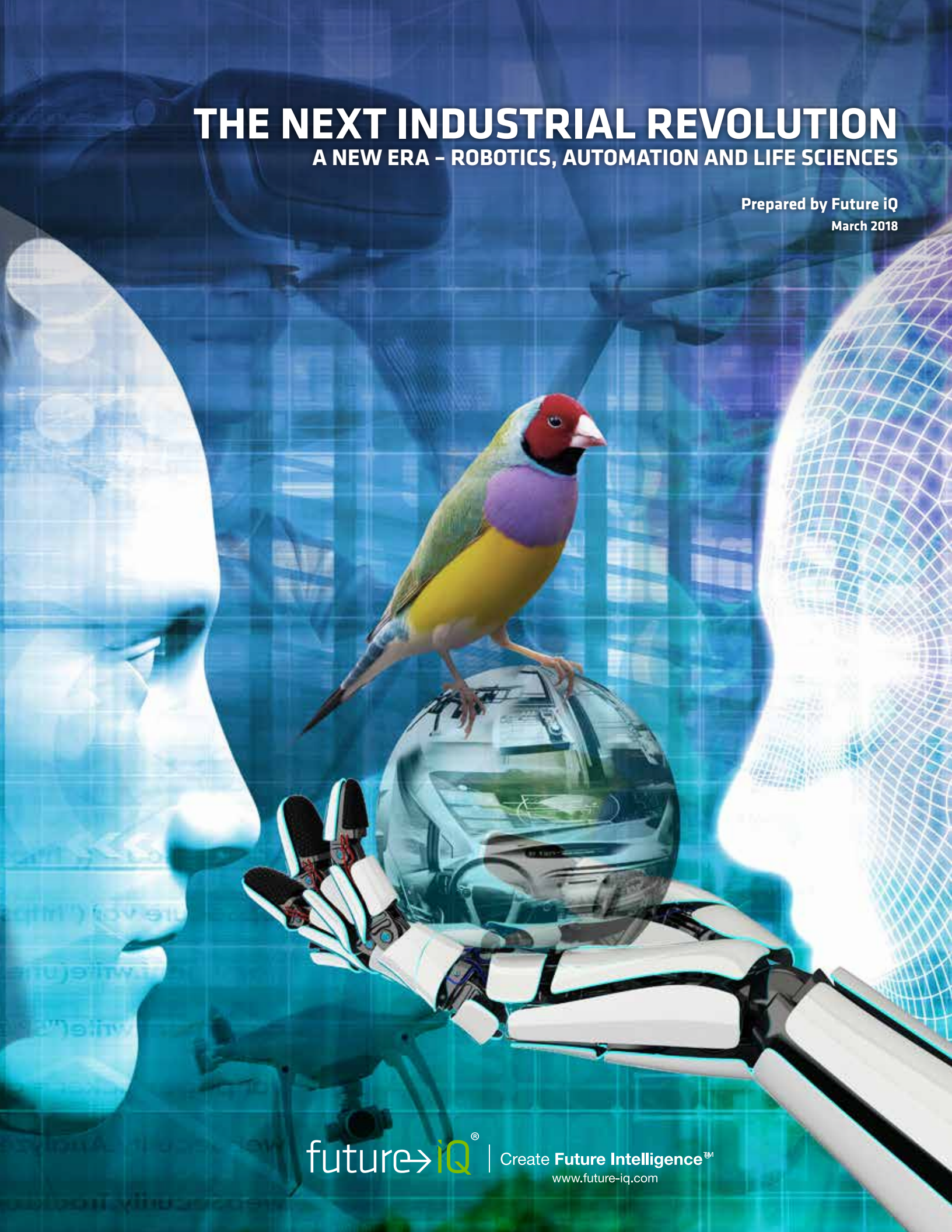

THE NEXT INDUSTRIAL REVOLUTION

A NEW ERA – ROBOTICS, AUTOMATION AND LIFE SCIENCES

Prepared by Future iQ

March 2018

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THE NEXT INDUSTRIAL REVOLUTION

A NEW ERA - ROBOTICS, AUTOMATION AND LIFE SCIENCES

This foresight report aims to explore the emerging era of the Next Industrial Revolution. This revolution is a continuation of the industrialization the world has seen over the last 200 years. While initially driven by industrial advances, this era of innovation will have implications and ramifications for all societies and human beings across the planet.

March 2018

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Richard King Mellon Foundation

This work has been funded by the Richard King Mellon Foundation. This foresight report is a part of a larger study exploring the potential impacts and implications of the Next Industrial Revolution on the Pittsburgh and Southwest of Pennsylvania region. Since 1947, the Richard King Mellon Foundation has invested in the future of Southwest Pennsylvania, and in the protection and restoration of America's environmental heritage.

INTRODUCTION

The Next Industrial Revolution foresight research is presented by Future iQ as an exploration of emerging trends, and potential implications. Whilst driven initially by the industrial sector, this stage of industrialization will ultimately transform our lives and the planet.

What is remarkable about this stage of industrialization is that it is being driven by the systemic transformation of technology, information and innovation on a global scale, and at a pace faster than ever before. We examine some of the factors driving this revolution and which are catalytic to the transformations taking place. 3D printing, autonomous vehicles, robotics and automation will become the new normal. We look at the Internet of Everything and advances in life sciences and we ask some probing questions.

- How will Artificial Intelligence, predictive modeling, cyber systems and big data impact us, and what will be the speed and scale of change?
- What will the Next Industrial Revolution mean on a global scale? What will the implications be for manufacturing, the global workforce and society in general?
- As we look into the future, how will the Next Industrial Revolution impact on our cities, human health and ageing and our capacity to feed the world?

From our perspective at Future iQ, we view this emerging era of the Next Industrial Revolution with intense interest. It holds the promise of delivering solutions for some of our larger societal challenges, and it has the potential to delivery untold good to billions of people. We have absorbed enormous change in the past 40 years, without societal meltdown. However, we believe the future pace and nature of change will test human ingenuity and resilience at new levels. Our ability to adapt and thrive will require an increasingly astute and keen appreciation of the broader challenges.

One thing we don't have on our side is time. For many communities and regions, this highlights the necessity to invest in understanding, anticipation and preparation.

DAVID BEURLE

CEO, Future iQ

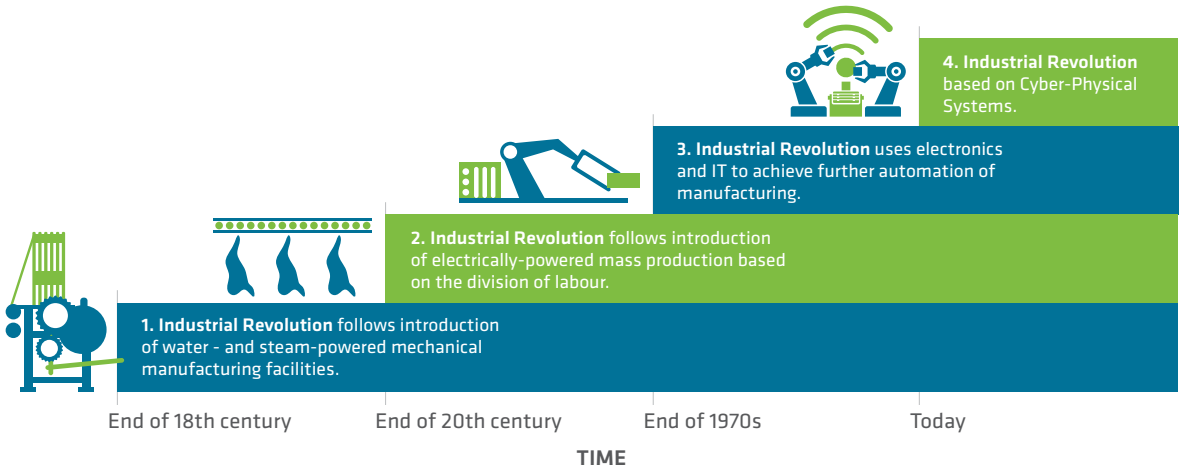
The Next Industrial Revolution will fundamentally change our lives. Are we ready?

1.0 DEFINING THE NEXT INDUSTRIAL REVOLUTION

The world is changing – fast. We are entering a new era of the broader industrial revolution that has been occurring in stages over the last 200 years. This new era of industrial revolution, commonly referred to as Industry 4.0 or Fourth Industrial Revolution, will again change our lives and humanity.

Billions of people and countless machines are connected to each other and becoming more so. Through groundbreaking technology, unprecedented processing power and speed, and massive storage capacity, data is being collected, harnessed and used like never before. Automation, machine learning, mobile computing, artificial intelligence and augmented reality – these are no longer futuristic concepts, they are our reality.[1]

THE FOUR STAGES OF INDUSTRIAL REVOLUTION



Source: Industry 4.0: the fourth industrial revolution – guide to Industrie 4.0. November 2017.

Throughout this foresight report, we are using the term **Next Industrial Revolution**. We are using this term as we aim to explore the broader implications beyond just industry. Previous stages of the industrial revolution have reshaped every aspect of our lives, and the effects continue to reverberate through society. The speed and magnitude of change associated with this stage is likely to be greater than anything we have previously seen.

"All of us need to understand that quantum change is happening and that preparing for it is our collective duty. Technology's march toward the future is inevitable. What's not inevitable is the quality of our preparedness. We all have some work to do."

Tim Pawlenty, "We're at the Dawn of the Fourth Industrial Revolution", Star Tribune, 2 June 2017. (Former Governor of Minnesota, 2003-2011).

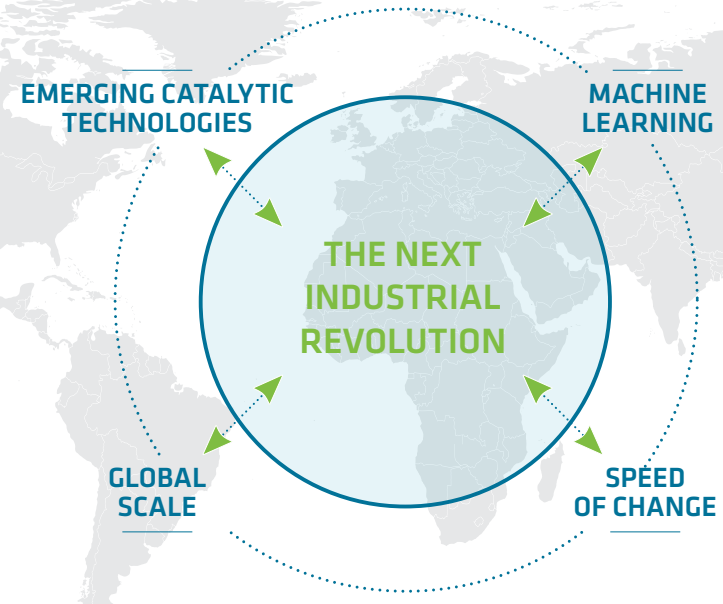
How will humanity adjust to the advent of Artificial Intelligence?

2.0 FACTORS DRIVING THIS REVOLUTION

The Next Industrial Revolution is being driven by the systemic transformation of technology, information and innovation on a global scale.

This report does not intend to detail every aspect, but it will delve into four primary factors driving this stage of industrialization. These factors will reshape our industries, and will transform many facets of societies and human lifestyle.

The four primary factors of the Next Industrial Revolution are emerging catalytic technologies, machine learning, speed of change, and the global scale of the revolution. These factors combine Internet Technology and Operational Technology which drive industry to automate and optimize. This will occur with increasingly higher speed and across many more horizontal and vertical sector networks worldwide. Increasing connectivity allows for a rapid rate of change and fluidity across the life-cycle of evolving products and services. This is moving us towards more autonomous decision making, a changing role for the workforce, new organizational and collaborative paradigms, and new 'smart systems'.[2]



"Never before in history has innovation offered promise of so much to so many in so short a time."

Bill Gates, Microsoft Cofounder

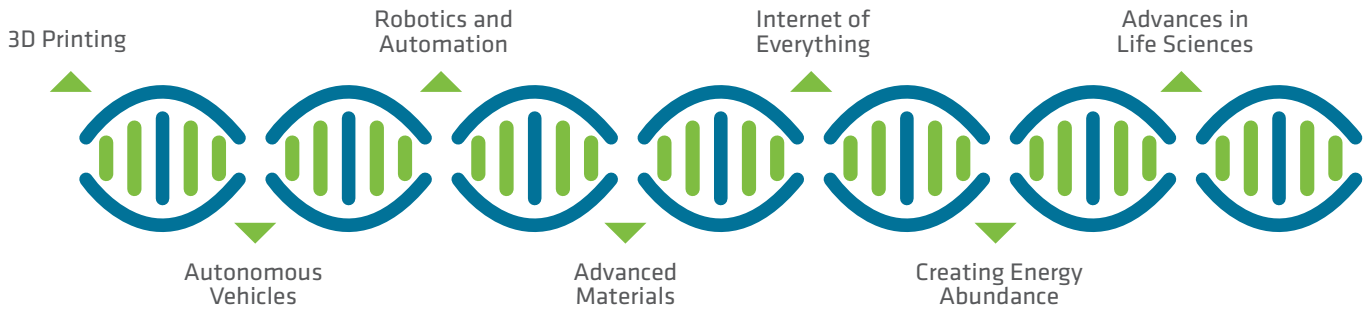
Which catalytic technology will have the biggest impact on your life?

2.1 EMERGING CATALYTIC TECHNOLOGIES

The Next Industrial Revolution brings with it an explosion of technological advances, some of which are catalytic to the transformations taking place. This section will explore the emergence of seven catalytic technologies impacting the global landscape of future technology: 3D printing, autonomous vehicles, robotics and automation, advanced materials, the internet of everything, creating energy abundance, and advances in life sciences.

The merging of the digital (IT) and physical (OT) technologies has resulted in smarter products and processes emerging from new combinations of advanced hardware and software, sensors, and massive amounts of data and analytics.[3] These advances are automating, integrating and optimizing the way we use materials, connect with each other and create products and services. What makes all of this possible is the way the Next Industrial Revolution is disrupting – and deepening – the relationships between manufacturing, customers, and suppliers. [4]

EMERGING CATALYTIC TECHNOLOGIES



Source: Adapted from: Advanced Technologies Initiative: Manufacturing and innovation, Deloitte Global and US Council on Competitiveness, 2012.

"Everyone gets smarter because of this technology...and the empowerment of people is the secret to technological progress."

Eric Schmidt, Executive Chairman, Google, USA, at Davos 2015.

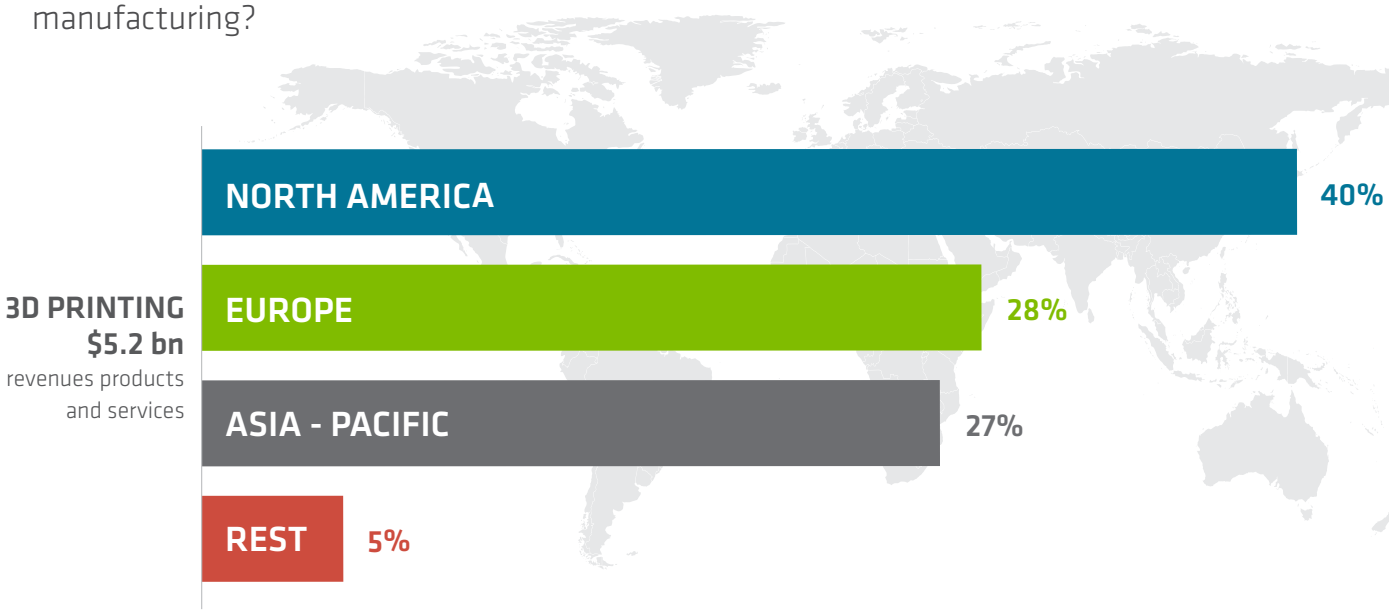
3D printing offersthe chance to revolutionize all scales of manufacturing. How will it disrupt the nature and location of traditional manufacturing?

2.1.1 3D PRINTING

3D printing, also known as additive manufacturing, is a technology that is revolutionizing production in the industrial sector on a global scale. It uses a process that builds components and products layer-by-layer rather than cutting them from larger stock or casting them in pre-formed molds. This leads to decreases in weight and variability, coupled with increases in strength and speed of production. [5]

This type of production is a hallmark of the New Industrial Revolution. It will enable people to customize and personalize 3D products not only to individual preferences, but also for example, to personal health needs such as food and medicines. Current research is also experimenting with the 3D printing of biologically healthy viable body parts with the eventual goal of eradicating chronic disease. In the near term, 3D printing has proven best suited to industries where customization and time to market are key value drivers – typically with low-volume, high-value parts, such as aerospace and healthcare. [6]

GEOGRAPHIC ADOPTION OF 3D PRINTING TECHNOLOGIES - MARKET SIZE



Source: International Federation of Robotics, Wohlers Associates, Technavio, IDC, expert interviews, A.T. Kearney

"3D printing is already shaking our age-old notions of what can and can't be made."

Hod Lipson, Director of Columbia University's Creative Machines Lab, New York.

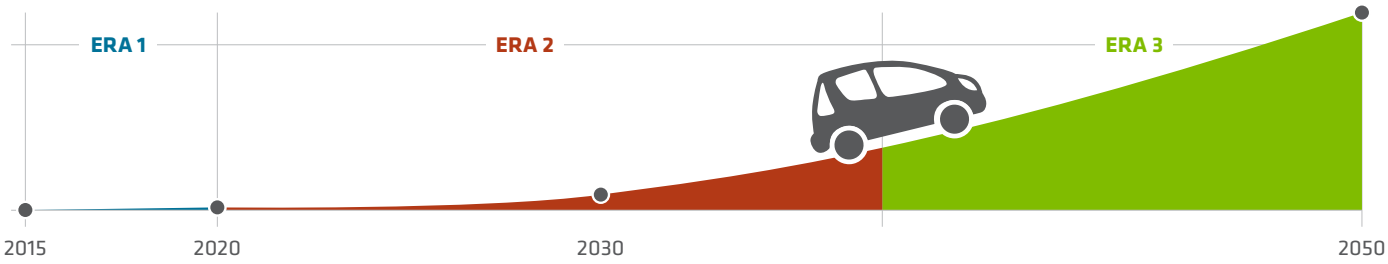
What would our cities look like without directional signs for drivers?

2.1.2 AUTONOMOUS VEHICLES

The Next Industrial Revolution ushers in an era of mobility driven without the human hand. Autonomous vehicles are not only cars and trucks on our roads, they are any vehicle you can imagine – from drones used in the military to rockets to autonomous machines used in vast warehouses. In cities and across the rural areas, the rapid adoption of autonomous vehicles will transform our global transportation systems and our community landscapes, making them safer, healthier, and better connected. [7]

Autonomous tractor-trailers have been used in Australia since 2014 to help with farming operations, and starting in October 2017, fleets of driverless cars are being test driven without backup drivers on public roads in the United States. [8] It is estimated that within the next ten years, over a million autonomous vehicles are expected to be in use worldwide. [9] The benefits of autonomous vehicles on our roads are many – most prominently vehicle safety (90% of all crashes are caused by human error), improved traffic flow, and increased mobility for segments of the population such as the elderly, people with disabilities, and the poor. [10]

THE SELF-DRIVING VEHICLE REVOLUTION - AN ILLUSTRATION OF POTENTIAL GROWTH



ERA 1:
Fully autonomous vehicles (AVs) being developed for consumers

- AVs are already a reality in industrial fleets
- Car OEMs begin to assess strategic impact
- New moblity models being to emerge

ERA 2:
Consumers begin to adopt AVs

- The after-sales service landscape is reshaped
- Insurers shift from covering individuals to covering technical failures
- Supply chain and logistics are redefined

ERA 3:
AVs become the primary means of transport

- AVs free up to 50 minutes a day for drivers
- Parking space is reduced by billions of square meters
- Vehicle crashes fall by 90%, saving billions of dollars
- AV technology accelerates development of robots for consumer use

Source: Ten ways automated driving could redefine the automotive world. McKinsey, 2015

"I don't think there's ever been a better, more exciting time to be a part of the automotive industry. Automated vehicle technology is going to revolutionize mobility – and transform society – in ways more profound than the move from the horse-drawn carriage to the Model T."

Larry Hutchinson, President and CEO of Toyota Canada, 2017 Talk AUTO Conference.

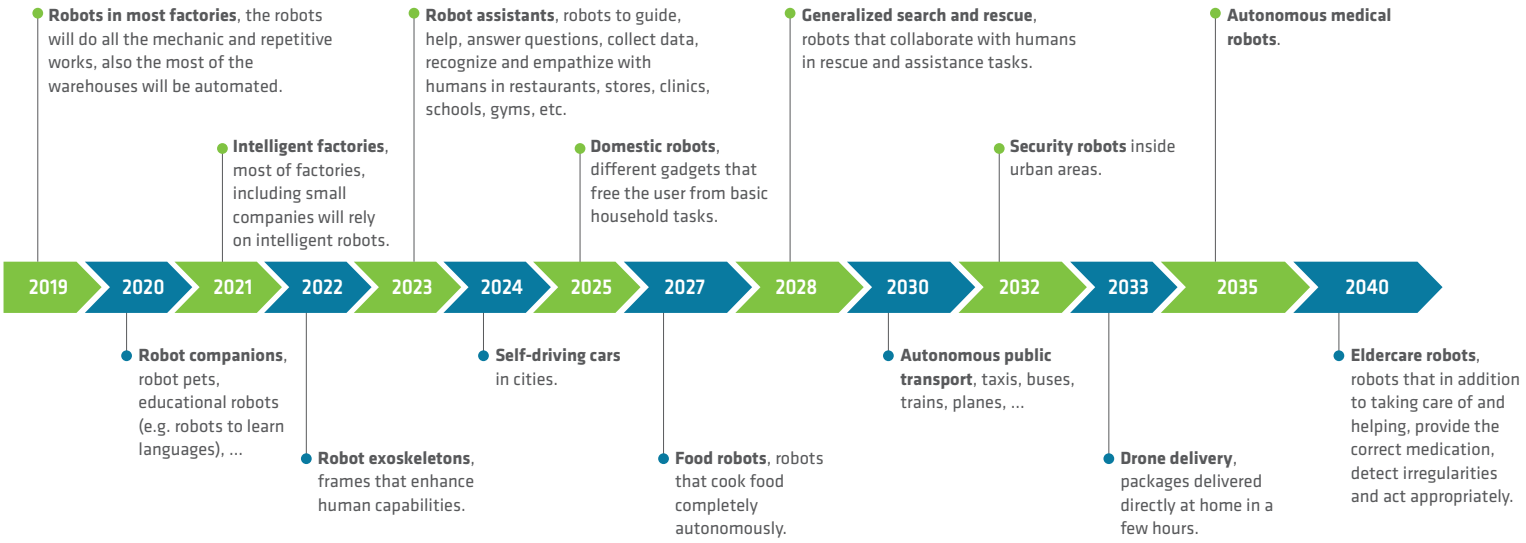
How will everyday activities change as robotics and other technologies advance?

2.1.3 ROBOTICS AND AUTOMATION

Next Industrial Revolution technologies are transforming robotics. As our understanding of Artificial Intelligence develops, the complexity of robotic decision making and autonomy will increase.[11]

Robots assisting people in everyday activities will become the norm, and transform our lives in a similar manner to mass integration of computers in recent decades. Mobile personal and service robots will become ubiquitous in our homes, retail and restaurant environments, offices and more, providing services such as delivery, carrying loads, complete meal preparation and serving, self-driving cars, cleaning, smart home management, medical procedures and care, education and agriculture. Ultimately, robots will be able to interpret detailed verbal cues, facial expressions, and body language, and provide appropriate responses, potentially providing companionship.[12] Some areas of development that could be particularly helpful are elder care and assisting people with physical limitations through connecting to remote care or family, monitoring how, where and when people move (looking out for falls or abnormal behaviors), and exoskeletons for mobility and strength.[13] The market for mobile robots is expected to reach $17.39 billion by 2020,[14] and robot technology will likely continue to develop to create special purpose equipment that increases the quality of life in many aspects.

THE FUTURE OF ROBOTS 2019-2040



Source: Envisioning Robotics, Robots Technology for Society, Acutronic Robotics, 2017, in Envisioning the future of robotics, Víctor Mayoral Vilches, CTO of Erle Robotics, March 26, 2017.

"Robots will become abundant in our homes, stores, farms, offices, hospitals, and all our work places. Like our current day hand-held devices we won't know how we lived without them."

Rodney Brook, co-Founder, Chairman and Chief Technical Officer of Rethink Robotics, November 10, 2014.

As connectivity increases exponentially, how will human communication and interactions evolve?

2.1.4 INTERNET OF EVERYTHING

The Next Industrial Revolution brings with it a level of connectivity like never before. Beyond the Internet of Things, the Internet of Everything is the intelligent and transformative connection of people, processes, data and things. It brings these elements together to make networked connections more relevant and valuable by allowing convergence, orchestration and visibility across previously disparate systems.[15]

The Internet of Everything is changing how people and things connect, how we collect and harness data, and how they all work together to enable intelligent processes.[16] While IoE will become the inevitable, all industries will need to deal with the issues of security, privacy, hardware compatibility, software compatibility, synchronization, wired infrastructure, data mining, data analysis and other issues to make IoE work worldwide.[17] It can be argued that the positives of this new connectedness far outweigh the potential negatives. The positive transformative nature of these connections can be demonstrated by examples in the healthcare industry - people monitor their health through their personal *FitBits*; can now be connected to doctors and monitored by swallowing a pill; and, looking ahead, expectant mothers will wear "smart tattoos" to monitor the health and activity of their babies and send their doctor an early alert when labor begins.[18]

THE INTERNET OF EVERYTHING: NETWORKED CONNECTION OF PEOPLE, PROCESS, DATA, THINGS

PEOPLE
Connecting people in more relevant, valuable ways

PROCESS
Delivering the right information to the right person (or machine) at the right time

DATA
Leveraging data into more useful information for decision making

THINGS
Physical devices and objects connected to the Internet and each other for intelligent decision making

Source: https://www.slideshare.net/CiscoIBSG/internet-of-everything-ioe-value-index-cisco

"When people ask why IoE (Internet of Everything) matters, there are many reasons we can offer. Perhaps the human element is the most important reason, as we work to make IoE more than just a game changer into a lifesaver."

How the Internet of Everything is Changing Lives.
Karen Walker. HuffPost, 20 October 2016.

How will the energy needed to fuel the Next Industrial Revolution be generated?

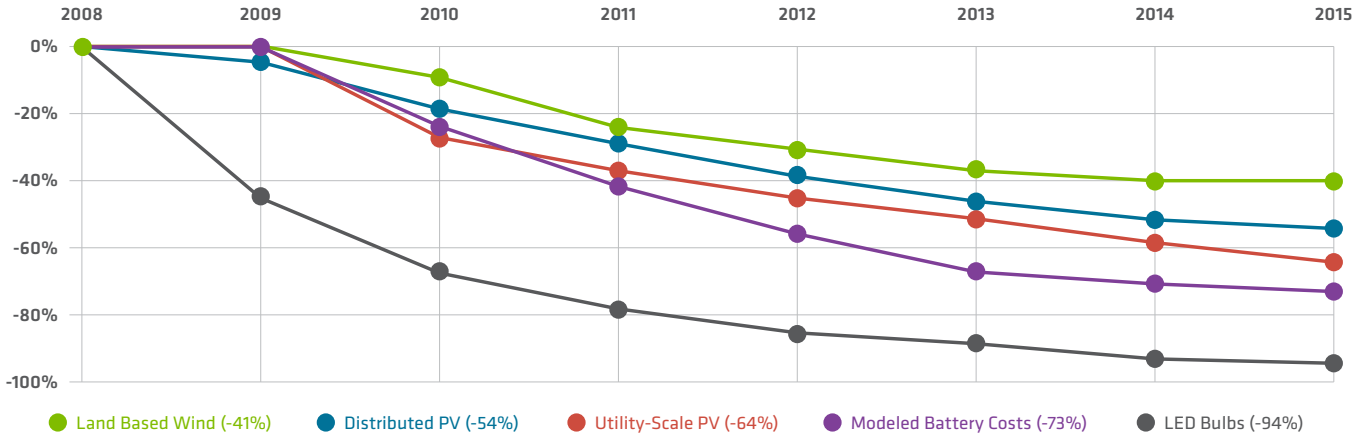
2.1.5 CREATING ENERGY ABUNDANCE

The shift in the dominant source of energy of past industrial revolutions has gone from the steam engine to coal to petroleum. The energy industry will likely look very different as it evolves in the coming decades with the shift from fossil fuels to renewal energy, and the incorporation of technologies within the Next Industrial Revolution. Electrification, decentralization and digitalization are converging to create widespread disruptions, smart connected technologies such as distributed storage, distributed generation, smart meters, smart appliances and electric vehicles are changing the electricity system.[19]

The energy industry is shifting to customers, from individuals to factories, being "prosumers"– both the producers and consumers of power. Local production and battery storage systems will allow users to be part of decentralized systems, such as small regional grids, and, even micro-grids of a few homes, rather than being dependent on a centralized grid infrastructure.[20] The decreasing cost of renewable energy, in particular, solar and wind, combined with net metering, regional grids and micro-grids will incentivize renewable energy, and reduce the stress on the grid infrastructure.

These changes have the potential to be part of the solution to addressing climate change, by reducing the current contribution of the energy industry's two-thirds of global greenhouse gas emissions.[21]

COST REDUCTIONS IN ENERGY TECHNOLOGIES 2008 - 2015



Daniel Wood, Data Visualization and Cartographic Specialist, Office of Public Affairs, NREL (Sept 2016).

"When solar energy is adopted by hundreds of factories and thousands of houses, the power supply system will be totally changed. Every school, every factory and every family will become a micro clean energy power station. We will be both energy consumers as well as energy producers. The direction of new energy revolution is to build an energy-sharing system, based on a large database and a smart-energy connection platform."

The Next Energy Revolution is Already Here: World Economic Forum, 2017

Will virtual and augmented realities eventually develop beyond immersive environments and mixed-reality experiences into augmentations and implants, blurring the lines between biology and machine?

2.1.6 ADVANCES IN LIFE SCIENCES

Technological innovations are transforming life sciences. Of the twelve key emerging technologies identified at the World Economic Forum in Davos in 21016, three are directly related to the life sciences and the Next Industrial Revolution.[22]

- **Biotechnologies** - Innovations in genetic engineering, sequencing and therapeutics, as well as biological-computational interfaces and synthetic biology.
- **Geoengineering** - Technological intervention in planetary systems, typically to mitigate effects of climate change by removing carbon dioxide or managing solar radiation.
- **Neurotechnologies** - Innovations such as smart drugs, neuroimaging, and bioelectronic interfaces that allow for reading, communicating and influencing human brain activity.

These fields have the potential to create many benefits for the environmental, energy, and healthcare sectors, amongst others. Examples of areas of research and development include: environmental improvements through the development of pollution metabolizing bacteria; energy advances through biomimicry design for solar panels and wind turbines, and production of cellulosic ethanol; and, healthcare through 3D printing of tissues and organs, genome-specific medications, and physical and cognitive personal enhancements.[23,24] Regulation and policies will also need to evolve alongside this technological development to ensure the possible positive outcomes are not overshadowed by the potential negative effects of these advances.

"Biology isn't just the study of nature, but one of the most important technologies in our hands today."

Sean Ward, Founder and CTO, Synthace, July 18, 2016

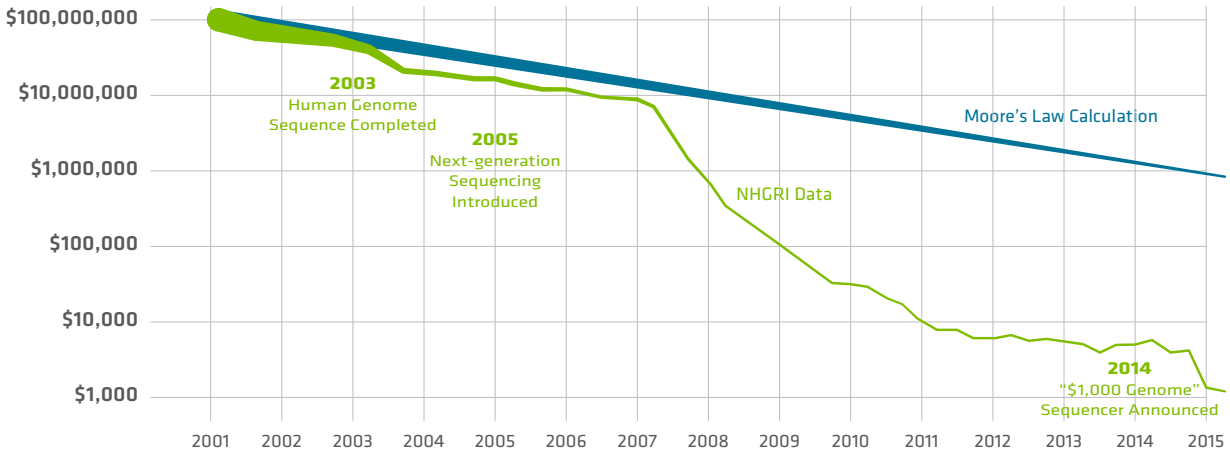
How could society change with the ability to model, sequence and edit genetic code?

2.1.7 ADVANCES IN GENOMIC TECHNOLOGIES

The food we eat, plants we grow, and even our own cells could be transformed through advances in genomic modeling and genetic engineering. As the costs decrease and regulations allow widespread implementation, the technologies have the potential to radically change medical fields and food production. How human health will be managed is likely to shift to where gene editing can be used to modify DNA and treat disease, and treatments can become more precise and personalized. Potentially, diseases could be prevented or cured, and effectiveness of medicines improved.[25] Food systems have already been affected through the introduction of genetically modified organisms (GMOs) to increase pest and disease resistance in crops and improve longevity of harvested produce, and advanced genetic technologies will be utilized to make new developments, such as the development of nitrogen-fixing cereal crops, to improve global food security. [26]

The accumulation of genomic data, and ability to use technologies such as CRISPR to modify genetic components, along with the potential for misuse or unintended results, brings with it potential moral, ethical and legal issues that must evolve alongside the technology.[25, 27]

DNA SEQUENCING COSTS OVER TIME



Decline in real costs compared to expected declines based on Moore's Law. Trend line: Cost per human genome. Line width: Cost per megabase (Mb). (Data: NHGRI https://www.genome.gov/27541954/dna-sequencing-costs-data/)

"We are on the threshold of a massive wave of genomic utility – a transition from the more academic research focus of today to a transformed medical landscape where sequencing is a routine part of patient care. Sequencing applications are poised to expand (e.g., embedded environmental sampling, food chain monitoring). And moving analysis to the cloud (which is already happening) will allow for new modes of research and lead to increased insight into the genomic roots of disease. Combine all this with a stronger toolset for genome editing (think CRISPR), and we will see a huge leap in sequencing demand, with a market easily 1,000 times bigger than what we see today. That demand will drive the creation of cheaper, better, and faster solutions."

Andy Hollinger, Broad Genomics, September 13, 2016

Will humans still control machines if they become smarter than human beings?

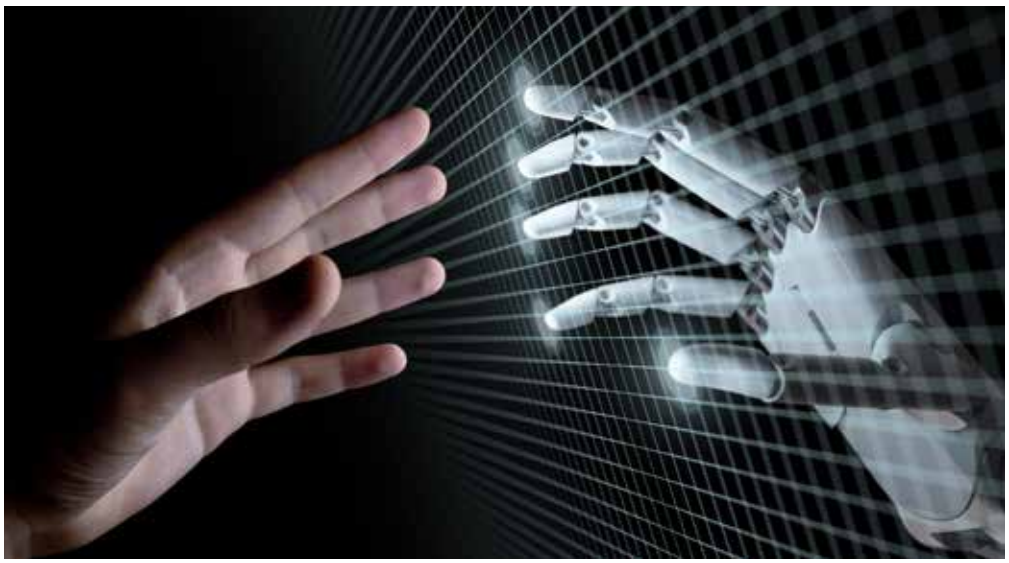
2.2 ARTIFICIAL INTELLIGENCE

The Next Industrial Revolution is the era of artificial intelligence (AI). Artificial intelligence, broadly speaking, is any technique that enables computers to mimic human intelligence.[28] This section of The Next Industrial Revolution report will explore four aspects of artificial intelligence that we consider will make the most impact on industry and society as we know it: machine learning, big data, predictive modeling and cyber-physical systems.

The overarching concern expressed by many about artificial intelligence is that it will reach the point of 'singularity" – the tipping point when superintelligent machines start improving themselves without human involvement and are exponentially smarter than humans.[29] Ray Kurzweil, well-known futurist and Google engineer, has predicted this will happen by 2045, maybe as soon as 2029. Yet others, such as Paul G. Allen who cofounded Microsoft in 1975, believe that due to the complexity of the human brain, without having a scientifically deep understanding of cognition, we cannot create the software that could spark singularity.[30] Time will tell how soon and if singularity will occur – in the meantime, we should prepare ourselves for its potentiality.

"The world will always need human brilliance, human ingenuity and human skills."

Brad Keywell, Co-founder and CEO, Uptake



"We still have miles to go in terms of developing truly intelligent AI, and we don't exactly know yet what the singularity would bring. Would it herald humankind's doom or might it usher in a new era where humans and machines co-exist? In either case, AI's potential to be used for both good and bad demands that we take the necessary precautions."

Stephen Hawking: "I Fear That AI May Replace Humans Altogether". Dom Galeon. Futurism, 6 November 2017.

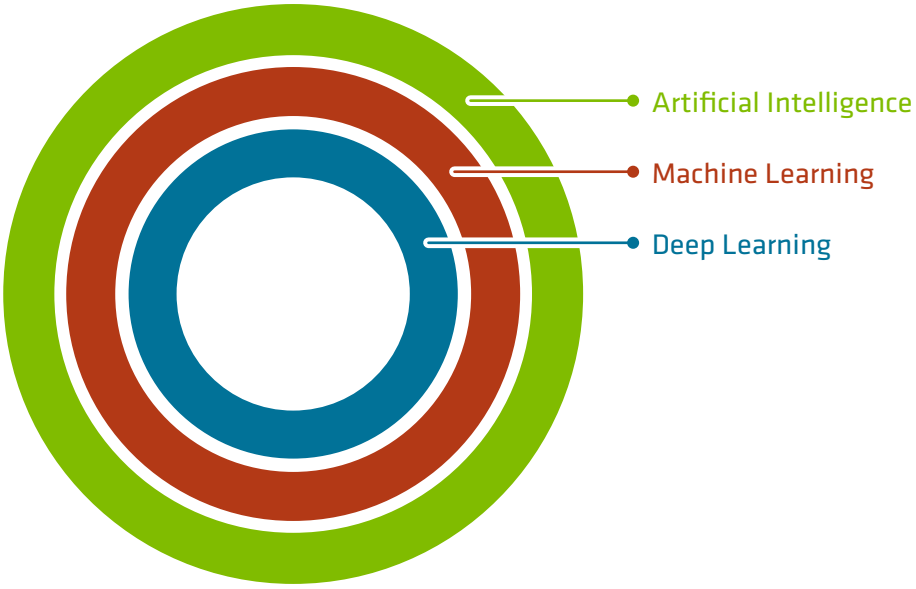
When will machines become smarter than humans?

2.2.1 MACHINE LEARNING

Machine learning has been utilized for some time to explore large amounts of data, but the Next Industrial Revolution is causing exponential growth in the use of machines to accomplish tasks that accumulate data and act on it, especially in the areas of recognition and problem solving.

Machine learning refers to the ability of computer systems to improve their performance by exposure to data without the need to follow explicitly programmed instructions.[31] What is novel about this is that the process enables a machine to keep improving its performance without humans having to explain exactly how to accomplish all the tasks it is given (also known as deep learning).[32] At its core, machine learning is the process of automatically discovering patterns in data, and once discovered, the pattern can be used to make predictions.[33] Machine learning is used across industries but is especially useful in healthcare diagnostics, for example, to recognize illness from test results and calculate treatment regimes. Another example is in precision agriculture where soil and weather condition data can be entered into a system that calculates needed nutrients and moisture.

HOW DOES MACHINE LEARNING RELATE TO ARTIFICIAL INTELLIGENCE?



Source: http://usblogs.pwc.com/emerging-technology/a-look-at-machine-learning-infographic/

"By combining vast amounts of patient data with artificial intelligence, we're beginning to be able to predict illnesses before they've even developed. If machines can see a life-threatening illness before it strikes, this has the potential to save countless lives."

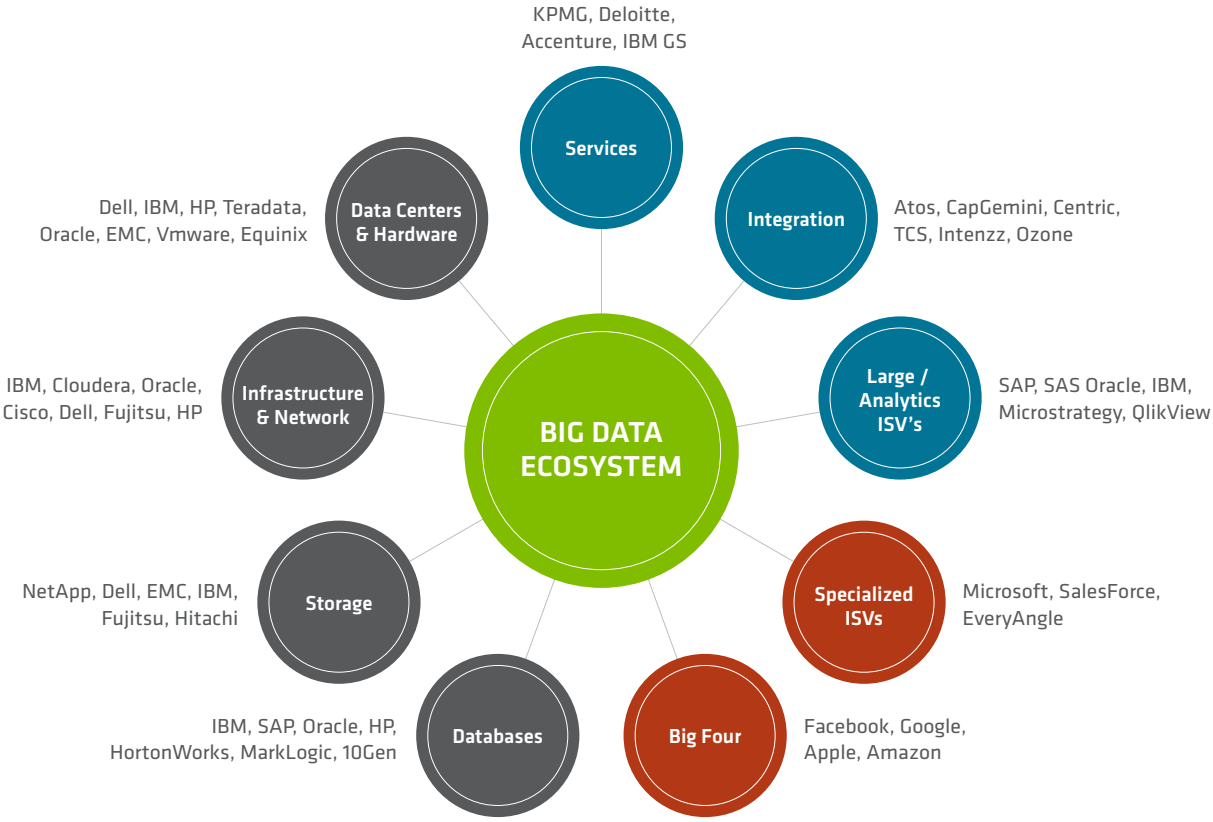
Machine learning: what's the diagnosis? Hitachi Inspire the Next, 2016.

How much data is too much data?

2.2.2 BIG DATA

Data, and the collection of it, is a primary driver of all components of the Next Industrial Revolution. Big data refers to datasets whose size is beyond the ability of typical database software tools to capture, store manage, and analyze.[34] The availability of data, a new generation of technology, and a cultural shift toward data-driven decision making continue to drive demand for big data and analytics technology and services.[35]

Big data is generated by almost everything we do – not only do we leave our digital footprints everywhere, machine-generated data is also rapidly growing. Big data works on the principle that the more you know about anything or any situation, the more reliably you can gain new insights and make predictions about what will happen in the future.[36] Combined with machine learning and predictive modeling, big data has transformed areas such as healthcare, agriculture and security and is pushing the needle on artificial intelligence.



BIG DATA ECOSYSTEM

Source: Big Data Brotherhood. Simone de Bruin. The Metis files, 26 April 2013.

"Big data is transitioning from a tool primarily for targeted advertising to an instrument with profound applications for diverse corporate sectors and for addressing chronic social problems."

Alec Ross, The Industries of the Future. Simon and Schuster, New York, 2016.

Will machines be able to predict the future?

2.2.3 PREDICTIVE MODELING

The smart connectivity of the Next Industrial Revolution makes it possible for massive amounts of data and information to be analyzed simultaneously and accurately to create likely outcomes known as predictive models.

Predictive modeling, also known as predictive analytics, is the use of data, statistical algorithms and machine learning techniques to identify the likelihood of future outcomes based on historical data. It uses known results to develop (or train) a model that can be used to predict values for different or new data.[37] The use of predictive modeling is increasing across all industries and sectors, not only in areas such as retail and insurance, but also in realms such as fighting crime and preventing terrorism. It will be important to balance the benefits of predictive analytics with the democratic control needed to secure personal integrity.[38]

PREDICTIVE MODELING

Source: https://www.predictiveanalyticstoday.com/predictive-modeling/

"No matter the type of model ..., one thing is for certain: Predictive models are already shaping our experiences wherever we go and whatever we do. They recommend products and services based on our habits. They help healthcare providers design and implement preventive life saving measures given our susceptibility towards a particular disease."

Predicting the future, Part 2: Predictive modeling techniques. Alex Guazzelli, developerWorks, 19 June 2012.

Will all networks someday connect to make a 'smart world'?

2.2.4 CYBER-PHYSICAL SYSTEMS

Cyber physical systems (CPS) of the Next Industrial Revolution are creating 'smart systems' worldwide and play an increasingly important role in critical infrastructure, government and everyday life. Automobiles, aircraft, medical devices, building controls and the smart grid are all examples of cyber physical systems that we use every day and connect us to each other and our broader world.[39]

Cyber-physical systems refer to the bridging of digital (cyber) and physical technology in an industrial context. Cyber-physical systems are combinations of intelligent physical components, objects and systems with embedded computing and storage possibilities, which get connected through networks and are enablers of the 'smart processes' used within and across industry sectors.[40] These cyber-physical systems can be localized (as in a 'smart factory') or regionalized (as in energy grids) and will be the building blocks of infrastructure in 'smart cities' of the future.

Adapted From: http://icc.mtu.edu/cps/

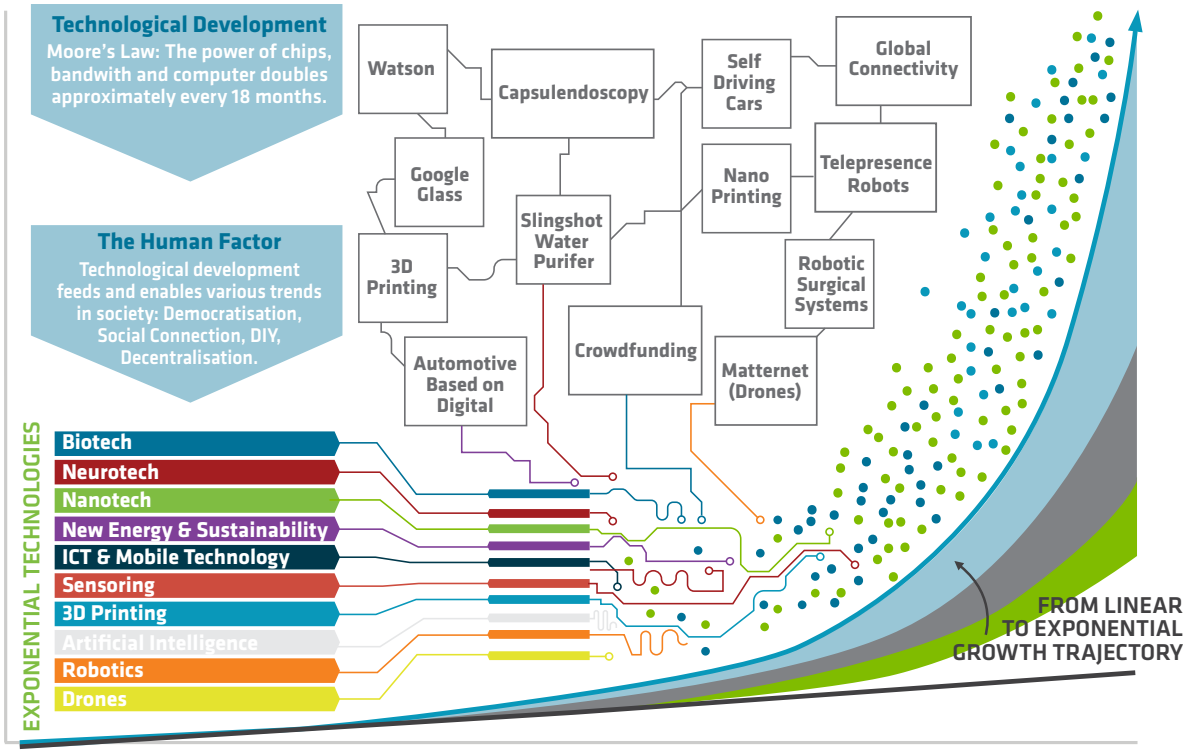
"In the future, cyber-physical systems will make contributions to human security, efficiency, comfort and health in ways not previously imaginable. In doing so, they will play a central part in addressing the fundamental challenges posed by demographic change, scarcity of natural resources, sustainable mobility, and energy change."

http://industrie4.0.gtai.de/INDUSTRIE40/Navigation/EN/Topics/The-internet-of-things/cyber-physical-systems.html

How big will the impacts of the Next Industrial Revolution be and how fast will they occur?

2.3 SPEED AND SCALE OF CHANGE

The innovations developing in the Next Industrial Revolution are being implemented globally at all scales, thereby changing the face of industries and society in a rapid and profound way. Technological development and adoption is increasing in speed, reaching an exponential rate of change, and affecting almost all industries in all countries. Manufacturing is at the forefront of this transformation, but other industries are also quickly developing such as health care, biomedical research, infrastructure, energy, transportation and mobility, shipping and logistics, food services, hospitality, financial services, and retail. Shifts in these industries are changing how we live, work, play, and interact and will transform the functions of our buildings, neighborhoods, cities and beyond, with the potential to address global issues such as climate change, energy, housing, and disease.[41]



Source: Deloitte. 2014. Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies.

"The impact of this shift cannot be overstated. It will fundamentally transform every industry, from IT-driven sectors like banking or insurance, to industrial and consumer product manufacturing, to biologically based industries like healthcare and agriculture. The breadth and depth of this cross-industrial impact will be unprecedented in technological history."

Andy Zhulenev Vice President of Innovation, Silicon Valley Innovation Center, June 9, 2017

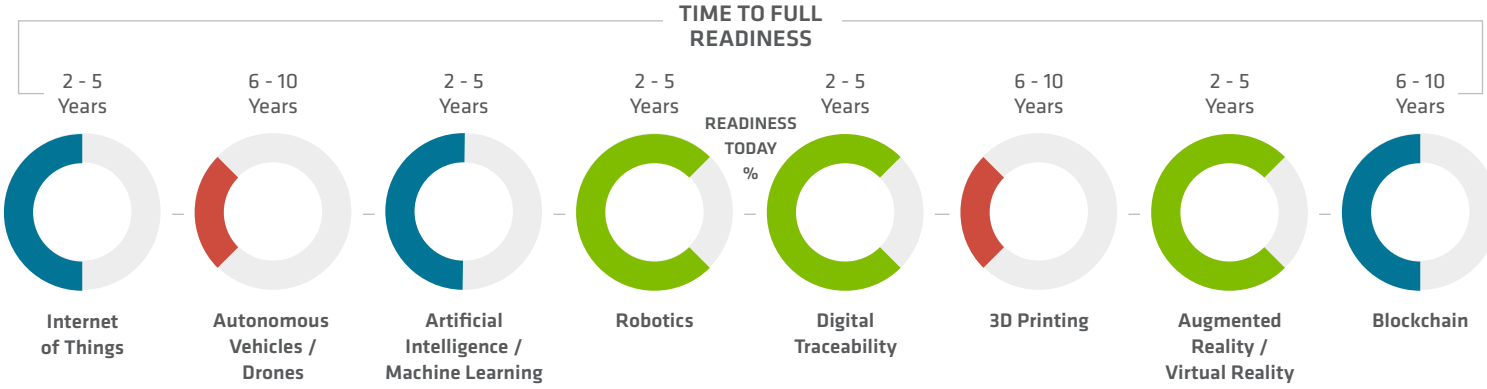
When will the future arrive?

2.3.1 ANTICIPATED SPEED OF CHANGE AND DISRUPTION

Compared to previous industrial revolutions, the Next Industrial Revolution is proceeding at an exponential, rather than linear rate, and it is creating disruptions in every country, and almost every industry.[42] It is difficult to estimate timing of potential disruptions, and there have been two main scenarios proposed: early adoption and late adoption. Early adoption indicates that disruption began around 2016; and late adoption expects adoption beginning around 2030, however with the level of investments currently being observed and predicted, the early adoption scenario seems most likely.[43] For example, Business Insider estimates that robotic shipments will nearly triple between 2015 and 2021, and IDC predicts spending on artificial intelligence (AI) technologies is expected to grow from $8 billion in 2016 to $47 billion in 2020.[44]

The unprecedented speed of change, as well as the broad range and scale of the disruptions in new digital, robotic and 3D technologies, is having major impacts on what we produce and do, how and where we do it and how we earn a living.[45] The implementation of the Next Industrial Revolution will proceed differently in advanced and developing parts of the world, but the wave of transformation will be global. The all-encompassing nature of these changes indicate the coming transformation of entire systems, including production, management, and governance.[46]

CURRENT READINESS LEVELS OF DISRUPTIVE TECHNOLOGIES AND KEY ENABLERS TO REACH FULL READINESS IN THE RETAIL INDUSTRY.



Source: World Economic Forum, January 2017. Shaping the Future of Retail for Consumer Industries. A World Economic Forum project in collaboration with Accenture

"The Fourth Industrial Revolution is still in its nascent state. But with the swift pace of change and disruption to business and society, the time to join in is now."

Gary Coleman, Global Industry and Senior Client Advisor, Deloitte Consulting

How are accelerating technological capabilities influencing the Next Industrial Revolution?

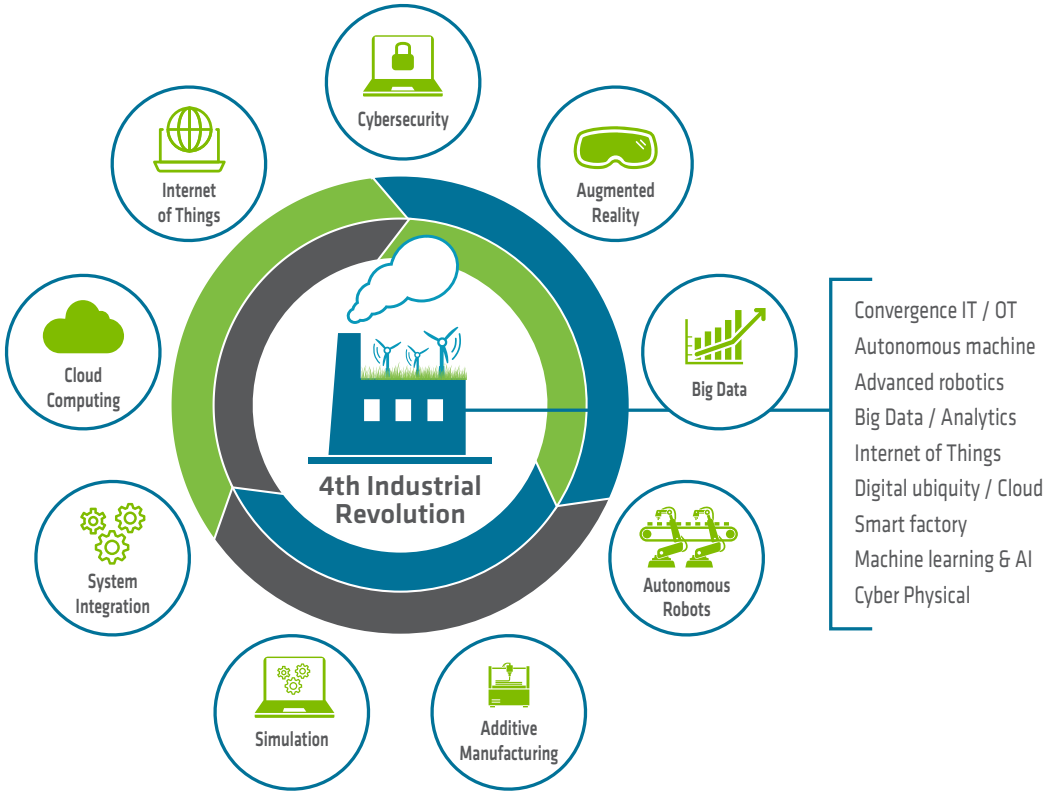
2.3.2 EXPONENTIAL IMPACT OF CONVERGING TECHNOLOGIES

The Next Industrial Revolution is combining the digital, physical, and biological worlds with the accelerating convergence of powerful technological capabilities – artificial intelligence, Internet of Things, advanced robotics and cobots, 3D printing, autonomous vehicles, mobile devices, gene editing, materials science, augmented and virtual reality, application development, cyber-physical systems, autonomous production, and edge and big data analytics.[47, 48] It also includes the convergence of two worlds which have historically been disconnected: Information Technology (IT) and Operational Technology (OT).[49]

The Next Industrial Revolution is not only about manufacturing (even if manufacturing is the main sector involved today), it is changing the ways we live, work, produce, consume, communicate, move, relate to and interact with one another resulting in the co-evolution of technology, business and society.[48, 49]

Four technologies are projected to have the greatest impact, based on three criteria: *widespread application, resulting efficiencies, impact on labor*: [50]

- Internet of Things
- Autonomous vehicles/drones
- Artificial intelligence/machine learning
- Robotics



Source: Industrie 4.0: the fourth industrial revolution – guide to Industrie 4.0.

Engineers, designers, and architects are combining computational design, additive manufacturing, materials engineering, and synthetic biology to pioneer a symbiosis between microorganisms, our bodies, the products we consume, and even the buildings we inhabit."

Klaus Schwab, Founder and Executive Chairman of the World Economic Forum, January 14, 2016.[51]

How fast will widespread adoption of technological advances occur?

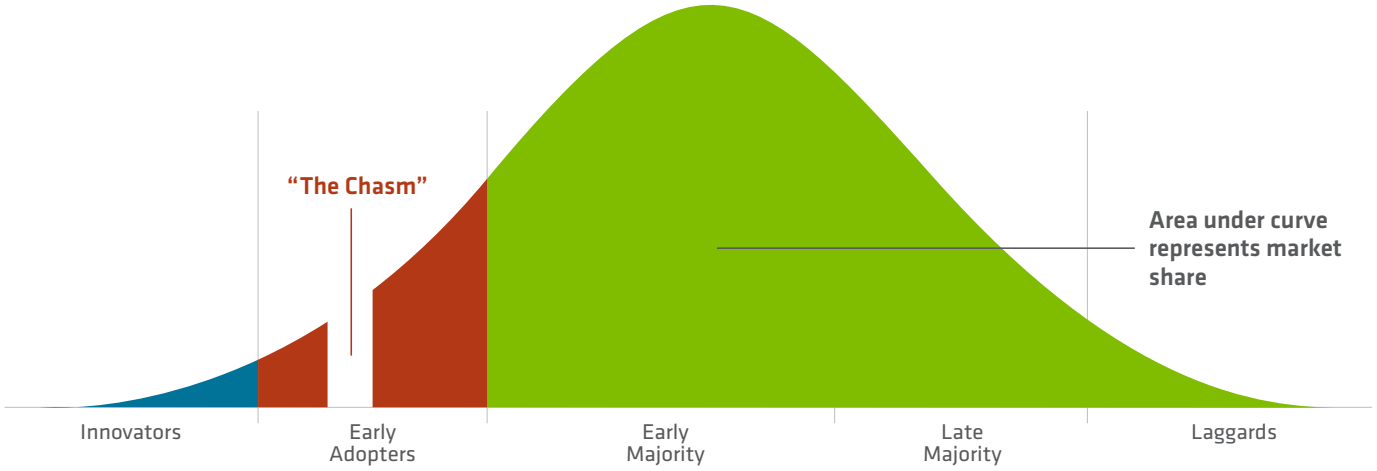
2.3.3 TECHNOLOGY DIFFUSION

Two key components are responsible for the integration of new technological innovations - cost and risk. Innovators and early adopters initially accept the risk and higher cost of utilizing new technologies and also have the benefit of early successes and profits if the implementation is successful. Subsequent adopters start to build the market share and establish the technology within the industry.

The most difficult step for creators of new technological innovations is making the transition between early adopters and majority. If a technology creates a major effect and enough momentum builds, then the product becomes a new standard.[52]

With the Next Industrial Revolution, we are on the cusp of the widespread implementation of technologies that have been developed and are in the innovation and early adoption phases. The cost of technologies such as robotics, artificial intelligence, internet of things sensors, 3-D printing, mobile devices, green energy infrastructure, batteries, is decreasing. Concurrently their extraordinary value within industries is being demonstrated, helping them "cross the chasm" into widespread implementation. This process is becoming faster, leading to more technologies entering mainstream, faster.

TECHNOLOGY ADOPTION LIFECYCLE



Source: Geoffrey Moore. 2006. Technology Adoption Lifecycle in Crossing the Chasm.

"Introducing breakthrough technologies benefits greatly from coordination among firms, including suppliers that can improvise, do new things, and understand the whole as full partners in innovation."

Secretary Penny Pritzer, U.S. Department of Commerce, March 2015.

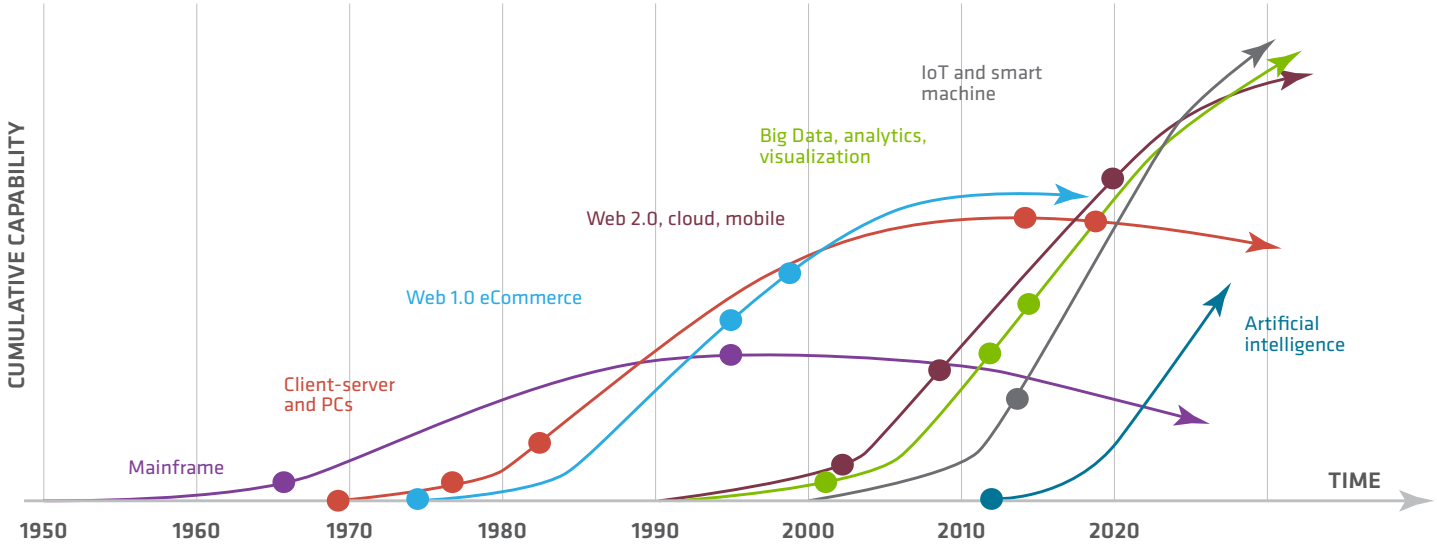
The decreasing cost of technology is driving the Next Industrial Revolution. How will this transform your life?

2.3.4 ACCELERATING DROP IN THE COST OF TECHNOLOGY

Across many sectors, the cost of innovative technologies is decreasing. This is occurring across diverse technologies such as green energy infrastructure, batteries, 3D printing/ additive manufacturing, connected sensors, and biotechnology processes. Decreasing costs make technology much more accessible for smaller firms and consumers. For example, 3D printing is estimated to be 50% cheaper and 400 times faster in the next 5 years, providing access to new industries, as well as increasing production capacity.[53]

Decreasing costs mean combinations of technologies can be used to further advance fields of research. For example, solar PV and batteries combined at lower costs can provide a reliable energy source at a price competitive with standard utilities.[54] This provides the potential for the evolution of local energy systems, and transformation of the overall energy grid and system. Another example of transforming potential is combining biomedical research with 3D printing and the movement towards "printing" organs and other tissues.[55] As technological advances continue to decrease in cost, all of these technologies will diffuse into mainstream use and become the new standards for production and processes.

THE INCREASING CAPABILITY OF DIGITAL TECHNOLOGIES



Digital Transformation Initiative Mining and Metals Industry, White Paper, World Economic Forum / Accenture analysis, January 2017

"Developments in previously disjointed fields such as artificial intelligence and machine learning, robotics, nanotechnology, 3D printing and genetics and biotechnology are all building on and amplifying one another. Smart systems–homes, factories, farms, grids or entire cities–will help tackle problems ranging from supply chain management to climate change."

World Economic Forum, January, 2016. The Future of Jobs Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution

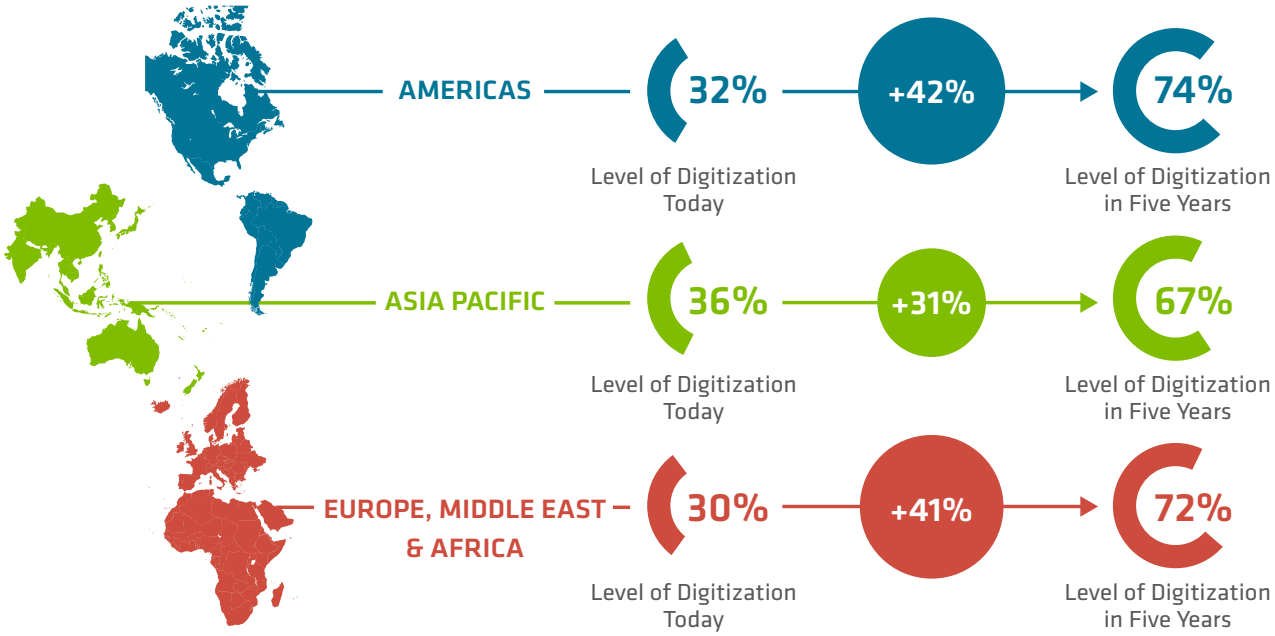
Which regions and countries will be first to capture the full potential of the emerging industrial revolution?

2.4 THE GLOBAL SCALE OF THE NEXT INDUSTRIAL REVOLUTION

The Next Industrial Revolution has caused rapid deployment of technologies around the world, with the anticipated implementation rate relatively similar amongst major industrial countries. About one third of 2,000 companies surveyed in 2016 in 26 countries rated their level of digitization as high, and this value is expected to rise on average from 33% to 72% within the next five years.[56]

Thanks to the exchange and diffusion of technologies enabled by the Next Industrial Revolution's global connectivity, less industrialized countries are able to leap-frog many developmental stages that are costly and a drain on resources. Nevertheless, there are significant advantages for those who are creating and inventing, for it is this group that will steer the direction of innovation and application of new technologies worldwide.

COMPANIES ALL OVER THE WORLD ARE EXPECTING TO DRAMATICALLY INCREASE DIGITIZATION OVER THE NEXT FIVE YEARS



Source: 2016 Global Industry 4.0 Survey. 2016 Pricewaterhouse Coopers LLP.

"By 'flat' I did not mean that the world is getting equal. More people in more places can now compete, connect and collaborate with equal power and equal tools than ever before. That's why an Indian in Bangalore can take care of the office work of American doctors or read the x-rays of German hospitals."

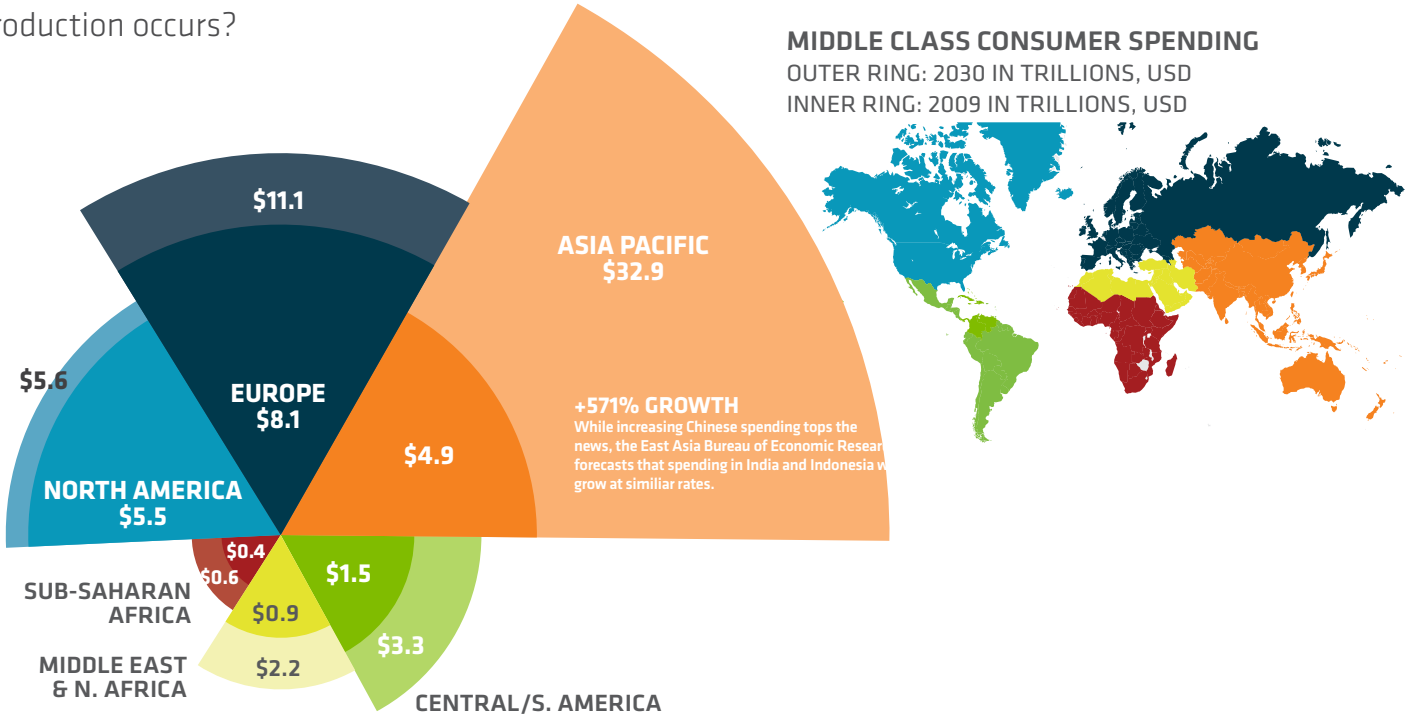
The World is Flat. Thomas L. Friedman, 2005.

How will the growing global middle class spending power reshape where industrial research, innovation and production occurs?

2.4.1 LOCATION OF CONSUMER DEMAND

The Next Industrial Revolution is allowing consumers to become more connected to the global marketplace, enabling the growing global middle class spending power to reshape emerging economies. Between 2005 and 2015, the increase in expenditures of the middle class in fast-growing economies accounted for one-fifth of total global economic expansion.[57]

The global middle class will grow from 2 billion to almost 5 billion in 2030, with most of that growth coming from industrializing countries.[58] Rising wages and costs caused by growing regional economies are disrupting traditional supply chains and production centers, and a growing diversity of options presents companies with significant challenges as they try to apply traditional business models to a more complex and fragmented reality.[59] The most successful companies will be those who rapidly adapt themselves towards a connected, smart, and highly efficient supply chain ecosystem that reaches across countries and regions.[60]



Source: Kou, L. 2013. The world's middle class will number 5 billion by 2030. Quartz. Figures based on OECD, 2012. An emerging middle class.

"Consumers are no longer online or offline. They integrate multiple channels all along the purchasing pathway, and they do so in new and different ways as their particular needs and real-time circumstances dictate."

Digital Insurgents, Emerging Models, and the Disruption of CPG and Retail. Bob Black, Gabrielle Novachek and Leslie Hinchcliffe. Boston Consulting Group, 11 May 2017.

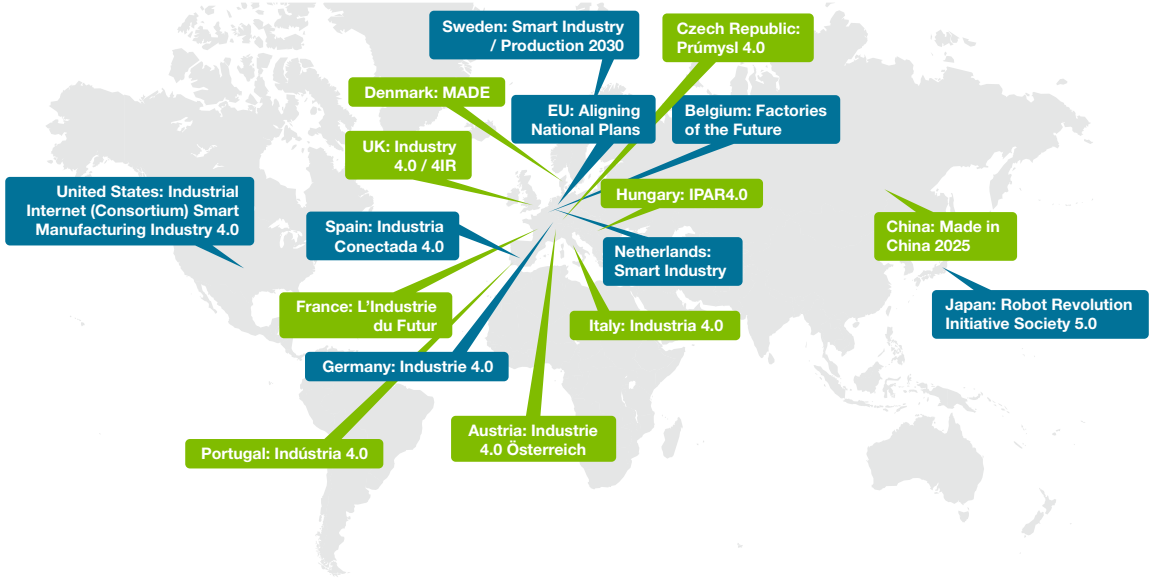
Which companies will drive the Next Industrial Revolution?

2.4.2 MULTINATIONAL DRIVERS OF COLLABORATION

The Next Industrial Revolution brings with it a rush by large multinational corporations and governments to adopt 'Industry 4.0'. The Internet of Everything is enabling not only a vertical integration of new technologies and connectivity within traditional business ecosystems, but also a rapid horizontal global expansion across sectors unseen before. Amongst companies of all sizes, there is a realization that collaboration across ecosystems allows for a leveraging of capabilities, services and data/intelligence they would not have on their own.[61] Such a shift towards collaborative approaches makes business sense – it enables firms to accelerate innovation and create more competitive market positions – whereas firms that remain internally focused face slower time-to-market, higher development costs, and loss of competitive position.[62]

One example of such cross-sector collaboration is Farm2050, a global collective of diverse partners across the world committed to advancing the future of food through supporting AgTech entrepreneurs and startups. Farm2050 brings together researchers, farmers, entrepreneurs, manufacturers, and distributors to accelerate the path for new disruptive AgTech ventures.[63]

INDUSTRY 4.0 ACROSS THE GLOBE: MAIN INITIATIVES, PARTNERSHIPS AND INFLUENCES AS OF MARCH 2017



Source: https://www.i-scoop.eu/industry-4-0/

"My view is that the geographic spread of domain expertise in the industries of the future will ensure that the next stage of globalization produces centers of innovation and commercialization that are more geographically diverse than the last stage, when Silicon Valley enjoyed 20 years of domination."

Alec Ross, The Industries of the Future. Simon and Schuster, New York, 2016.

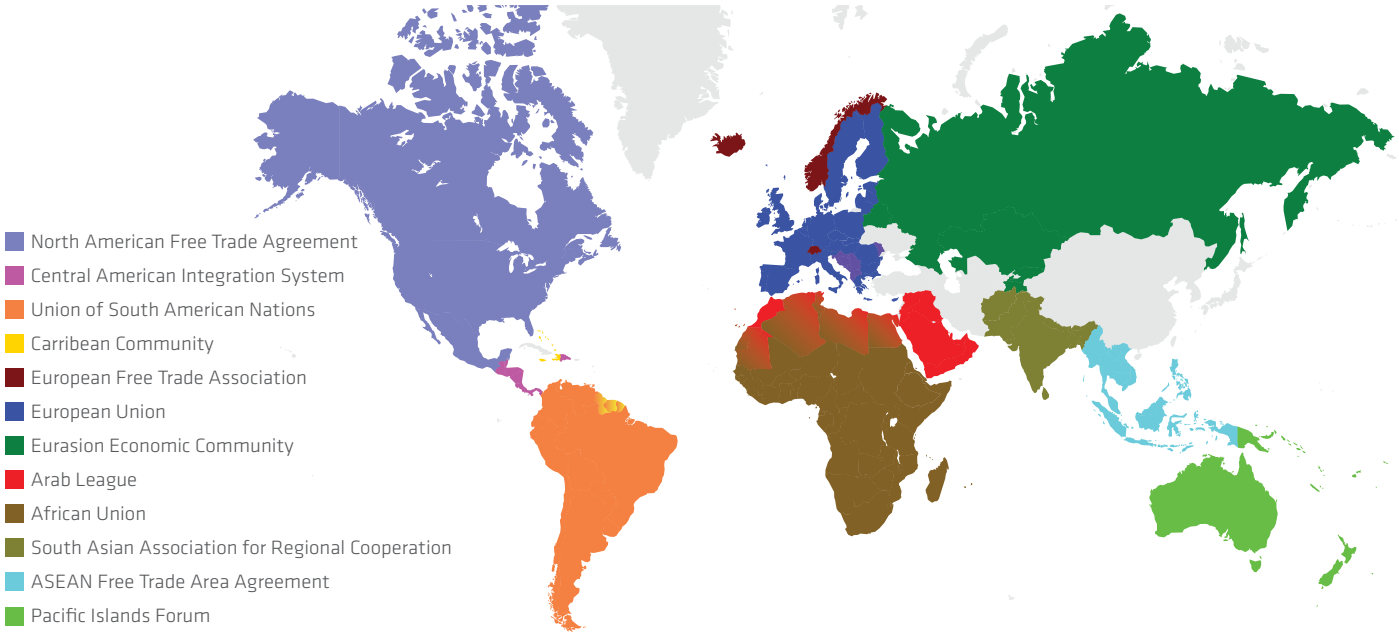
In a flatter world, what will industry competition look like?

2.4.3 GLOBALLY COMPETITIVE LANDSCAPE

With a global landscape for competition, the Next Industrial Revolution is evening the playing field for the world of business and industry. 21st century manufacturing competitiveness has fully converged the digital and physical worlds where advanced hardware combined with advanced software, sensors, big data and analytics results in smarter products, processes, and more closely connected customers, suppliers, and manufacturers.[64]

Competition is emerging in the form of flexible and collaborative ecosystems marking a shift in the landscape as unexpected alliances are forged, sector boundaries blur, and long-standing strengths count for less.[65] To compete, not only are companies reaching across borders to form global connections, many companies are focusing on strengths and innovation using local expertise in the form of 'domain expertise' regions and innovation hubs.[66] This process is helped by trade agreements that allow the creation of global rules that preserve the ability to transfer data across borders and prevent forced localization.[67]

TRADE BLOCS



Source: What is a single market? Definition and meaning. Market Business News. 2017

"As boundaries between industry sectors continue to blur, CEOs – many of whose companies have long commanded large revenue pools within traditional industry lines – will face off against companies and industries they never previously viewed as competitors. This new environment will play out by new rules, require different capabilities, and rely to an extraordinary extent upon data."

Competing in a world of sectors without borders. Venkat Atluri, Miklos Dietz and Nicolaus Henke. McKinsey Quarterly, July 2017.

The Next Industrial Revolution is reshaping just about everything. What are your reactions to the future?

3.0 POTENTIAL IMPACTS AND IMPLICATIONS

There is no doubt that the Next Industrial Revolution is transforming our future. Such significant periods of industrial and societal change provoke very understandable human reactions.

Currently the range of reactions covers the spectrum from great excitement and anticipation, to a more dystopic view, and even a deep fear of an existential threat to human existence. This diversity of views is reflected in the coverage by many magazines and journals, probing the range of plausible outcomes and their implications on humanity and the planet. History would likely suggest that the reality will lie somewhere in-between. Humans and society have proved to be remarkably resilient and adaptable. Over the last 200 years, we have traveled through three significant stages of industrialization, which have completely reshaped the planet. At the same time humanity has progressed with huge gains in many metrics such as longevity, health status, educational attainment and technological innovation.

In this section, we explore several of the potential impacts and implications. If we can successfully navigate some of the pitfalls and challenges, The Next Industrial Revolution offers the promise of enormous benefit and value to people and the planet.

"The changes likely to be brought about require not just an economic but also a spiritual response. This is not just about money, it is about what it is to be human"

Justin Welby, Archbishop of Canterbury 2016 [68]

Source: New Yorker Oct 23, 2017, and Max Planck Research 2009

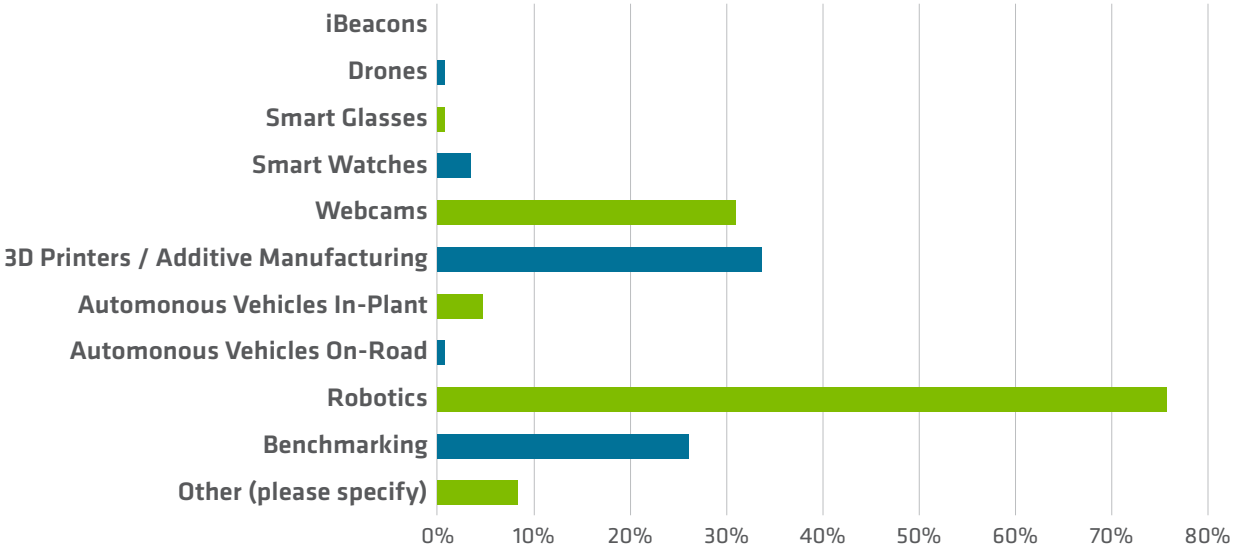
Technology is evolving and redefining how industries and sectors function. How will manufacturing look in 2050?

3.1 IMPLICATIONS FOR MANUFACTURING

Manufacturers are at the forefront of the Next Industrial Revolution, taking advantage of the connectivity that the cloud, Internet of Things, advanced robotics, sensors and other technologies offer for connecting machines, devices, products, suppliers, partners, and customers. These technologies are redefining what is produced and how it is made. Technological advances are changing the way we use materials, stay connected, the speed of production, and shrinking the time between design and production, and providing faster delivery from plant to customer. These innovations are being implemented globally, at all scales, thereby changing the face of manufacturing in a rapid and profound way.

There are waves of types of technology that are still in the research and testing phases and are waiting to be adapted for mainstream use. This will create a continually evolving environment in the manufacturing sector as the Next Industrial Revolution reshapes industries and society.[69]

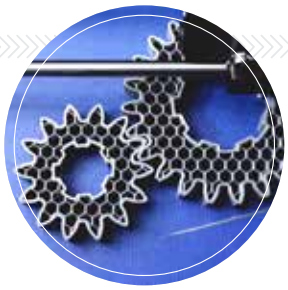
THE CURRENT USE OF EMERGING TECHNOLOGIES AND PROCESSES USED IN MANUFACTURING OPERATIONS (2017)



Source: Connected Manufacturers are Driving the Fourth Industrial Revolution, September 2017. PLEX Manufacturing Blog, www.plex.com, results from 2017 State of Manufacturing Technology survey.

"Manufacturers have been among the most eager and innovative users of advanced technologies throughout each industrial revolution, whether in processes, products, or across ecosystems. Connected manufacturing is quickly becoming one of the most powerful technology-based shifts in a generation, no less important than the arrival of steam power, electricity, or the automated production line. Those manufacturers who are leveraging the technology that supports connected manufacturing will truly define the fourth industrial revolution as we know it."

Kaitlin Rebella. September, 28, 2017, Plex Manufacturing Blog

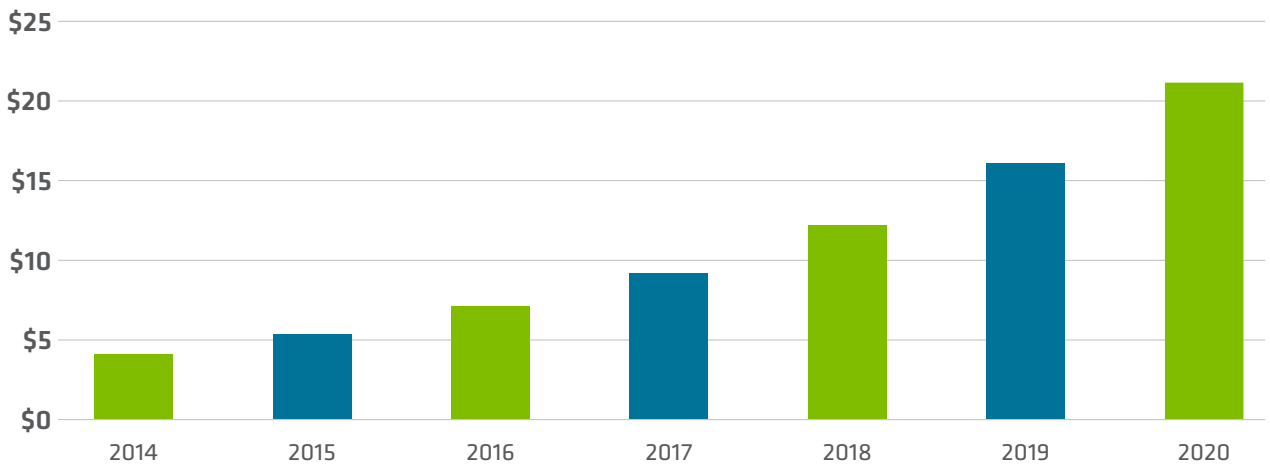


How fast will widespread adoption of technological advances occur?

3.1.1 ADDITIVE MANUFACTURING

Additive Manufacturing (AM and 3D Printing) is currently firmly established for design and prototyping, and it is increasingly being adopted for industrial use. Its use is expanding because it can help to deliver better products by complementing traditional manufacturing processes. Developments in Additive Manufacturing and material sciences are increasing the number of substances available for manufacturing, and improving production of complex geometries, while reducing the number of components required to make a product, and a streamlining of work flows.[70] It currently works best in the creation of low-volume, high-value parts, where customization is critical. And, it could also reduce physical trade, as more parts and/or products are "printed" where they are consumed, eliminating the need for shipping.[71]

Additive Manufacturing is on the cusp of mainstream adoption in certain geographies and industries, more than half of 3D printing units have been installed in three industries: aerospace, automotive and electronics, and, North America and Europe together have almost 70% of industrial 3D printing units.[70]



WORLDWIDE 3D PRINTING INDUSTRY REVENUE FORECAST IN BILLIONS

Source: Wohlers and Associates, 2014.

"3D Printing is revolutionary, but not because it can replace conventional manufacturing, render traditional factories obsolete and localize all production (the economics will not support this currently and in the foreseeable future). It is revolutionary due to its ability to complement traditional manufacturing processes, revolutionize product design and create new value."

World Economic Forum, 2017.

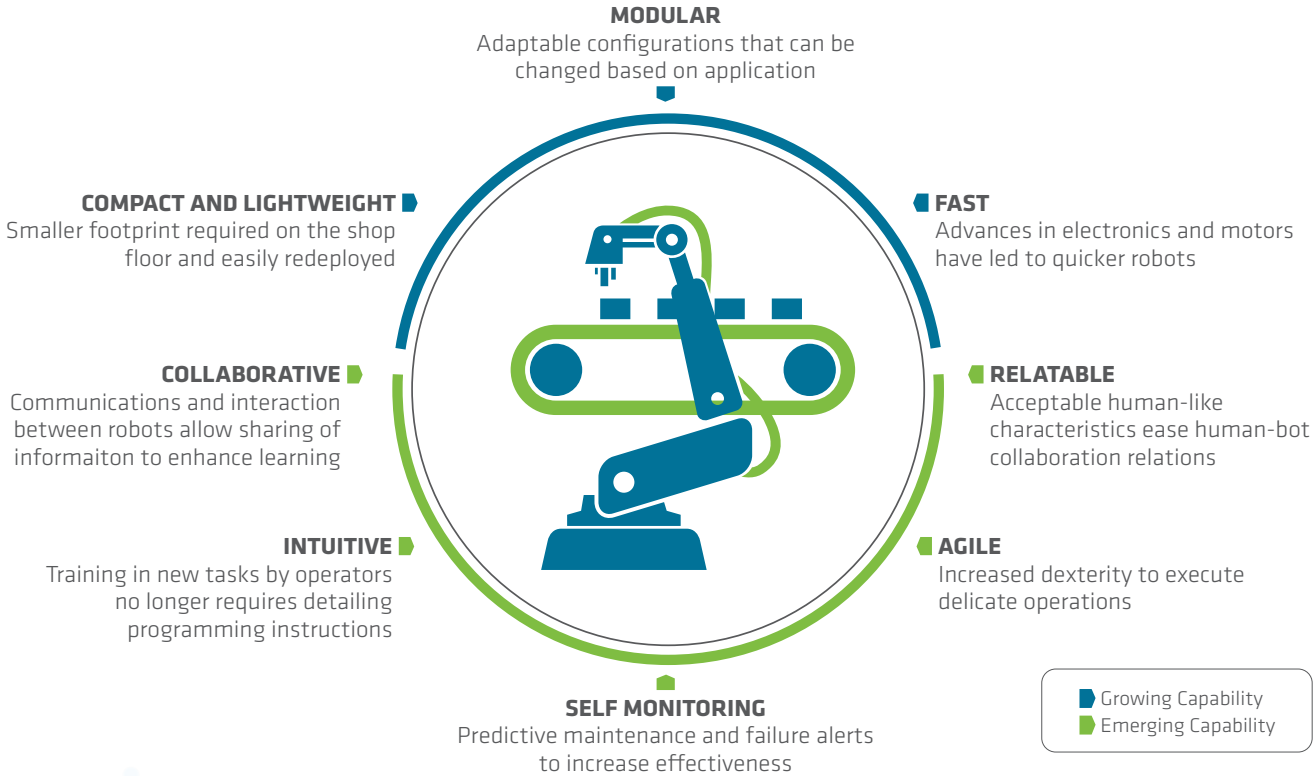
What if the best robot on the factory floor is the technology-augmented operator?

3.1.2 POTENTIAL FOR INDUSTRIAL AUTOMATION

Throughout the previous industrial revolutions, automation has replaced human effort and increased the productivity than can be accomplished by an individual worker. Workers now are producing 47 percent more than 20 years ago.[72] However, while automation has increased overall output and saved money, it has not resulted in large increases in jobs. In the US from 2010 to 2016, manufacturing has seen 10 to 20 percent increases in output, but only a 2 to 5 percent increase in jobs.[72]

In the Next Industrial Revolution, efficiency and productivity increases will continue to increase. This is no longer about repetitive factory work, advances in technologies are now able to tackle much more complex tasks. Traditionally, robots have been used primarily in manufacturing, but other industries including healthcare, shipping and logistics, food services, retail, hospitality, and more are starting to also use robots.[73] A 2016 survey by Boston Consulting Group found that 44% of U.S. and 66% of German manufacturers plan to install autonomous robots and other automation systems within the next five years.[74] An estimated 50% of jobs have the potential to be automated by adapting currently demonstrated technology, however, very few can be fully automated. Most occupations have some portion that can be automated, this means that automation will change many more jobs than completely eliminate them.[75]

PREDICTED ASPECTS OF ROBOTIC IMPROVEMENT AND INNOVATIONS



Source: International Federation of Robotics, World Robotics: Industrial Robots 2015.

New industrial materials help make the impossible, possible. What new products will be invented, that we have not even thought of yet?

3.1.3 THE PROMISE OF NEW MATERIALS

The development and discovery of new materials and processes is critical in the Next Industrial Revolution. These contributions enable sectors to turn their ideas and innovations into real-life products. Designers can now consider products and processes at the atomic level. This allows them to make things smaller, lighter, less costly, more efficient, long-lasting, and more sustainable. It allows rethinking a material's lifetime of use, from its source materials, all the way through to the end of its life with adaptive reuse and recycling.

Materials science is creating new products, from the macro to the molecular level. Some emerging new materials that are at the forefront of technological innovation are graphene, with efficient heat and electrical conductivity which can be used in many ways.[76,77] Resource scarcity and technological innovations are shifting what products are made from. New developments in advanced materials and recycling processes will make use of every available resource from molecule to molecule.[78]

CHEMISTRY AND ADVANCED MATERIALS: ENHANCING THE DIGITAL REVOLUTION

		Growth rates for key innovations	Examples of relevant products from chemistry and advanced materials industry
Mobility	Electric Vehicles	Annual sales of electric vehicles 2020: 4.9 million	Plastics, composites and battery technologies
	Drones	Market size for drones 2015: $10.1 billion; 2020: $14.9 billion	Plastics, composites and battery technologies
Renewalbe Energy	Photovoltaic (PV)	Installed PV capacity worldwide 2015: c. 245 GW; 2020: > 500 GW	Perovskites, crystalline silicon and thin-film technology
	Wind Energy	Installed wind power 2015: 413 GW; 2020: 712 GW	Wind turbine coatings, foams and silicones
Mobile and Smart Devices	Smartphones and Tablets	Mobile devices in use 2015: 8.6 billion; 2020: 12.1 billion	Substrate, backplane, transparent conductor, barrier films and photoresists
	Flexible Displays (e.g. wearable devices, VR, TVs)	Market for AMOLED displays 2016: $2 billion; 2020: $18 billion	Substrate, backplane, transparent conductor, barrier films and photoresists
Fonnectivity & Computing	High-Speed Internet	Fixed broadband speed 2015: 24.7 Mbps; 2020: 47.7 Mbps	Ultrapure glassis chlorosilane
	More efficient and smaller integrated circuits	Processor logic gate length 2015: 14mm; 2019: 7mm	Dielectrics, colloidal silica, photo resists yield enhancers, and edge-bead removers

Source: Three ways digital innovation is revolutionizing chemistry & advanced materials, September 21, 2016. Fernando J. Gómez and Bernd Kreutzer. World Economic Forum.

"The history of humanity is full of examples demonstrating the importance of materials. Inventors of major technological breakthroughs such as transistors, lasers, and fiber optics dreamt of these innovations decades before they became reality: simply put, the materials had not yet reached the required degree of purity. However, in all these cases, the Nobel Prize related to these technological breakthroughs was attributed not to those who had had the idea but to those who brought them to life."

Sylvain Cloutier, Director of Faculty Affairs, Research and Partnerships at ÉTS, Université du Québec, January 13, 2017

When machines become the workers, what is the human role?

3.2 FUTURE OF WORKFORCE

As automation develops at an accelerated pace, cognitive abilities and tasks that were once thought to be reserved for people are increasingly being carried out by machines. This is causing growing concern about the impact on the labor landscape and the subsequent risks for people and society.

The term 'technological unemployment' [79] was popularized by economist John Maynard Keynes in the 1930s, referring to humanity's discovery of the means of economizing the use of labor outrunning the pace at which we can find new uses for labor. In short, that technological advances would change the future of work. The impact of the 'gig economy', robotics, and cognitive technologies are creating a future in which machines are becoming smarter and more flexible at an increasing rate. Correspondingly, demographic upheavals have made the workforce both younger and older, as well as more diverse. 77 million Millennials now make up more than half the workforce in the US. [80]

This section of The Next Industrial Revolution Report will explore the Future of Workforce, and the widespread implications. We will explore how our increasingly aging workforce and burgeoning millennial workers might survive in a changing employment landscape. This changing work landscape will displace some traditional blue-collar workers and will likewise disrupt their white-collar counterparts. Human beings have been resourceful throughout previous industrial revolutions, and it is worth considering how people will compete with robotics and automation in the workplace of the future. What bearing will this have on the global economy? However, there will be some losses and certainly some gains. The future workforce will create new waves and categories of jobs and lifestyle adaptations which could be of benefit to both the individual and society.

STAGE 1:
Sharing Economy Platforms
The Gig Economy

- Nonemployee freelance workers
- Temporary assignments

40%
of US workers independent contractors by 2020

STAGE 2:
Artificial Intelligence and Robotics
The Machine Economy

- Massive labor disruption
- Human labor displaced and supplemented
- Jobs unbundled into tasks

40%
White collar and creative work not immune

5.1 MILLION
net job loss by 2020

Source: The Upside of Disruption: Megatrends shaping 2016 and beyond, EYQ 2016

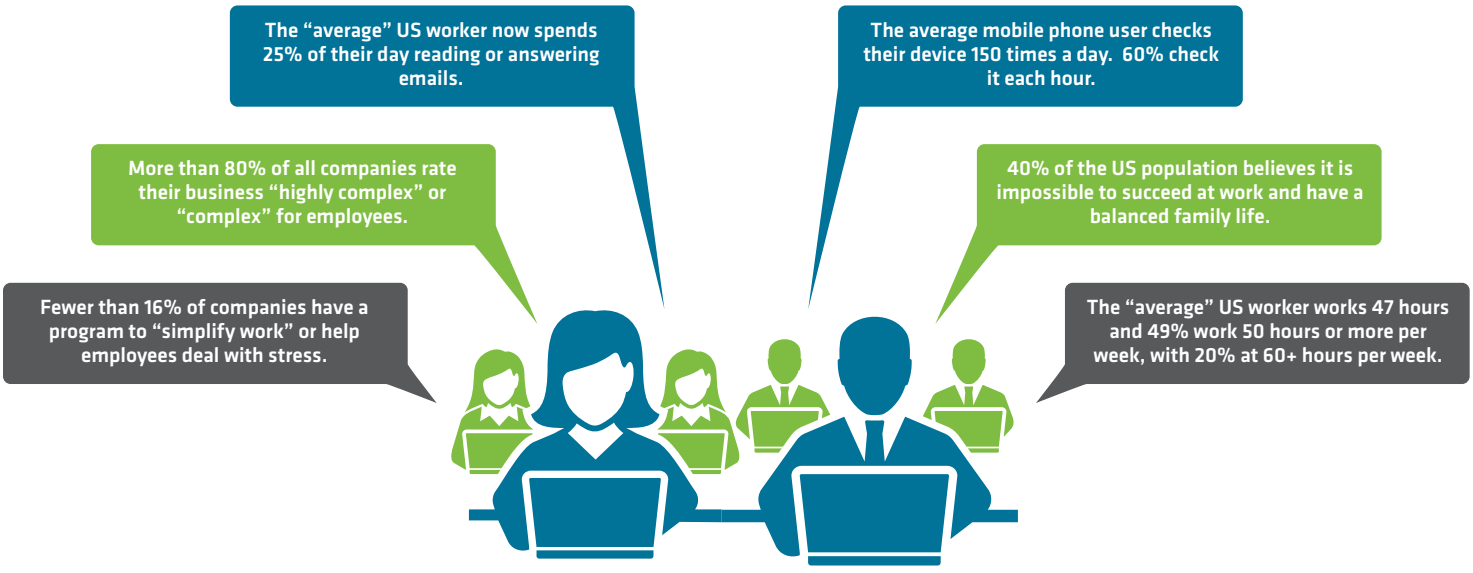
Perhaps we need to change the way we think about work?

3.2.1 IMPLICATIONS ON WORKFORCE AND JOBS

Will 40% of jobs be lost to automation or will the nature of work be just different in the future? In the United States, technology has been attributed to a loss of more than 6 million jobs in the manufacturing sector in the last decade[81]. Demographic upheavals including baby boomers working into their 70s and 80s, the rise of the millennial working population and an increase in women's participation in the workforce suggest that there will be increased competition to source jobs that may look very different in the future[82]. This will mean adjusting how we relate to the concept of what is work and how new forms of work can be created in the future.

In fact, the current concept of work may very well be outdated, and this will be exacerbated with the rise in attention on activity over productivity in workers. A new approach to work may have many upsides. Some current research suggests that workers are overwhelmed by complexity, and that the Next Industrial Revolution may deliver a positive transformation in worker experience and effectiveness.

THE OVERWHELMED EMPLOYEE



Source: Deloitte Human Capital Trends 2014 and 2015.

"Employers won't think in terms of employees – they will think in terms of specialisms. Who do I need? And for how long? Future work may also be focused around making complex decisions – using creativity, leadership and high degrees of self-management."

Julia Lindsey, CEO of iOpener Institute, 2016

How will the labor landscape change? Will the gender gap finally close?

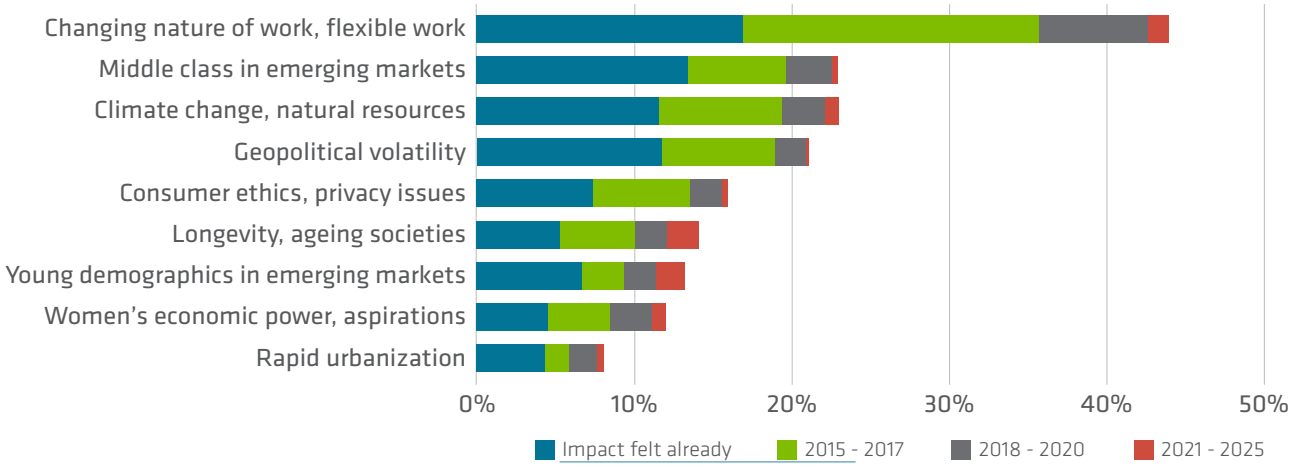
3.2.2 LABOR LANDSCAPE

Disruptive changes will have a profound impact on the labor landscape in the future. Many of the major drivers of transformation currently affecting global industries are expected to have a significant impact on jobs, ranging from significant job creation to job displacement, and from heightened labor productivity to widening skills gaps. There will be jobs in the future that haven't been created yet. The fundamental alteration of the workplace will require a new degree of co-operation between workers and technology.[83]

The changing labor landscape could have beneficial future impacts. For example, it will enable the narrowing of industry gender gaps, as automation can continue to reduce household work and encourage women to increasingly use their skills in the formal economy. Flexible working is re-shaping the existing labor market, and that will also enable the rebalance of the work gender divide.[84] It is expected that there will be a substantial shift to this flexible contingent and freelance work in the future. Today, more than one in three US workers are freelancers, and this figure is expected to grow to 40% by 2020.[85] The shift to freelance work is also being fueled by demographic changes with the role of the millennial generation in the current and future workforce. It has been suggested that the expectations of this generation are directly contributing to the changing labor landscape.[86] As new jobs created in the Next Industrial Revolution replace outdated forms of employment, there will be a heightened requirement for the education system to equip the worker with these necessary skills.

DRIVERS OF CHANGE - SURVEY RESULTS (2016) OF CHIEF HR AND STRATEGY OFFICERS OF LEADING GLOBAL EMPLOYERS

Source: The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution. World Economic Forum, 2016



"Innovation creates jobs – new products, new processes, new possibilities. Study after study confirms the net gain of jobs produced by technical innovation."

Howie Choset - Chief Technology Officer, Advanced Robotics for Manufacturing (ARM) Institute, Pittsburgh 2017

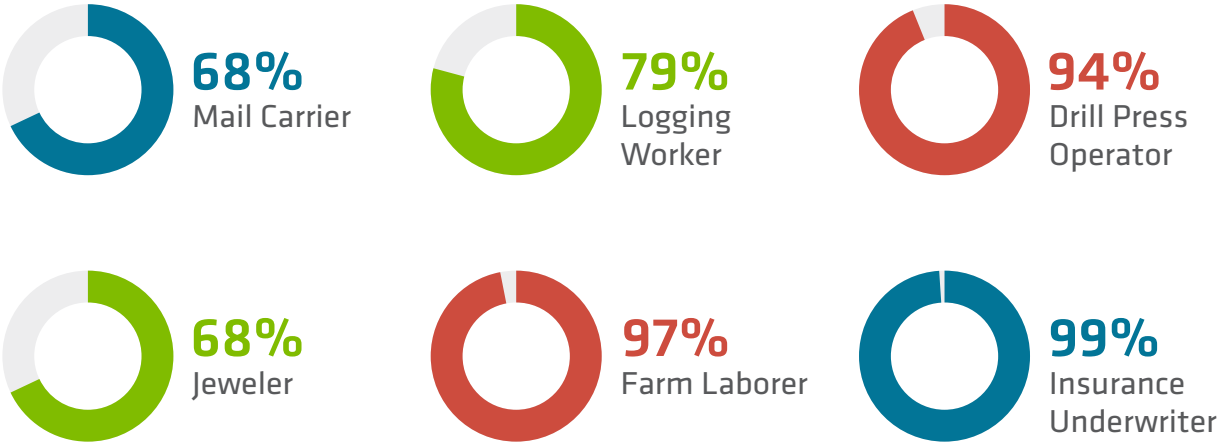
What happened to all the blacksmiths? What can we learn from previous disruptions to workforce?

3.2.3 DISPLACED TRADITIONAL WORKERS

The United States has seen a steady erosion of traditional blue-collar work over the past several decades. These jobs are those which primarily make use of physical skill or manual labor. Research consistently finds that the jobs that are most threatened by automation are highly concentrated among lower-paid, lower-skilled, and less-educated workers. Frey and Osborne believe that 83 percent of jobs making less than $20 per hour would come under the most pressure from automation.[87] As autonomous vehicles are now a reality, it has been estimated that this alone could threaten or alter almost 3.1 million existing US jobs.[88]

The challenge will be how to assist potentially displaced workers. The US spends approximately 0.1% of its GDP on programs designed to help people deal with changes in the workplace, and this funding has declined since the 1980s.[89] Changes to how people work and the dislocation of some workers due to automation increases the need for a robust safety net to ensure that people can still survive financially, retrain, and potentially transition careers.

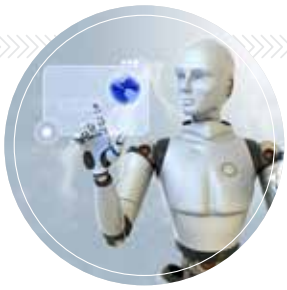
REPLACED BY ROBOTS: JOBS WITH HIGH PROBABILITIES OF BEING AUTOMATED IN THE NEAR FUTURE[90]



Source: The Future is not what it used to be. CITI GPS: Global Perspectives and Solutions, 2016.

"The story of the US economy is of repeated dislocations and losses of jobs and people figuring out ways to make new opportunities. In my grandparents' time, most Americans were farmers, and practically no Americans are farmers now, even though it is a leading agricultural nation in the world." [91]

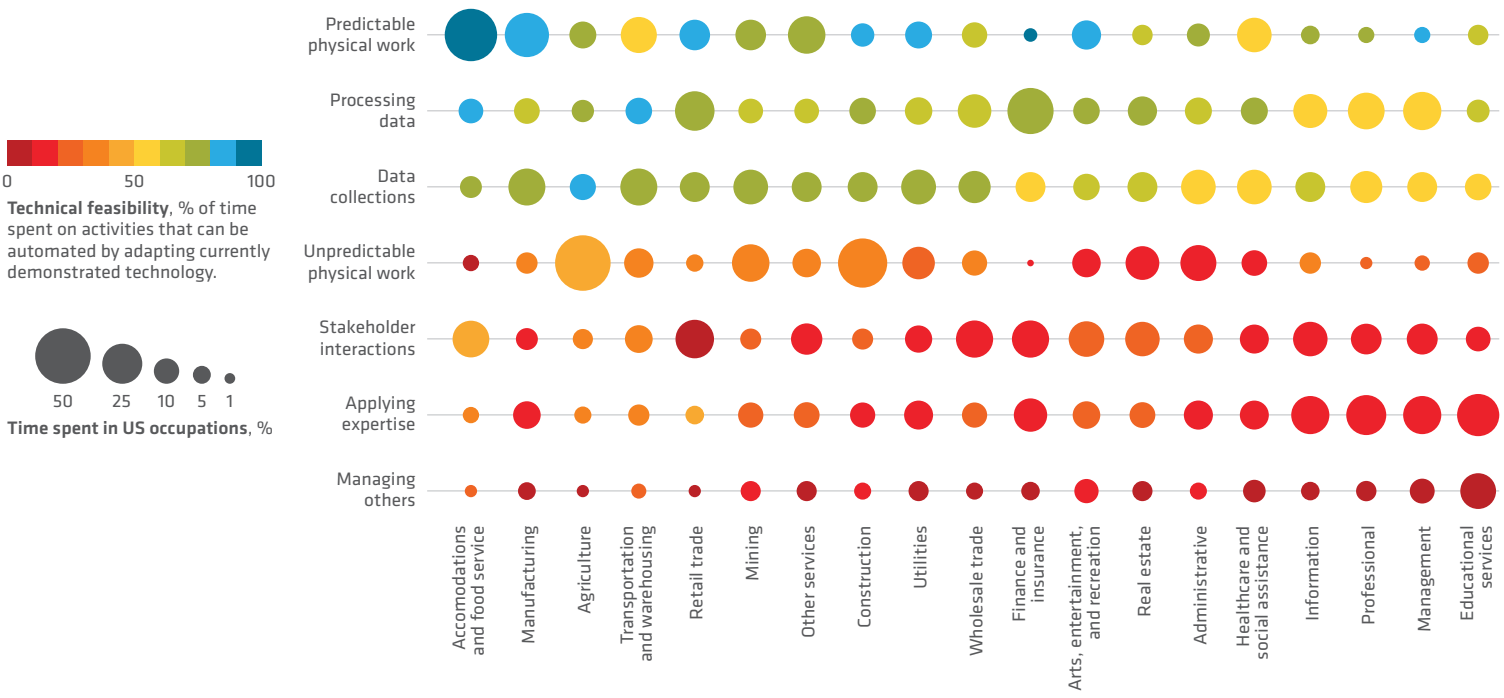
James Fallows, National correspondent for the Atlantic Monthly, 2017



Will robots start using our computers?

3.2.4 DISRUPTION OF THE WHITE COLLAR WORKFORCE

We often think of low wage and low skill jobs being at the most risk from the rapid increase of automation and robotics that is defining The Next Industrial Revolution. White collar work carried out in offices globally is now also under threat of automation. Taking this to another level, Artificial Intelligence is now disrupting jobs long considered immune to technological displacement. Algorithms have uprooted white-collar work in the high-frequency trading sector and are starting to do so in health care with robotic surgery and diagnosis by algorithm.[92] Does this mean that workers will soon be just the supervisors of robots, until that role is also automated? However, not all jobs will be affected and not all affected jobs will be eliminated, ideally automation will both replace and complement human labor.[93] Workers will need to retrain, diversify and return to education in order to equip themselves with the skills to stay relevant in The Next Industrial Revolution. Roles that require creativity, social skills and negotiation will initially need people rather than robots.



Source: Where Machines could replace humans – and where they can't by Michael Chui, James Manyika, and Mehdi Miremadi, McKinsey Quarterly 2016.

"As we automate a lot of the repetitive work, we are going to see an increased demand for creative skills and we are also going to see an increased demand for social skills, interpersonal skills and negotiating skills"

Erik Brynjolfsson, director of the Massachusetts Institute of Technology (MIT) Initiative on the Digital Economy, 2017

We are on the cusp of enormous change. How will this redefine society and how we live?

3.3 IMPACT ON SOCIETY

The evidence of the dramatic change within society that the Next Industrial Revolution is heralding cannot be ignored. Mobile supercomputing, artificially intelligent robots, self-driving cars, genetic editing and neuro technological brain enhancements are redefining society as we know it. These developments, coupled with trends such as mass urbanization, changing demographics and an interconnected world, will redefine society. The Next Industrial Revolution will be characterized by a range of new technologies that are bringing together digital, physical and biological systems. This will have an impact upon work, as outlined in the previous section, education, energy, health, how we live and what it will mean to be human. This is an exciting prospect when considering the potential benefits to mankind and the planet. While the full spectrum of possibilities can only be imagined, we are already seeing how relationships, networking, and community building have changed as a result of technology and the information access it facilitates.[94] The changes brought about by the Next Industrial Revolution are inevitable, not optional. The possible rewards are staggering with heightened standards of living; enhanced safety and security; and greatly increased human capacity.[95]

This section of the report will explore the notion of what it means to be human in the face of change and who will be the winners in the Next Industrial Revolution. How will income be distributed and what will this mean for equality?

Source: Society-in-the-loop: Programming the Algorithmic Social Contract. M.I.T, 2017

"We need to take responsibility at every level of society from the individual and personal, the institutional to the global to adapt to these technological challenges and changes which are redefining what it means to be human." [96]

John Kabatzinn, University of Massachusetts, 2015

What happens when humans can live in a virtual world? As the fundamental nature of both the individual and society changes, how will humanity adapt?

3.3.1 WHAT WILL IT MEAN TO BE HUMAN

As the division between what is natural and artificial blurs with advances in neuroscience and technology, it is imperative to consider how this will impact the individual human being. Virtual and augmented reality are key technologies helping drive the Next Industrial Revolution. Thomas Aquinas believed that human beings interpret the material world, discern order within it, derive meaning from it and act decisively upon it.[97] How will the individual adjust as society changes due to technological advances and how will the individual react to these advances which will impact perceived reality, cognitive function and brain connectivity?

Neuro-technologies are opening new approaches in potentially augmenting cognitive capacity. This has the potential to help unlock the human brain potential. With a market place of 7.5 billion human brains, innovation and commercialization in neuro-technology has the potential of being huge business. While this will create new possibilities in treating brain illness and mental health disorders, the overall capacity to improve the brain's function is an enormous opportunity. This also presents ethical challenges. Will we see fundamental changes in individual identities, and will it create inequality between those who engage with neurotechnology and those who don't?

WHAT IS PERVASIVE NEUROTECHNOLOGY?

NON-INVASIVE
It does not involve surgery or ingestion.

SCALABLE, POTENTIALLY UBIQUITOUS:
Thanks to cost / safety profile, it can extend beyond hospitals or research facilities into multiple industrial and consumer fields.

1. ELECTROENCEPHALOGRAPHY (EEG)
Monitors, and reacts to, electrical actibity in the central nervous system.

2. NEURO-MONITORING
Evaluates – often in real-time – mental states, brain functioning, the presence of disorders.

3. NEUROCOGNITIVE TRAINING
Targets and improves neurocognitive functions such as attention, memory, decision-making, self-regulation.

4. TRANSCRANIAL STIMULATION (TMS / TDCS)
Stimulates neurological activity either electrically (tDCS) or magnetically (TMS).

Source: Market Report on Pervasive Neurotechnology: A Ground-breaking Analysis of 10,000+ Patent Filings Transforming Medicine, Health, Entertainment and Business. SharpBrains, 2017. [98]

"The Fourth Industrial Revolution will change not only what we do but also who we are. It will affect our identity and all the issues associated with it: our sense of privacy, our notions of ownership, our consumption patterns, the time we devote to work and leisure, and how we develop our careers, cultivate our skills, meet people, and nurture relationships." [99]

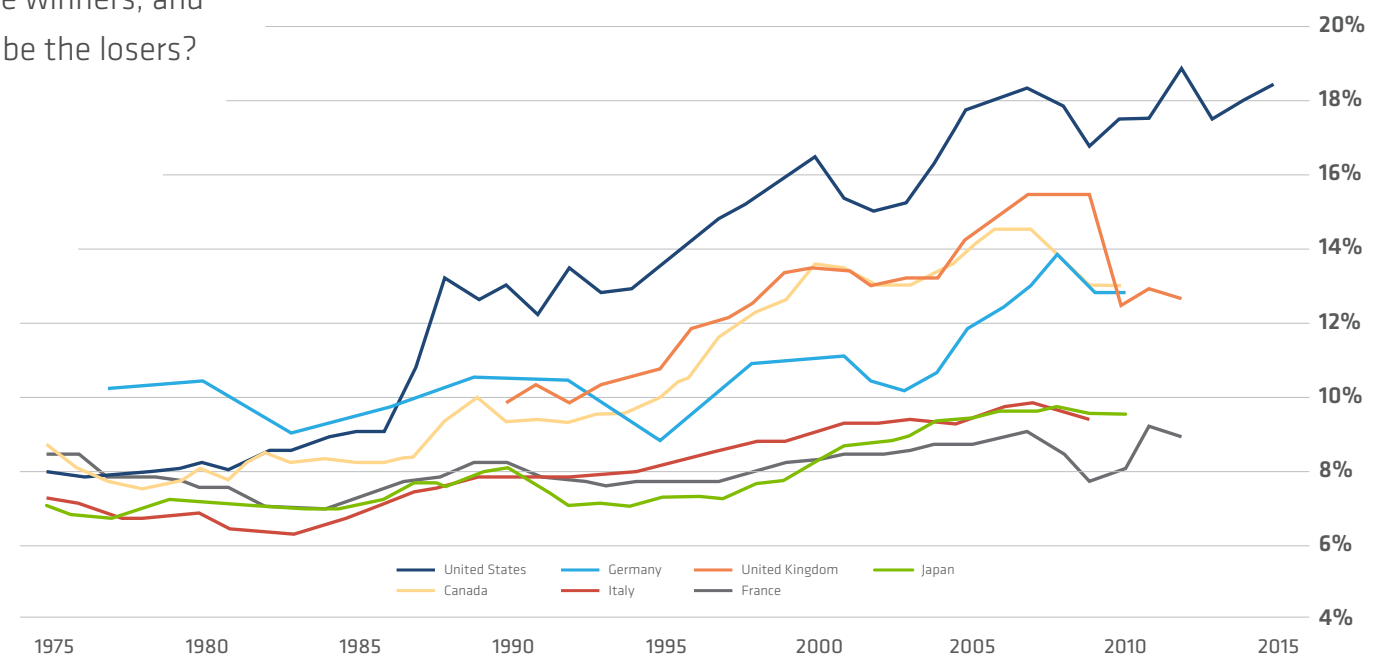
Klaus Schwab, Founder and Executive Chairman of the World Economic Forum, The Fourth Industrial Revolution, 2017

There will be enormous areas of new economic activity associated with innovation, invention and production. Who will be the winners, and who will be the losers?

3.3.2 IMPACT ON INCOME DISTRIBUTION AND EQUALITY

A broader societal implication of the evolving future workforce is the potential upsurge in income inequality. The polarization between highly skilled workers and displaced lower skilled workers could give rise to extensive income inequality and broader challenges at a societal level. A universal basic income may have the capacity to balance out this income disparity. There are many advocates insisting on instituting this basic income program to cope with the effects of automation.[100] The machine economy also promises to deliver an unprecedented 'leisure dividend' [101] with profound social implications. Work is a means of earning an income but it is also an activity that gives the individual both purpose and meaning.[102] The Next Industrial Revolution will generate enormous wealth from new innovations. What is not clear, is how this wealth will accrue or be distributed across various income classes. In addition, some regions of the world will be winners and some will be losers. This is an area that will necessitate further research and inquiry.

SHARE OF INCOME EARNED BY TOP 1 PERCENT 1975-2015



Source: World Wealth and Income Database 2015

"The Fourth Industrial Revolution will lead to greater income inequality implying larger gains for those at the top of the income, skills and wealth spectrums"

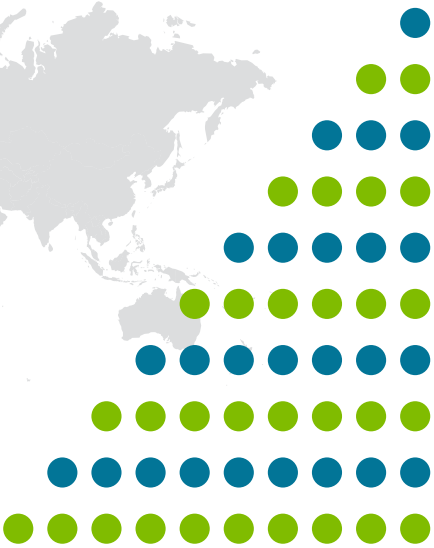
Axel Weber - Chairman UBS Bank, World Economic Forum Davos, 2016

Which country can cope with the changes that we are facing?

3.3.3 WHO WILL BE THE WINNERS?

The Next Industrial Revolution is characterized by extreme automation with the growing presence of robotics and artificial intelligence in many facets of life. It is also based on extreme connectivity and communication between humans and machines. The sheer speed of the changes that we are experiencing in this environment means that not everyone will be able to keep up. A polarized labor force, unequal income distribution, rising risks to cyber security and increased geopolitical threats will mean that flexibility will be key in order to be a 'winner' in the Next Industrial Revolution. Economies with the most flexible and responsive labor markets, educational systems, infrastructure, and legal systems will be better equipped to meet and adapt to the changes that we are experiencing. Global financial services firm, UBS, has put together a ranking of countries most likely to do well in the next 20 years based on a combined metric of the flexibility of their labor markets, how skilled their workers are, and how prepared the education system is for change. They also take into account how well the countries' legal systems protect private property rights and whether their physical infrastructure can cope with the change.

THE TOP 10 MOST COMPETITIVE GLOBAL ECONOMIES: GLOBAL COMPETITIVENESS REPORT 2016-2017



SWITZERLAND	GLOBAL RANK: 1
SINGAPORE	GLOBAL RANK: 2
UNITED STATES	GLOBAL RANK: 3
NETHERLANDS	GLOBAL RANK: 4
GERMANY	GLOBAL RANK: 5
SWEDEN	GLOBAL RANK: 6
UNITED KINGDOM	GLOBAL RANK: 7
JAPAN	GLOBAL RANK: 8
HONG KONG SAR	GLOBAL RANK: 9
FINLAND	GLOBAL RANK: 10

Ranked out of 138 economies.

Source: The Global Competitiveness Report, 2016-2017

"Youngstown's story is America's story, because it shows that when jobs go away, the cultural cohesion of a place is destroyed. The cultural breakdown matters even more than the economic breakdown" [103]

John Russo, Professor of Labor Studies, Youngstown State University, 2015

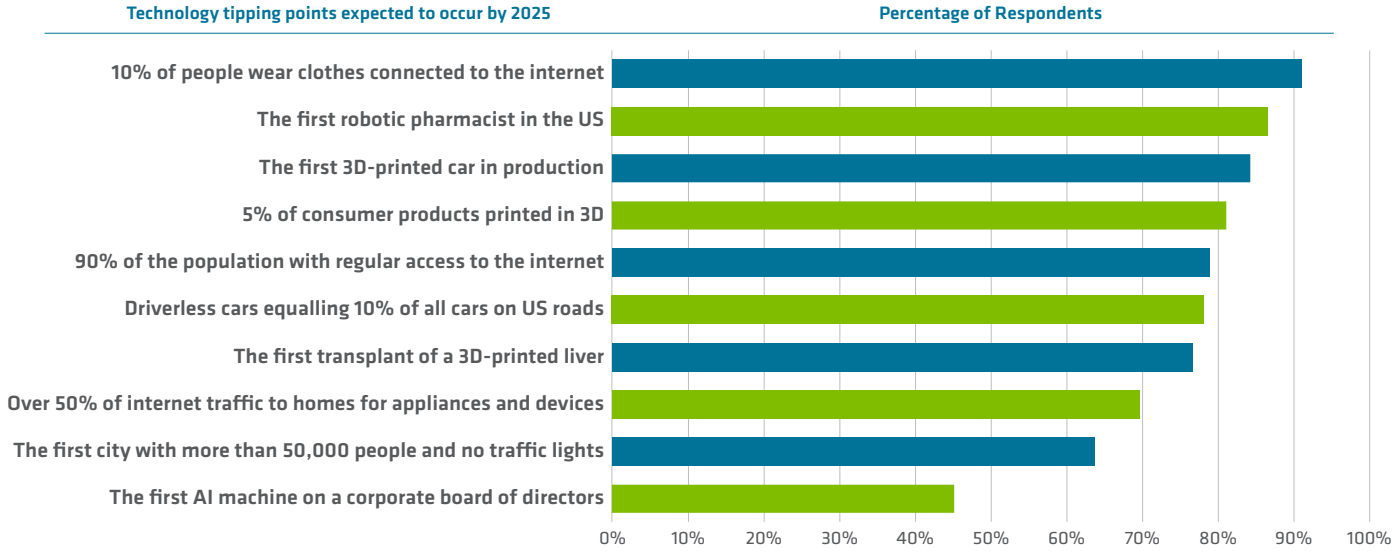
How different might our daily life look in 20 years from now?

3.4 LIFE IN THE FUTURE

How will our lives change in the future? Having looked at the factors driving the Next Industrial Revolution and the potential impacts and implications of these factors throughout this report, we need to turn to contemplating about how our actual lives will change.

From a macro perspective we know that our world is being impacted on many levels. The world is becoming increasingly urban and by 2050 it is estimated that 66% of the world's projected population will live in an urban environment.[104] Technologies that have and are being developed in this next epoch of the Next Industrial Revolution will transform the future urban landscape and infrastructure. As people continue to live longer, due in part to technological advances, the global population is forecast to grow to over 9 billion people in the next thirty years.[105] With a declining birth rate, the global population could become an increasing aging population. Environmental issues which are currently escalating will impact upon the global population and food production. Feeding the world will be a challenge.

As we move from the macrocosm to the microcosm view we can see that the advances generated through emerging catalytic technologies will change our individual day to day lives. Autonomous transport, household robots, genomic medicine and flexible working will be but a few of the changes that we will experience in the future.



800 Technology executives and experts from the information and communications technology sector were surveyed as part of the World Economic Forum's Technology Tipping Points and Societal Impact Report.

Source: World Economic Forum: Technology Tipping Points and Societal Impact Report, 2015

"The Fourth Industrial Revolution has the potential to empower individuals and communities, as it creates new opportunities for economic, social, and personal development"

Klaus Schwab. Fourth Industrial Revolution, 2016

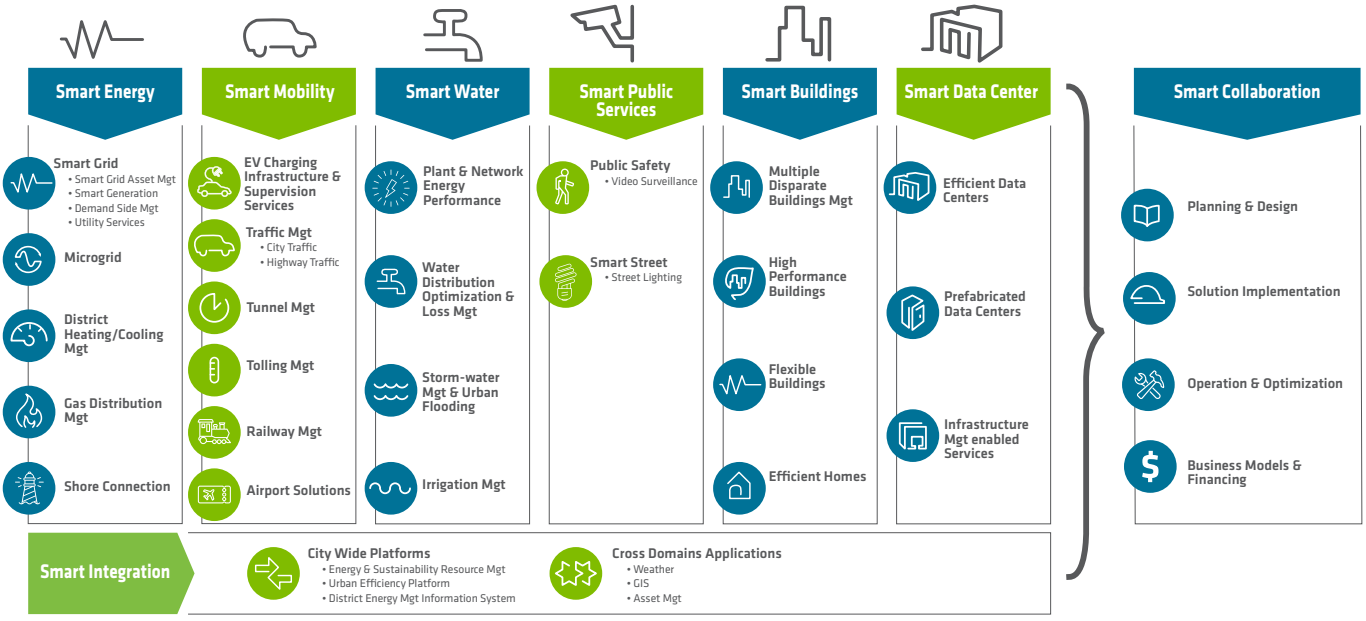
How can technologies improve conditions in existing and new cities?

3.4.1 CITIES OF THE FUTURE

The world population is becoming increasingly urban. On the current trajectory, by 2050 the urban population is estimated to be 6.3 billion (66% of the world's projected population). Cities and those that live within them are becoming one of the most influential factors shaping the future of the planet.[104] Next Industrial Revolution technologies such as the Internet of Things, autonomous vehicles, advanced robotics, artificial intelligence, and machine learning are beginning to change and will fundamentally transform urban systems, including energy, waste and water infrastructure, mobility and transportation, logistics, buildings, communications, retail, the sharing and circular economies, hospitality, schools, cultural spaces, and healthcare.[105]

As urban areas transform, and if Next Industrial Revolution technologies are utilized in a systematic and strategic manner, we will see changes in the movement and interaction of people and things, modes of work, reduced congestion, and improved health and wellness, which could lead to sustainability with social equity, ecological health, and economic prosperity.

THE SEGMENTS OF FUTURE SMART CITIES



Source: Schneider Electric, Smart City Segments, from Back to School... and Smart City Fundamentals, August 2015.

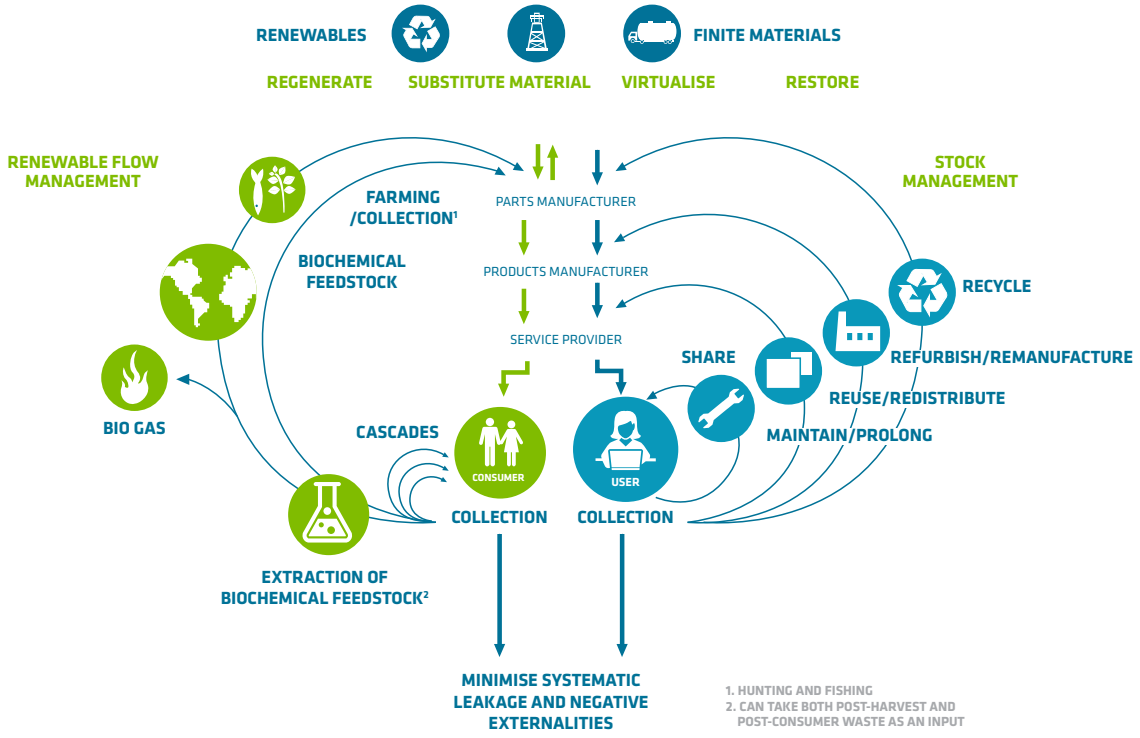
"To build a Future City, we will require technology and a digital platform. This is the easy part. For us to live, learn, and work in cities that we haven't fully imagined yet requires incremental innovation, and a culture of inclusion and creativity. Just based on our experiences from the past 20 years we do know that the next 20 years will show even more change and disruption. Municipal leaders have the daunting task to lead the process of re-imagining our communities. Future cities are for people and by people."

Dr. Rick Huijbregts, Vice President of Digital Transformation and Innovation, Cisco Canada, December 16, 2016

Will technological innovations help clean the environment and reverse climate change?

3.4.2 TECHNOLOGY AND THE ENVIRONMENT

The technologies being developed in the Next Industrial Revolution have the potential to work towards solving major global environmental challenges. For instance, the decreasing cost of solar, wind and battery technologies are bringing green energy into competition with traditional fossil fuel-based energy sources and could substantially decrease greenhouse gas emissions. The Ocean Plastic Clean Up is developing an autonomous, energy neutral, scalable system to collect ocean plastics. Collected materials will be brought back on land and recycled. They estimate that a full-scale deployment of the system could clean up 50 % of the Great Pacific Garbage Patch in 5 years.[106] The Circular Economy, Cradle to Cradle design, Additive Manufacturing, the Sharing Economy, combined with data analysis, sensory, robotics, and artificial intelligence are changing how things are made, repurposed and recycled, increasing efficiency, utilizing fewer raw materials and energy, and creating less waste.[107]



Source: Ellen MacArthur Foundation, SUN and McKinsey Center for business and Environment; Drawing from Braungart & McDonough, Cradle to Cradle (C2C).

"The Fourth Industrial Revolution will be about the marriage of minds and machines. The machines will help us be smarter, more productive, predictive and social. They will not be the answer to our environmental challenges, but they can help us deliver the answer, from changing the dynamic of our cities and how we build things, to mobility, consumption, and how we power and feed society. Our lives will never be the same, but the good news is that the change can be both positive and sustainable."

Celine Herweijer, PhD, Partner, PwC's Sustainability and Climate Change Team, September 24, 2017, 7 ways the Fourth Industrial Revolution can help the planet.

If the population can get older and healthier, how does this define ageing?

3.4.3 HUMAN HEALTH AND AGEING

As birth rates decline and the world's population ages in the coming decades, innovative technologies will enable us to live longer, healthier and more productive lives due to the advances that have arisen from the Next Industrial Revolution. Wearables, connected devices, robotics and artificial intelligence will advance social connectivity and emotional health, cognitive ability and physical functioning.[108]

Neurological and psychological disorders have a profound impact upon quality of life and ageing. Rapid advances in genetics and regeneration biology have produced new tools that are revolutionizing the ability to maintain healthy brain cells. As people continue to live longer, the technological advances that are being produced in the Next Industrial Revolution are needed now, more than ever to assist the health of the global population.

GLOBAL AGEING IN A NUTSHELL

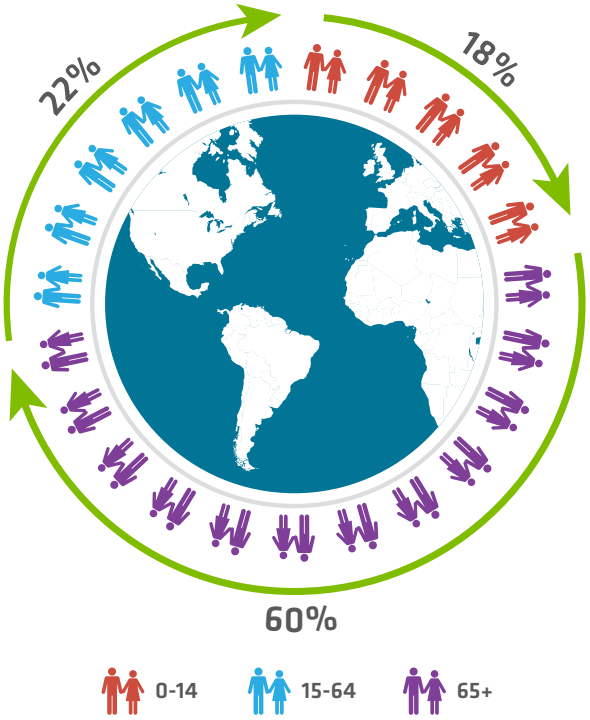
2.1 Billion
people aged 60+ in 2050, versus 901 million in 2015

70%
of world's population evetually falling below replacement level of 2.1 births per woman

8 Out of 10
of the world's 60+ population will live in developing countries by 2050

6 Out of 10 women
and 5.2 out of 10 men born during 2000-2005 are expected to live to 80

US $15 Trillion
spending power of consumers 60+ globally



26.1 Years
is the world's median age by 2050, versus 29.6 today

7 Workers
per older person globally, will fall to 4.9 in 2030

48%
of the retirement-age population does not receive a pension

1 in 4
of 65+ expect to never be able to fully retire

US $15-25 Trillion
amount of longevity risk globally

Source: Bank of America Merrill Lynch Global Research, 2016

"By 2020, individuals aged over 60 will be greater than children younger than five. By 2050, the world's older adult population will have doubled to 2 billion"

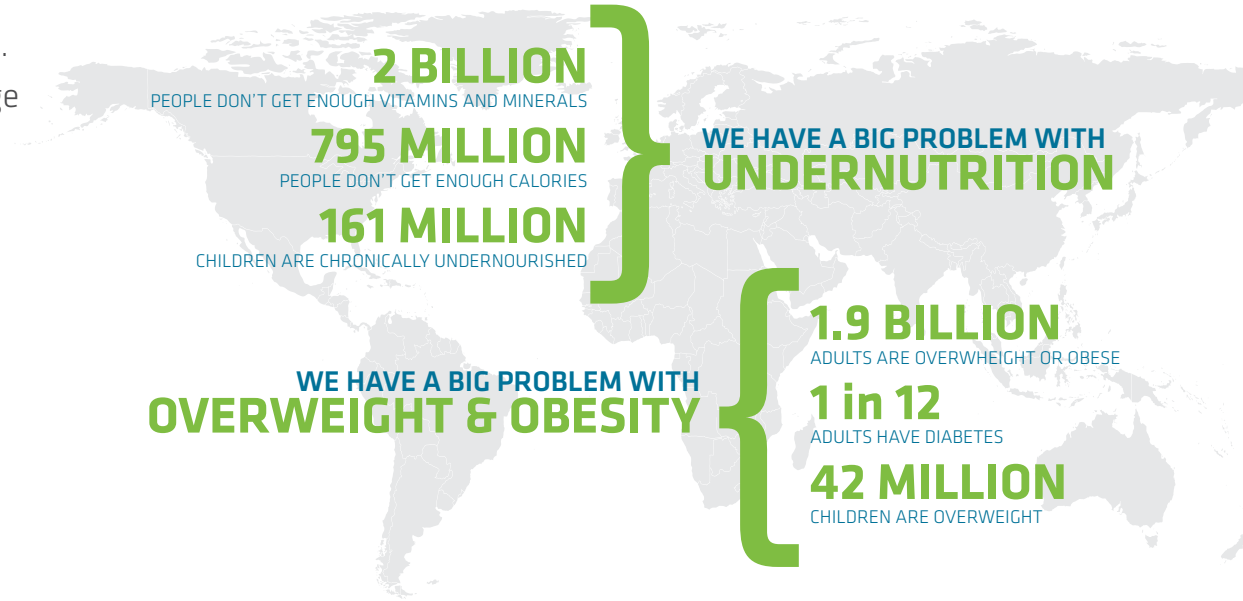
Ageing and Health Fact Sheet. World Health Organization, 2015

Within a decade or two, 3D printing of food might dominate customized meal assembly in hospitals, schools, institutions, and fast food outlets. How might this change your health?

3.4.4 FEEDING THE WORLD

The global population is forecast to grow to over 9 billion people in the next 30 years. Increasingly this population will be living in mega cities. The productive capability in traditional food producing areas will be severely impacted by climate change and water shortages. In addition, there will be significant discrepancies in human health with extremities of undernutrition and obesity.[109]

To solve the challenge of feeding the world, there will have to be substantial technological breakthroughs in the key areas of food production capacity and delivery of suitable healthy nutrients to consumers.[110] From a perspective of human health and feeding the world, the technology driving the Next Industrial Revolution has arrived just in time. This technology offers the opportunity for food and diet choices to be made for us, even if we don't know it. Just like driverless cars will save us from bad drivers, maybe technology will save us from bad diets.



Source: International Food Policy Research Institute: Global Nutrition Report 2015

"Providing food and nutrition for 9 billion people without compromising the global environment will be one of the greatest challenges our civilization has ever faced...It will require the imagination, determination and hard work of countless people from all over the world, embarking on one of the most important causes in history"

Jon Foley, University of Minnesota. 12 October 2011. Solutions for a cultivated planet. GLI Publications (Emily Dombeck).

The Next Industrial Revolution promises great opportunity, and perhaps presents significant challenges. How can we best prepare?

"Over time I think we will probably see a closer merger of biological intelligence and digital intelligence,"

Elon Musk, February 2017

4.0 A GLIMPSE INTO THE FUTURE

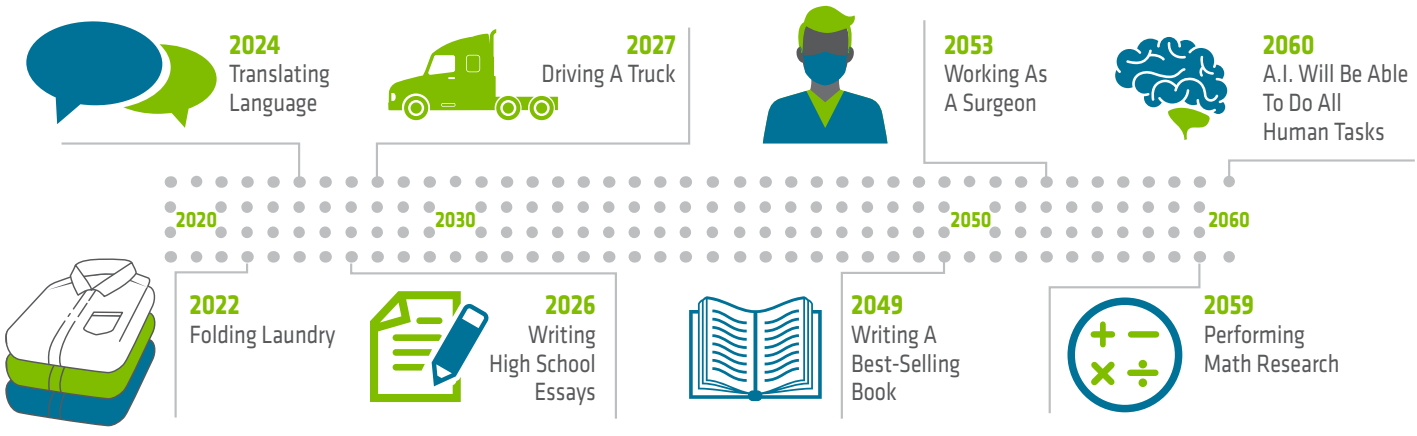
The material presented in this foresight piece on the Next Industrial Revolution reiterates the speed of technological progress we are facing over the coming decades. In 1970, Alvin Toffler published the best-selling book 'Future Shock', which described a scenario where change happens too fast, resulting in social confusion.

To date humans have proven to be remarkably resilient and adaptable. However, famed futurist, Ray Kurzweil, currently Director of Engineering at Google, predicts that Singularity – the moment when technology becomes smarter than humans – will happen by 2045. Sixteen years prior to that, he says it will be just as smart as us. "2029 is the consistent date I have predicted for when an AI will pass a valid Turing test and therefore achieve human levels of intelligence." [111]

We have absorbed enormous change in the past 40 years without societal meltdown. However, the future pace and nature of change will test human ingenuity and resilience at new levels. Our ability to adapt and thrive will require an increasingly astute and keen appreciation of the broader challenges. One thing we don't have on our side is time. For many communities and regions, this highlights the necessity to invest in understanding, anticipation and preparation.

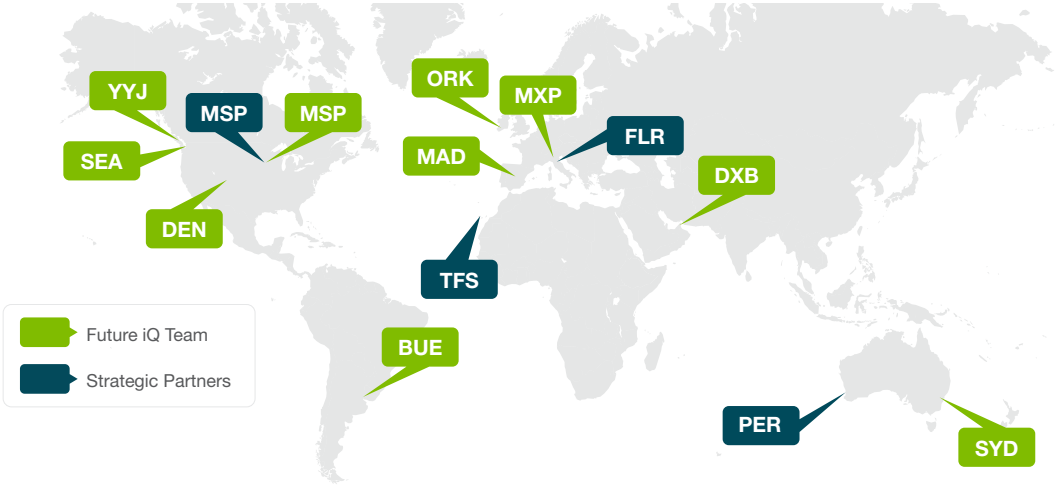
Researchers with Oxford and Yale surveyed 352 AI experts about when machines will be superior to humans at performing particular tasks. Their median answers are as follows:

AI WILL LIKELY OUTPERFORM HUMANS AT...



Source: 'You Will Lose Your Job to a Robot—and Sooner Than You Think'. Kevin Drum, Mother Jones, November / December Issue, 2017. (adapted from 'When will AI exceed human performance? Evidence from AI Experts', Oxford and Yale University 2017) [112]

GLOBAL PRESENCE – LOCAL SOLUTIONS



5.0 ABOUT FUTURE IQ

Future iQ's customized foresight research consists of extensive global trend analysis to help identify emerging risks, new growth areas and to explore opportunities for disruptive innovation. Our foresight publications are aimed at providing stakeholders with the critical information needed to anticipate and adapt to emerging futures.

To learn more about Future iQ, and our recent projects visit www.future-iq.com or by email at info@future-iq.com.

Future iQ specializes in the development and application of scenario planning, network analysis, industry and regional analysis, and stakeholder engagement.

We specialize in applying innovative tools and approaches to assist organizations, regions and industries plan for the future.

DAVID BEURLE, CEO

As CEO of Future iQ, David specializes in creating future planning approaches for the use in regional, community and organizational settings. David has worked in the field of organizational, industry and regional planning for over 20 years. His work in community and economic development has earned his work international, national and state awards.

CELINE BEURLE, COO

With an academic background in Sociology and Philosophy Celine is passionate about understanding society and this has led to her ongoing interest in pursuing societal change. She has drawn upon her research background, to write significant national policy papers and has published numerous technical and scientific papers.

HEATHER BRANIGIN, VICE PRESIDENT, BUSINESS DEVELOPMENT

Heather has worked in the fields of Development and Education for over 20 years. She has extensive experience in local government and growing small business and organizations, and is an accomplished project manager, research analyst and writer. Heather is Past President and current Advisory Council Member of the United Nations Association of Minnesota and is committed to encouraging international understanding and global collaboration.

LEHNA MALMKVIST, MANAGING DIRECTOR, CANADA

Lehna sees a future in which people live integrated within their ecosystems, and where their built environments mimic the processes and functions of nature. She strives to enable all sectors to achieve economic, ecological and social sustainability. Lehna has worked for over 10 years providing ecological expertise within multi-disciplinary teams across a wide range of projects. She has produced and presented extensive educational material, as well as coordinated conferences, workshops and courses.

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