Compact, Volans and partners – spotlights the best thinking in sustainable innovation. It showcases innovators across mainstream companies and next generation entrepreneurs who are developing solutions with the potential to achieve exponential impact. It features analysis and resources designed to help leaders understand the new business models and technologies that will be crucial in achieving the SDGs, catalysing action amongst today's businesses to meet the needs of tomorrow's world.



The Disruptive Technology Executive Briefs are produced in collaboration with PA Consulting Group, combining cross sector technology, innovation and business design expertise. The briefs are intended as an easy to digest introduction to disruptive technologies, to help organisations understand how they could advance the Sustainable Development Goals and business performance. These overviews explore key features, examples of applications, potential positive and negative impacts, and how they may enable the new business models.

Visit www.projectbreakthrough.io for more information, or contact projectbreakthrough@unglobalcompact.org



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