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PARTNERING FOR IMPACT
ACHIEVING THE SDGS

INDUSTRY 4.0

OPPORTUNITIES BEHIND THE CHALLENGE

Background Paper

ACKNOWLEDGEMENTS

While it is hazardous to accurately anticipate how the maturation of emerging Industry 4.0 technologies may impact society at large, it is important for policymakers to initiate the process of understanding the truly disruptive nature of these technologies. This Background Paper on Industry 4.0 attempts to lay out the central concepts related to Industry 4.0 and complementary technologies, their rapid progress, and discuss the attendant salient development and governance policy issues. The paper is not meant to be an exhaustive treatment of all issues, but rather aimed at providing a broad overview of key issues, thereby stimulating wide discussion on the topic.

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[4] http://www.tivinc.com/

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I. INDUSTRY 4.0 PARADIGM

DEFINITION

The term "Industrie 4.0" originates from a project in the high-tech strategy of the German government, which promotes the computerization of manufacturing. The German government established "Plattform Industrie 4.0" to support German SMEs by helping them understand and exploit Industry 4.0 strategies and opportunities, particularly in the areas of standardization and norms, security, legal frameworks, research, and workforce transformation.

Industry 4.0 is a comprehensive concept as well as a new trend in manufacturing (and relevant sectors), based on the integration of a set of technologies that enable ecosystems of intelligent, autonomous and decentralized factories and integrated products and services. Its pervasiveness has produced several conceptualizations, which have, however, let to a lack of clarity and definition. The term Industry 4.0 is linked to the smart collection and application of real time data and information by networking all individual elements, so as to reduce the complexity of operations, increase efficiency and effectiveness, and reduce costs in the long term.[1]

Industry 4.0 is often described as digitization or full-scale automation. It is also sometimes defined in relation to emerging technologies – advancements in IoT, big data and data analytics, robotics, autonomous systems, sensors and automation, and production methods, such 3D printing.

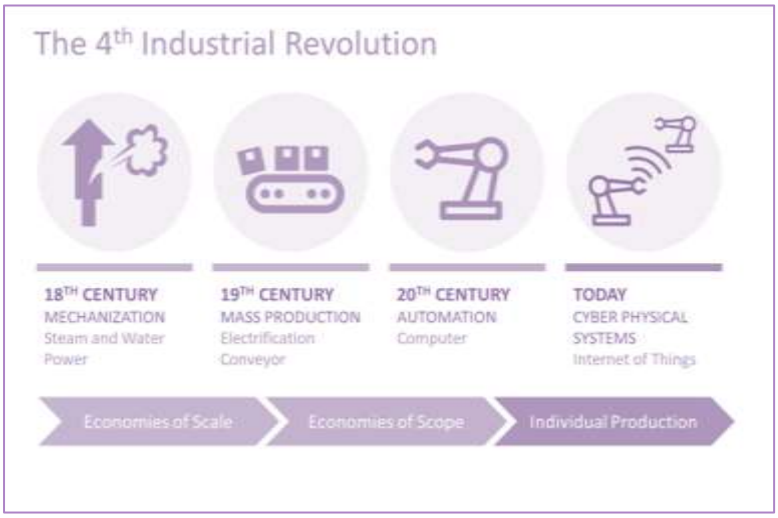
Yet while digitization has given rise to Industry 4.0, it cannot be defined purely from a technological perspective. Because of convergence, enterprise transformation – through changes in business models, organization and culture – is just as integral to Industry 4.0 as technology.

INDUSTRY 4.0 CHARACTERISTICS

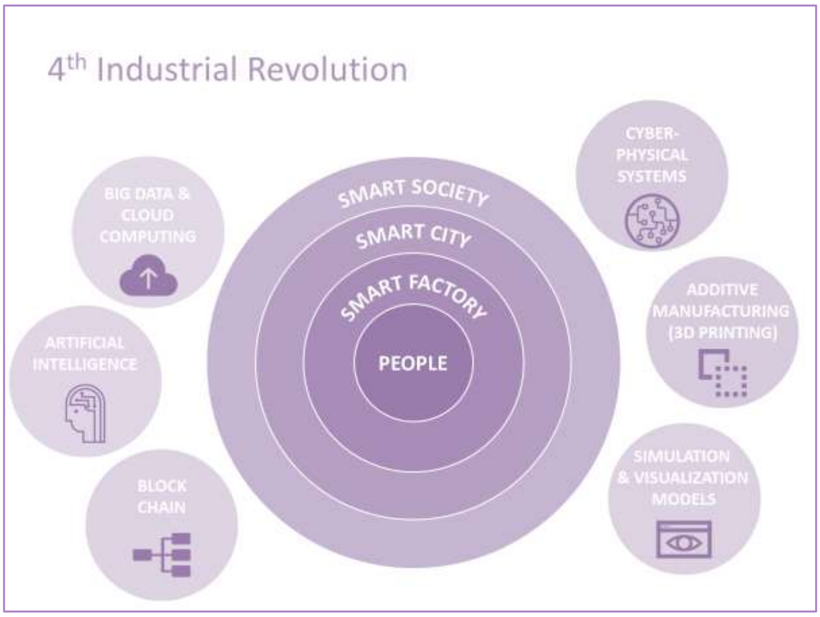
1 **Interoperability:** cyber-physical systems (workpiece carriers, assembly stations and products) allow humans and smart factories to connect and communicate with each other.
2 **Virtualization:** a virtual copy of the smart factory is created by linking sensor data with virtual plant models and simulation models.
3 **Decentralization:** cyber-physical systems make decisions of their own and produce locally (by using 3D).
4 **Real-time capability:** enabling the collection and analysis of data and providing the derived insights immediately.
5 **Service orientation**
6 **Modularity:** the flexible adaptation of smart factories to changing requirements by replacing or expanding individual modules.
7 **Convergence**
8 **Cost reduction and efficiency**
9 **Mass customization**

[1] https://www.sciencedirect.com/science/article/pii/S235197891730728X

Industry 4.0 is a paradigm shift from centralized to decentralized smart manufacturing and production. It refers to the computerization of manufacturing and the creation of a "smart factory". Physical objects are seamlessly integrated into the information network. Manufacturing systems are vertically networked with business processes within factories and enterprises, and horizontally connected to spatially dispersed value networks that can be managed in real time – from the moment an order is placed right through to the outbound logistics. The distinction between industry and services becomes blurred. Digital technologies are connected with industrial products and services into hybrid products that cannot be exclusively defined as goods or services.[2] Within the modular structured smart factories, cyber-physical systems (CPS) and networks monitor physical processes, creating a virtual copy of the physical world and making decentralized decisions. Using the Internet of Things (IoT), CPS communicate and cooperate among each other and with humans in real time. Through the Internet of Services (IoS), internal and cross-organizational services are offered and used by the value chain participants.[3] Smart data is collected and processed throughout the whole product life cycle. This generates optimization of smart, flexible supply chains and distribution models, and also efficient and optimized use of machines and equipment. Businesses are able to make quicker, smarter decisions, quickly responding to customer demands, while minimizing costs.



Industry 4.0 is expected to influence four long-term relationship paradigm shifts that are going to change the landscape of the global manufacturing industry: (i) ***Factory and nature***: improvements in resource efficiency and sustainability of manufacturing systems; (ii) ***Factory and local communities***: increased geographical proximity and acceptance, integration of customers in design and manufacturing processes; (iii) ***Factory and value chains***: distributed and responsive manufacturing through collaborative processes, enabling mass customization of products and services; and (iv) ***Factory and humans***: human-oriented interfaces and improved work conditions.[4]



[2] http://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf
[3] https://www.hightech-strategie.de/de/The-new-High-Tech-Strategy-390.php
https://www.hightech-strategie.de/de/Industrie-4-0-59.php
[4] https://www.sciencedirect.com/science/article/pii/S235197891730728X

The Fourth Industrial Revolution

Industry 4.0 is one of the major drivers of the Fourth Industrial Revolution. The first industrial revolution was triggered by water and steam power, moving from human labour to mechanical manufacturing. The second industrial revolution built on electric power to create mass production. The third used electronics and information technology to automate manufacturing. We are now at the dawn of a Fourth Industrial Revolution. In the same way that the internet created enormous value by connecting people virtually, the IoT will interconnect things. CPS will lead to smart production, with intelligent products, machines, networks and systems independently communicating and cooperating with each other over the entire manufacturing process – with minimal human intervention.

Breakthroughs in digital technologies, such as artificial intelligence, robotics, 3D printing, the IoT, combined with nano- and bio-technology and material sciences, are advancing the fourth industrial revolution. The impact of Industry 4.0 technologies will be profound, reaching all disciplines; redefining the boundaries between economic and industrial sectors; and between buyers and sellers; changing the role of the public and private sector; and changing the terms of competition. Current production systems, mediated by global value chains will become more dynamic, flexible, efficient, and sustainable, with high possibilities for customization and personalization.

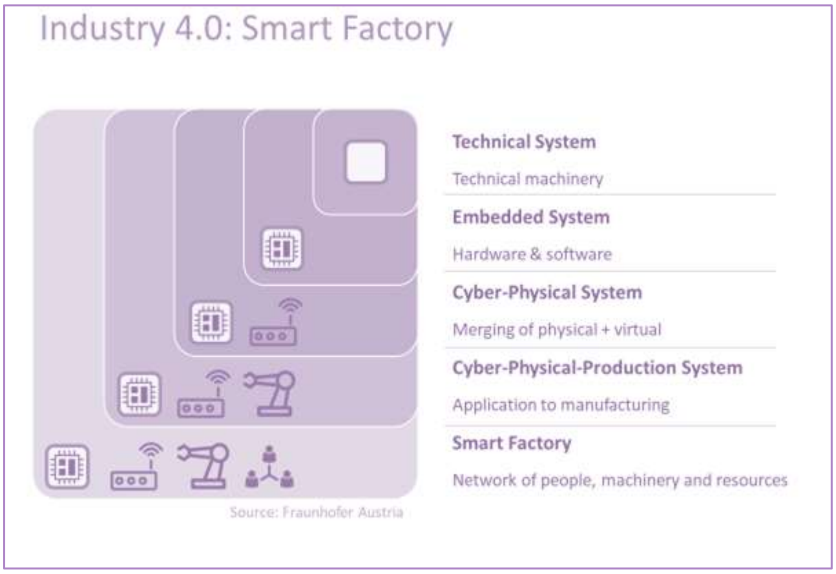
Although Industry 4.0 starts with advanced manufacturing, the ultimate impact will transcend into other segments including utilities and smart cities — where, at some point, production activities will be coordinated (or even suspended) to accommodate increased energy demand within the smart grid and other elements of the smart city. Hence there will be new IT- and technology-centric education and work opportunities, as well as the development of real-time data that will operate and manage broadband information and communication technology infrastructure, buildings and traffic systems.

CONVERGENCE

As everything is digitalized, data will become ubiquitous and connections will be made between everything via smart software. Industry 4.0 is breaking down barriers converging industries (e.g. information, communication and entertainment), converging disciplines (e.g. genomics, nanotechnology, robotics) and converging, biological, physical and virtual worlds (e.g. cyber-physical systems).

Even though Industry 4.0 is based and builds on the technologies and infrastructure of the Third Industrial Revolution, it represents entirely new ways in which emerging technologies become embedded within societies and even human bodies.[5] Industry 4.0 encompasses developments in previously fragmented and disconnected fields such as artificial intelligence (AI) and robotics, nanotechnology, 3D printing, and genomics and biotechnology. Illustrious examples include genome editing, new forms of machine intelligence, breakthrough materials and approaches to governance that rely on cryptographic methods such as the blockchain.[6] These emerging technologies are expected to cause disruption to existing models of governance by introducing cross-cutting economic, legal, regulatory and ethical challenges. In particular, Industry 4.0 is expected to have a h impact on labour markets (with changes in skillsets), global value chains, education, health, environment, and many economic and social aspects.[7]

[5] https://www.weforum.org/agenda/2016/01/what-is-the-fourth-industrial-revolution/
[6] http://theglobalforesightgroup.com/publications/the_new_production_paradigm_and_its_implications
[7] Industry 4.0 How to navigate digitization of the manufacturing sector, McKinsey Digital 2015 at: https://www.mckinsey.de/files/mck_industry_40_report.pdf

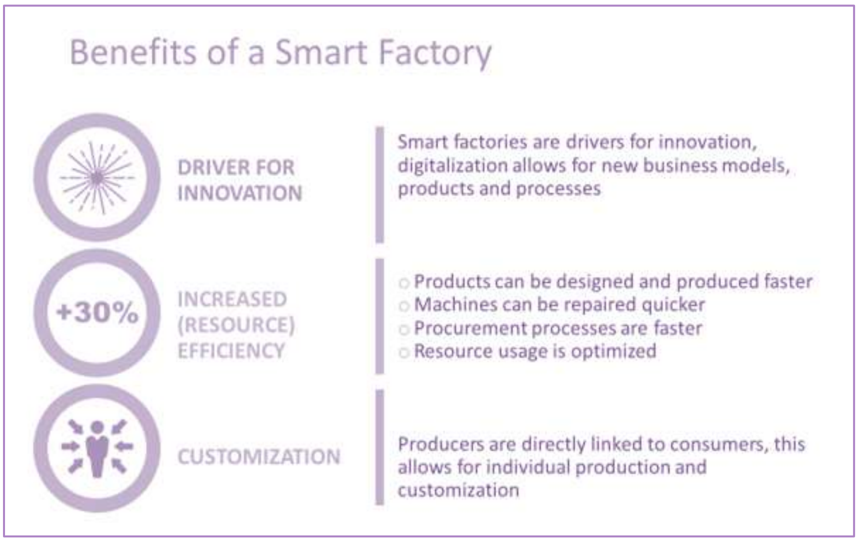


The smart factory connects the digital world of information technology with the physical world of operational technology, what many call IT/OT convergence. But Industry 4.0 is not a distant vision for the factory of the future. It is here and it is now. Networks of robots are connecting to the cloud and contributing mass amounts of insightful data. Today, manufacturers are using these information pipelines to simplify asset management and maintenance, maximize equipment and process efficiency, and improve product quality. Thus, innovating towards industry 4.0 encompasses digital convergence between industrial and business components, as well as between manufacturing models and internal processes. This process relies on combining data from external and internal sources to improve decision making; the development of digital skills for a better integration and management of resources within organizations, including security, cybersecurity and risk control; better understanding of how technology can affect Industry 4.0 localized manufacturing; and finally, the simultaneous work on the development of smart products and manufacturing processes.

MASS CUSTOMIZATION

With the rise of digital fabrication methods, such as 3D printing, laser cutting, CNC-milling and robotic assembly, the ability to manufacture products economically in small batches, even in batches of one, becomes a real possibility. Mass customization could allow products to be accurately designed to the specific needs of each individual consumer, and with the consumer being part of the design process. This engagement can help to create a stronger emotional bond between consumer and product, which could help counter the current throwaway culture afforded by the mass production of low-cost, standardized products.

Furthermore, the expense of tooling and the need to produce high volumes in order to achieve economies of scale using traditional production methods, requires considerable up-front investment. Digital fabrication and the capacity to produce products in smaller batches may lower existing cost barriers to radical product innovation. This could encourage designers and entrepreneurs to be more experimental and innovative, which might lead to more circular product innovations and new products that address sustainability issues. The use of 3D printing for the on-demand production of spare parts would also improve maintainability and extend the life cycle of products and equipment. It would also affect product design in that future 3D part maintenance can be built into the process.



CYBER-PHYSICAL SYSTEMS (CPS)

Cyber-physical systems (CPS) are engineered systems built and dependent upon the integration of computational algorithms and physical components. Together with the internet, data, and services available online, embedded systems join to form cyber-physical systems. CPS are enabling technologies that will transform the way people interact with engineered systems. New smart CPS will bring virtual and physical worlds together and enable a networked world where intelligent objects communicate and interact. These technologies promise to revolutionize human interactions with the physical world in much the same way that the internet has transformed human interaction with information.[8]

CPS enable interactions between high performance software-based embedded systems and dedicated user interfaces integrated into digital networks. This creates a completely new world of system functionality. CPS use shared knowledge and information from processes to independently control logistics and production systems. They are the bridge that connects IoT with higher-level services, known as the Internet of Services (IoS). Software providers, service providers, brokers and users collaborate to develop flexible applications that can be dynamically integrated with one another.

CPS also represent a paradigm break from existing business and market models, as revolutionary new applications, service providers, and value chains become possible. Industry sectors such as the automotive industry, energy, economy and healthcare, will in turn be transformed by these new value chain models. In the future, advances in CPS will enhance human security, efficiency, comfort and health. It is expected that CPS will play a central part in addressing the fundamental challenges posed by demographic change, scarcity of natural resources, sustainable mobility, and energy change.[9]

The new generations of CPS and their emerging platforms, such as the IoT and the Industrial Internet of Things (or Industrial Internet) will influence the formation of future smart and connected environments, including smart cities. This will cut across several challenges that will need to be addressed through the creation of a sustainable Industry 4.0 governance model: ensuring control, dependability, networking, privacy, security, safety, transparency and interpretability.[10]

INTERNET OF THINGS (IOT)

The IoT blurs the boundaries between the real world and the virtual world. It introduces increased programmability, memory storage capacity, and sensor-based capabilities, thus allowing physical world objects to become intelligent and communicate independently, online. This would allow for established, centralized systems to operate in a decentralized and disruptive setting. The IoT goes beyond machine-to-machine communication, and extends to machine-to-infrastructure and machine-to environment communication. [11]

It is estimated that 10 billion of the 1.5 trillion things are currently connected. This means that more than 99 per cent of physical objects are not yet connected. According to some forecasts, more than 26 billion-unit devices will be part of the IoT by 2020, creating incremental revenue in excess of US$300 billion for IoT products and service suppliers.[12]

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[8] https://www.nsf.gov/pubs/2017/nsf17529/nsf17529.pdf

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

[10] https://cps-vo.org/group/iot

[11] The advent of the IPv6 internet protocol (which makes 600 quadrillion addresses per square millimetre of the earth's surface possible) means that all physical objects, in theory, can have their own IP address, creating a world of intelligent objects in an Internet of Things.

[12] Source: https://industrie4.0.gtai.de/INDUSTRIE40/Navigation/EN/Topics/The-internet-of-things/internet-of-things-what-is-it.html

INDUSTRIAL INTERNET (INDUSTRIAL INTERNET OF THINGS)

The Industrial Internet combines the global reach of the Internet with a new ability to directly control the physical world, such as machines, factories and infrastructure. It is currently in its early stages of development.[13] Research carried out by the World Economic Forum (WEF) predicts that the opportunities of the Industrial IoT will come in a form of new value created by gathering massive volumes of data from connected products, and the increased ability to make real-time, automated decisions. This will generate (i) improved operational efficiency via predictive maintenance and remote management; (ii) an outcome economy based on software-driven services, hardware innovations and increased visibility into products, processes, clients and collaborators; (iii) ecosystems connected by software platforms that will better facilitate data creation, aggregation and exchange; and (iv) new human-machine interactions that will increase productivity.

The outcome-oriented economy will rely on tangible outcomes, from guaranteed machine uptimes on factory floors and actual amounts of energy savings in commercial buildings, to guaranteed crop yields from a specific parcel of farmland. Platform owners and partners would be benefiting the most by being able to harness the network effect inherent in these new digital business models to create new kinds of value.

INTERNET OF SERVICES (IOS)

In industry, products, processes and services are increasingly being "refined" by being linked to form smart services. For both providers and users of IT services, internet-based services offer great potential for growth. Such services, for example, can lead to changes in product portfolios, optimization of industrial-plant operation – via new knowledge platforms – and virtualization of ICT infrastructures, with proper consideration of attendant IT security issues. [14]

The IoS and the IoT will significantly change the engineering and operation of future information systems and the economy as a whole. The convergence of IoS and IoT empowers new types of software-intensive systems which, among others, facilitate real-time observation and the adaptation of intra- and cross-organizational processes.

CLOUD COMPUTING

Cloud computing offers industry many opportunities for growth and development. This particularly applies to technologies that were previously primarily reserved for large companies.[15]

INTERNET OF ENERGY (IOE)

The imperative of climate change and pollution mitigation, at times where we expect population and individual demand to grow, rapidly dictates the optimized use of any available resource. The "circular economy" concept, which contrasts the concept of linear economy (take, make, use, dispose), requires that any resource is optimized in terms of renewability (energy used), reusability (recycling valuable metals, alloys and polymers beyond the shelf life of individual resources) and recyclability (compostable packaging). The concept of the circular economy is based on the optimization of energy and natural resource ecosystems, and this is achievable only by interconnecting the key stakeholders. The circular economy requires integrated information about demand and resource, and the balance between the two to be optimized.

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[13] http://reports.weforum.org/industrial-internet-of-things/executive-summary/
[14] https://www.bmbf.de/pub/HTS_Broschuere_eng.pdf
[15] Ibid.

The backbone of this optimization will be the IoT, which will allow assets to exchange data and machine learning algorithms to optimize demand dependent on priorities and available resources.[16] The number of connected devices, sensors and machines in the energy sector is continuously growing, resulting in the Internet of Energy, or IoE. Within the energy sector, the circular economy would be powered by an IoE.

> **Internet of Energy**
>
> IoE can be broadly defined as the upgrading and automating of electricity infrastructures, making energy production cleaner and efficient, and empowering the consumer.
>
> The IoE is influenced by the imperative of decarbonization (supported by transitioning sectors that today rely heavily on fossil fuels, such as heat and transport, to electricity-based power). The IoE would feature distributed generation with a high share of renewable energy, empowered by storage in all forms (grid, behind-the-meter and electric vehicles), a demand-response supported by smart grid assets down to "white goods"—and a fully transparent cost and value structure that takes into account the levelized cost of energy, the cost of externalities, the time and location of generation, the value of ancillary services and storage, opportunity costs, etc. This would mean a total restructuring of the current energy ecosystem, where operation at an entire system level could be optimized without barriers.

A suitable setup for an IoE could be a centralized electricity system with large-scale renewables, storage, and flexible back-up power interconnected to a decentralized electricity system with distributed generation, combined heat and power, electric vehicles, smart white goods, etc. The IoE would ensure that all grid-connected assets (from nuclear power plants to coffee machines) communicate and interact with one another, allowing for optimized generation and demand capacity management, while honouring some hard settings (for instance, hospital operations theatres need power no matter what). It would require a good set of energy market rules as well to drive behavior, while constantly adapting to user preferences and best performance. [17]

The vast amount of data generated by the energy sector, coupled with the increasing number of sensors added, makes the energy sector a perfect environment for machine learning applications. Artificial intelligence (AI) supports the growth of the IoE by finding subtle patterns in datasets of all shapes and sizes, particularly under complex or changing conditions.

Although data within the IoE is growing at exponential rates, much of that data is traditionally siloed across business units (generation, transmission and distribution, energy trading and risk management, and cybersecurity). Extracting the wealth of data out of each of the silos and putting that data to work is needed to promote a better IoE experience and receive the benefits out of machine learning. AI capabilities can be incorporated to gain insight from all the data uniformly, allowing business units to be transformed into a collaborative system.

GENERATION: this is the first major silo in the energy sector, largely dependent on the work of turbines. Turbines consist of thousands of moving parts, and even the smallest disturbance can create major problems, causing unscheduled downtime, loss of power, safety concerns and other issues. Applying AI and machine learning techniques to prevent unplanned downtime and catastrophic breakdowns is revolutionizing how utility companies operate. An AI approach can start analyzing data and provide insights on day one, and continue to improve upon its own accuracy and effectiveness by learning.

TRANSMISSION AND DISTRIBUTION: for the second silo of transmission and distribution, AI is able to tackle much larger problems. While smart meters and end user control of home appliances have generated excitement, they are not the most challenging big data problems being solved by machine learning. Three specific areas in transmission and distribution where AI is playing a key role are: (i)

[16] http://www.ioti.com/smart-energy-and-utilities/internet-energy-digitalization-and-circular-economy
[17] Ibid.

energy disaggregation; (ii) power voltage instability monitoring; and (iii) grid maintenance. In these areas, the collection, ingestion and action on the data have created efficiencies in expenses and operations for companies using machine learning and AI technologies, as well as for their customers.

CYBERSECURITY: this is the third major data silo in utilities. The recent and continuous onset of attacks to critical infrastructure makes the need for new cybersecurity methods vital. An AI offering can identify, categorize and remediate a variety of threats, including loss of personally identifiable information, zero-day malware, and advanced persistent threat attacks. To a mathematical algorithm, there is little difference between the aforementioned data and cybersecurity data. All input, regardless of source (e.g. a vibration sensor or a firewall log), is a piece of information with unique patterns to an algorithm. To combat the cyber front of industrial threats, an AI product can automate the threat research process, prioritize threats based on confidence, and display corroborating evidence to the analyst, significantly reducing both time for threat remediation, and overall risk.

ENERGY TRADING AND RISK MANAGEMENT: this is the final data silo in the energy sector. In the highly competitive and regulated utility business, there is a clear link between the company's bottom line and forecast accuracy and reliability. If new techniques can provide more accurate forecasting, utilities can begin to offer better pricing to their customers.[18] AI techniques are providing insight into this process. With thousands of features from hundreds of sources, there are infinite ways to combine and correlate information. Looking for subtle, transient movements of price data on an hourly or even a second-by-second basis with millions of combinations is where AI excels. Because utility companies need to buy oil, gas, coal, nuclear fuel and electricity, they are constantly at the mercy of volatile commodity prices. For this reason, utilities are using AI techniques to develop methodologies for market and credit risk aggregation.

With improvements in the sharing of data from data silos, the utilities industry can reap the wealth of new knowledge. From prescriptive maintenance to energy trading to cybersecurity, analytics will play an important role in how energy is produced and provided to consumers far into the future. As adoption increases, AI technologies will continue to learn and adapt, providing more value in the IoE.[19]

UNIDO REPORT "ACCELERATING CLEAN ENERGY THROUGH INDUSTRY 4.0: MANUFACTURING THE NEXT REVOLUTION"

This report looks at the linkages between Industry 4.0 and sustainable energy initiatives. This approach could simultaneously help achieve the UN Sustainable Development Goals (SDGs) related to affordable and clean energy (SDG 7), industry and infrastructure (SDG 9), and climate action (SDG 13). Both sustainable energy transition and Industry 4.0 are highly influenced by technological innovations, dependent on the development of new suitable infrastructures and regulations, as well as being potential enablers for new business models. Moreover, industries account for a major share of electricity consumption (42.5 per cent worldwide in 2014). But this has not yet translated into substantial policies to foster the transition to more sustainable energy systems and digital production at the same time and in an integrated way.

Developments in ICT, the spread of Internet access and mobile devices, such as smartphones, and the development of blockchain or distributed ledger technology is enabling new approaches and business models in the energy sector.

[18] http://internetofthingsagenda.techtarget.com/blog/IoT-Agenda/IoT-and-big-data-Opportunities-for-the-enterprise
[19] http://internetofthingsagenda.techtarget.com/blog/IoT-Agenda/Internet-of-energy-Extracting-value-from-data-silos-in-utilities

Smart grids

Digital technologies could offer solutions to the challenges of integrating renewable energy sources into small and large power grids. Smart grids draw on the potentials of ICT to monitor and efficiently manage the generation, delivery, and consumption of electricity from different – potentially decentralised – sources of electricity to meet the varying electricity demands of end-users. Such grids could provide the flexibility necessary to integrated renewable energies such as wind and solar into electricity networks on a large scale. However, many technical and regulatory barriers to smart grids remain. According to the study, the implementation of smart grids is unlikely to be done by the market alone.

Virtual Power Plants (VPP)

VPPS are heterogeneous coalitions of distributed energy resources, generally composed of intermittent renewable sources, storage systems, flexible loads, and small conventional power plants that need to negotiate some bilateral contracts in advance, prior to participating in the day-ahead market. VPP usually has a cloud-based central or distributed control centre and makes use of the IoT (devices and other digital technologies).

Saving energy in the manufacturing sector

The optimisation or replacement of specific technologies and the application of new software tools can offer opportunities for energy saving. An example could be the control of the behaviour of a large number of interconnected robots by an algorithm that reduces their energy consumption.

Digital technologies also offer the opportunity to replace conventional, often more energy-intensive, manufacturing procedures. In traditional methods of production, all features are included to meet the needs of all customers, with no way to customise products. The physical realisation of every function and feature requires resources. A digitised value chain can make on-demand customised products technologically feasible, thereby eliminating unnecessary functionality.

For the production of prototypes or products with low lot sizes, rapid prototyping technologies can provide a cheaper, quicker, and more energy-efficient alternative. A data connection from the factory to the energy system can help detect the current level of renewable energy in it or the market price, so that energy generation and energy consumption can be converged. Demand-response approaches can be used for time-flexible but energy-intense production processes, with production phases timed according to the availability of cheap electricity in the energy market (due to a surplus of renewable energy) whenever possible.

For some industries with high thermal capacities or steam-based processes, the power-to-heat concept can be used, which means that a surplus of renewable and therefore reasonably priced energy is converted into thermal energy (e. g. steam) that can be stored or directly used (typically temporarily substituting gas heating processes). It can also be applied on a smaller scale in private homes.[20]

BIG DATA, DATA MINING AND DATA ANALYTICS

The amount of information currently stored in relation to different processes and systems (both industrial and logistics), services (sales, connections between users, power consumption, etc.), or data traffic (logs in routers and equipment, etc.), is huge, thereby impossible to manage manually. A

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[20] UNIDO (2017). Accelerating clean energy through Industry 4.0: manufacturing the next revolution. Nagasawa, T., Pillay, C., Beier, G., Fritzsche, K., Pougel, F., Takama, T., The, K., Bobashev, I. A report of the United Nations Industrial Development Organization, Vienna, Austria., at http://www.unido.org/fileadmin/user_media_upgrade/Resources/Publications/REPORT_Accelerating_clean_energy_through_Industry_4.0.Final.pdf

comprehensive analysis of these data can provide valuable information about those processes; and can also prevent problems in particular industrial processes through the detection of abnormal measures (without the need to have previously defined to what extent the results are or are not abnormal); or even determine which events are related in more complex processes, thus facilitating management through prediction, knowing that one event may trigger another with a certain probability. Simulations can also predict what resources will be needed, and can optimize the use of those resources automatically, or proactively anticipate future events and needs.

"Big Data" is a concept that refers to the capacity of information and communication technologies to process massive amounts of data in order to derive the appropriate data for rapid decision making for increased productivity. This can refer to anything from a few terabytes to many petabytes of data. Doubling in size every year, the digital universe is forecast to grow to around 44 zettabytes (40 trillion gigabytes) by 2020. Embedded systems data in the IoT are expected to grow from just 2 per cent of the digital universe in 2013 to 10 per cent in 2020. The volume of global big data market has risen to more than €15 million in 2015. [21] Most of the Big Data is not produced by people, but by machines, as they talk to each other over data networks. Only a fraction of this data will be of real market value. Scalable data management and analytics systems allow the swift and effective management of "big data" to create "smart data," from which new products and services are created. Big data solutions allow for improved and optimized decision making, forecasting, and better consumer segmentation and targeting.[22]

Challenges related to big data are similar to the ones faced by other fields of Industry 4.0: data ownership, security, monopolization, privacy, intellectual property rights, transparency, and interpretability.[23]

ARTIFICIAL INTELLIGENCE (AI)

There is no universally accepted definition of AI. AI-pioneer Marvin Minsky defined AI as "the science of making machines do things that would require intelligence if done by men". Machines understanding human speech, competing in strategic game systems, driving cars autonomously, or interpreting complex data are currently considered to be AI applications. Intelligence in that sense intersects with autonomy and adaptability through AI's ability to learn from a dynamic environment. AI is going mainstream, enabling machines to perform humanlike cognitive functions. Enhanced by machine learning, big data and cloud computing, algorithms can identify increasingly complex patterns in large datasets and already outperform humans in some cognitive functions. While promising gains in efficiency and productivity, AI may amplify existing policy challenges and raise new policy and ethical questions, for example in relation to its potential effects on the future of work and skills development, or its implications for oversight and transparency, responsibility, liability, as well as safety and security.[24]

According to a new report from Tractica, these technologies have use cases and applications in almost every industry across the globe. ***These technologies will significantly change existing business models while simultaneously creating new ones. Tractica forecasts that annual worldwide AI revenue will grow from US$643.7 million in 2016 to US$36.8 billion by 2025.***

A few key industry sectors including consumer products, business services, advertising, finance & investment, media & entertainment, and defense applications will drive significant revenue for AI software implementations in addition to AI-driven hardware and service sales, but in the near future the technologies will have an effect on almost every conceivable industry sector.[25]

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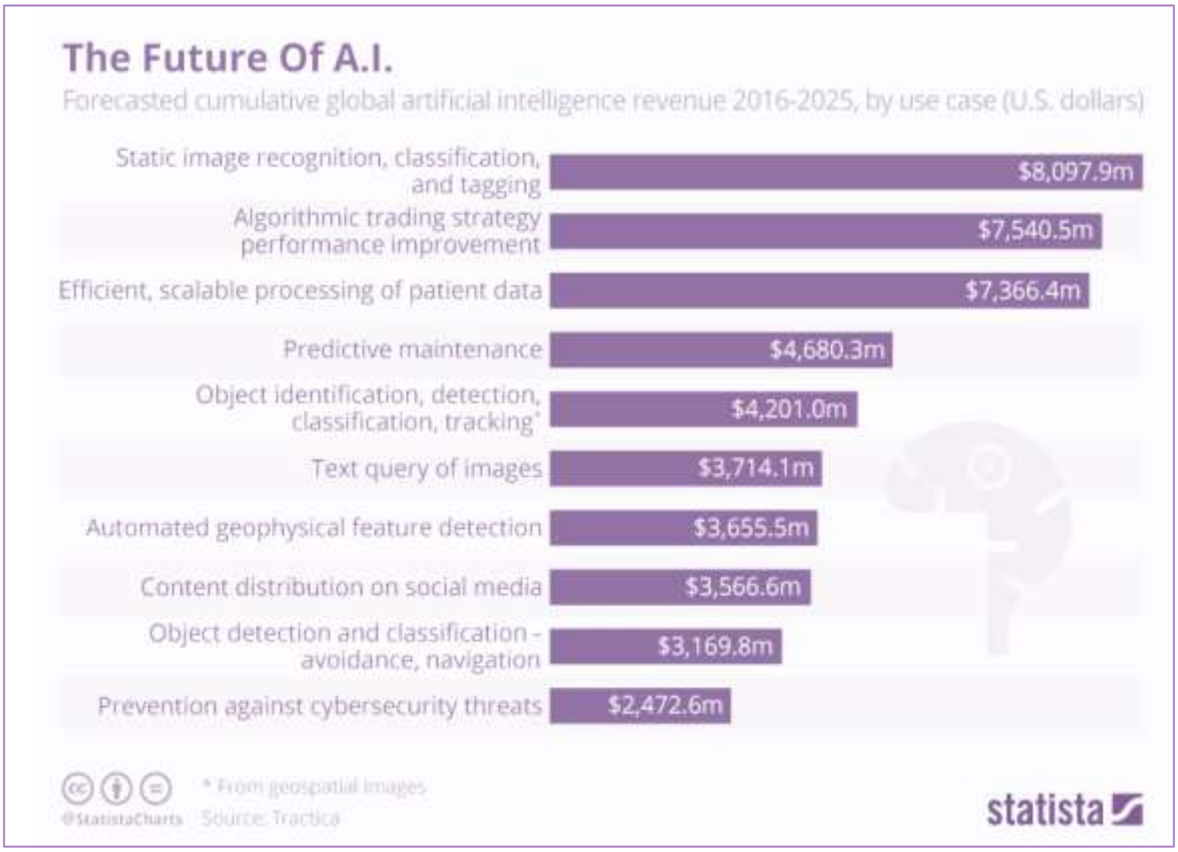
[21] https://industrie4.0.gtai.de/INDUSTRIE40/Navigation/EN/Topics/The-internet-of-things/big-data.html
[22] Ibid.
[23] http://www.oecd.org/daf/competition/big-data-bringing-competition-policy-to-the-digital-era.htm
[24] OECD Digital Outlook 2017.
[25] https://www.tractica.com/newsroom/press-releases/artificial-intelligence-revenue-to-reach-36-8-billion-worldwide-by-2025/



BLURRING LINES BETWEEN AI AND ROBOTICS

AI is mostly intangible in its manifestations. Robotics, which operates at the intersection between mechanical engineering, electrical engineering and computer sciences, is mostly physical in its manifestations. In an "autonomous machine", AI can be characterized as the intelligence or cognitive functions, while robotics refers to the motor functions. However, the distinction between cognitive and motor functions is porous and evolving, since mobility requires the ability to sense and analyse the environment

Popular examples of the convergence between AI and robotics are self-driving cars and humanoid robots. It is important to highlight that autonomous machines combining advanced AI and robotics techniques still struggle to reproduce many basic non-cognitive motor functions.

OPPORTUNITIES PRESENTED BY AI

IMPROVED DECISION MAKING, COST EFFICIENCY AND IMPROVED RESOURCE ALLOCATION: AI is expected to dramatically improve the efficiency of decision making, save costs and enable better resource allocation in basically every sector of the economy by enabling the detection of patterns in enormous volumes of data. Algorithms mining data on the operations of complex systems enable optimization in sectors as diverse as energy, agriculture, finance, transport, healthcare, construction, defence, or retail. AI enables public or private actors to optimize the use of production factors – land/environment, labour, capital or information – and to optimize the consumption of resources, such as energy or water.

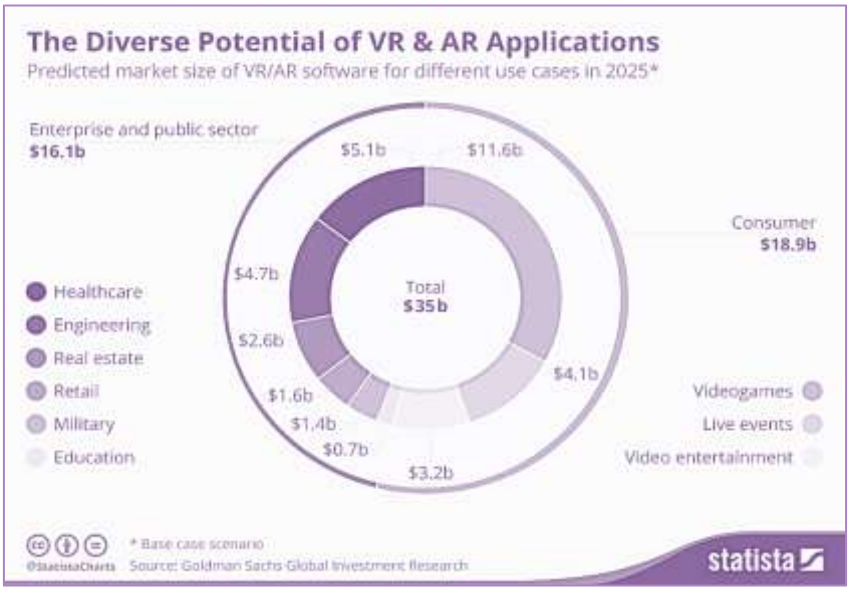
FRAUD DETECTION: AI can help identify suspicious activity, people or information. Machine learning is being used to detect criminal and fraudulent behaviour and ensure compliance in innovative ways. In fact, fraud detection was one of the first uses of AI in banking. For instance, in 2016, the bank Credit Suisse Group AG launched an AI joint venture with a Silicon Valley surveillance and security firm whose solutions help banks detect unauthorized trading.

IMPROVED TRANSPORTATION: AI is already impacting transportation significantly, with the introduction of itinerary mapping based on traffic data and autonomous driving capabilities. Advances in deep neural networks are one of the main drivers behind the impressive progress achieved in autonomous vehicles over the past decade, in particular thanks to computer vision. In combination with many other types of algorithms, deep neural networks are able to make the most out of complex sensors used for navigation and learn how to drive in complex environments. Benefits include fewer road accidents and enabling people to use commuting time for productive activity, leisure or rest. While the shape and timeline of the restructuring of the car industry is still unclear, many believe that connected and autonomous vehicles could help avoid many of the 1.3 million deaths per year on roads globally. Disrupted by the arrival of new actors such as Google, Baidu, Tesla or Uber, traditional automobile actors such as Ford Motors or Honda are now investing in promising AI start-ups, forging alliances or developing in-house capabilities.

IMPROVED CYBERSECURITY AND REAL-WORLD SECURITY: AI is effective against cyberattacks and identity theft through the analysis of trends and anomalies. It is used as defence against hackers as well as in proactive, just-in-time responses to hacking attempts. AI has a wide range of security applications beyond cybersecurity. For example, university-based research start-ups have used AI to detect lying in written text with potential applications, among others, to enhance online child safety. For emergency and disaster management, AI applications can optimize planning and resource deployment by aid agencies, international organizations, and non-governmental organizations.

AUGMENTED REALITY (AR)

Unlike virtual reality, which transports the user, usually via a headset, into a fully virtual world, augmented reality (AR) applications present an illusion of layers of graphic information superimposed on some portion of the worker's field of view. Most AR systems currently deployed are tablet-based or smartphone-based, although some are now moving aggressively in the direction of head-mounted displays (HMDs) that allow the worker to access AR data continuously without interrupting a task to refer to a tablet display.



AR is emblematic of Industry 4.0, a blurring of the lines between the physical and digital worlds, and, indeed, the public and private spheres. While many consider virtual and augmented reality the next big thing, there still appears to be a degree of uncertainty about what both technologies can and will actually be used for. Goldman Sachs predicts the industry reaching a value of US$80 billion a year (US$35 billion software and US$45 billion hardware) by 2025. The potential of AR/VR tech is extremely diverse and extends way beyond consumer space – according to Goldman Sachs' estimates, almost half the industry's revenue will be generated in the business and public sector, with healthcare and engineering being the most promising areas of use.[26]

There are myriad uses for AR in the wider public sector, and as with any new technological innovation, its potential is limited only by the creativity and ingenuity of its users. The following potential use cases –

[26] http://www.goldmansachs.com/our-thinking/pages/virtual-and-augmented-reality-report.html
https://www.statista.com/chart/4602/virtual-and-augmented-reality-software-revenue/

some of which are already being planned or in the proof of concept stage – provide a cursory overview of the possibilities.

E-GOVERNANCE: CITIZEN ENGAGEMENT AND E-SERVICES: AR could be used for providing government services where government forms and applications can be accessed, viewed and completed through a variety of AR devices – smartphones, smart glasses, in-office displays and readers – with a full range of accessibility aids (sound, language translations, visual and graphic instructions, etc.). AR might be used for the creation and use of policy, and legal, regulatory documents and frameworks that can interact with citizens and officials via AR-enabled devices. AR might be used for giving citizens and businesses the possibility to actually "see", using AR, what planned public works projects will actually look like – such as highways, water and energy facilities, public parks, new transit lines and stations, etc. – and even interact with the augmented project.

ASSET MANAGEMENT AND MAINTENANCE: Imagine municipal workforces that are able to efficiently and accurately maintain city assets – from streetlights, cell towers and fire hydrants, to water wells, communal stock and roads – using head-up windshield displays on maintenance vehicles, smart goggles, hard hat-mounted devices and other hands free AR devices. Imagine optimizing the reach and impact of high-value experts, specialists and supervisors who are enabled to provide real-time guidance and technical expertise to field workers with remote AR connections – audio, visual, data, and sensory. [27]

PUBLIC SAFETY AND EMERGENCY SERVICES: AR disaster applications could be used to provide visual and audio guidance for citizens seeking refuge, evacuation routes, or emergency assistance in a disaster situation. Real-time data-driven AR applications would allow law enforcement officers to access location-specific information and data on dangerous situations via smart glasses, in-vehicle displays and other wearables. Citizens and businesses would be able to access authorized geo-specific data on crime statistics and other environmental factors just by pointing their mobile devices at a building, down a street, or at an entire community. [28]

PUBLIC HEALTH, WELLNESS AND SUSTAINABILITY: AR might enable inspectors of all kinds – health, building and public safety, environmental quality, etc. –to instantaneously interact with data and information related to a facility, an agricultural area, a neighbourhood, or a district. Communities interested in encouraging healthy and sustainable living for their citizens can connect healthy amenities – parks, recreation facilities, farmers' markets and urban farms, community health festivals – to healthy activities such as walking and biking, orienteering and resources that offer "healthy" options, or those with the lightest carbon footprint. Imagine a host of environmental quality (air, water, ground, etc.) detectors and AR combined with environmental sensors to allow environmental officials and citizens to make real-time decisions on movement, activity, and official responses. [29]

TRANSPORTATION AND URBAN MOBILITY: AR might enable to see and visually "connect" the various transportation systems – from traditional highway, roadway and fixed-rail infrastructure, to modern on-demand and shared mobility services and active transit (walking and biking). Operators of rolling stock – trains, buses, shuttles, car/vanpools – could have AR windshield displays providing real-time information such as traffic incidents, scheduling and route changes, customer needs, vehicle maintenance and health, etc. Users (visitors and residents) can use augmenting physical maps of transit systems that will allow them to visually and/or audibly access the portion of the transit network that they actually use and need.[30]

[27] https://www.weforum.org/agenda/2017/02/augmented-reality-smart-government/
[28] Ibid.
[29] Ibid.
[30] Ibid.

INDUSTRIAL 3D PRINTING (ADDITIVE MANUFACTURING)

Additive manufacturing (or industrial 3D printing) is a concept that refers to a group of technologies that build physical objects directly from 3D (Computer-Aided Design – CAD) data. In contrast with established subtractive manufacturing technologies (cutting, lathing, tuning, milling or machining), in additive manufacturing the object is built up by the consecutive addition of liquids, sheets or powdered materials in ultra-thin layers.[31] The most commonly used materials by 3D printers currently are polylactic acid and acrylonitrile butadiene styrene. In general, 3D printers function by constructing items from numerous thin layers of material. Depending on the type of printer used (Selective Laser Sintering [SLS], Fused Deposition Modelling [FDM], or Stereolithography), the choice of material and how the layers bond to one another vary.[32]

> Additive manufacturing is an emerging technology due to rapid reduction in cost of 3D printers, increase in accuracy, increase in the variety of supporting material, and expiration of critical patents in the field. It will change production lines and value chains. Functions like tooling and welding became obsolete and first small production lines have been replaced. In health and dentistry, the dynamic is highest. In the long run, additive manufacturing will enable a shift from mass production to mass customization.

With advancing technology and falling prices in recent years, domestic 3D printers are now available in the United States for less than US$1000. Although plastic has primarily been used for printed objects or "printouts," attempts are being made to make metal and edible materials more affordable. The Filabot, developed by Tyler McNaney, looks to solve two of the biggest issues with 3D printing: to eliminate the cost of currently used plastic filaments (US$40 per 1kg spool), and get rid of any waste produced.[33] The device accomplishes this goal by melting existing plastic waste into the filament, thereby recycling and producing more filaments. In addition, 3D printing could markedly reduce carbon emission from factories by reducing shipping costs. Additive manufacturing by nature also produces much less waste. This technology is already proving helpful in numerous developing countries, and as commercially available 3D printers fall below the US$500-mark, 3D printers will become more common. By 2019, the worldwide market for 3D printing is expected to double to more than US$6 billion. 3D printing offers the possibility of manufacturing precisely designed objects inexpensively and readily. These may potentially include the production of basic medical supplies, vaccination beads, laboratory equipment, and prosthetic limbs. It has the ability to promote initiatives across the entire developing world, increasing living standards and providing a higher quality of healthcare to its residents. There are still numerous untapped applications for 3D printing in medicine that have yet to surface, but if harnessed correctly may positively affect millions of lives.[34]

The number one social sustainability goal is eradicating poverty, especially in developing countries. 3D printing may help, and people are already trying to use it for this. However, its greatest potential remains mostly untapped, not making products for the rural poor, but acting as venture capital for small urban manufacturers. Some rural development projects do work, such as Fenix International,[35] however, most of these projects are not sustainable in the long run, after the funding from international donors has ended. But programmes which succeeded in the long term do so because they spend as much time and money designing appropriate business models as they do designing products. The same should be done

[31] http://www.europarl.europa.eu/RegData/etudes/STUD/2015/563445/IPOL_STU(2015)563445_EN.pdf
[32] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4527617/
[33] Used by NASA, Dupont, MIT and others all across the globe: Filabot is a plastic company that builds machines for filament extrusion. The Filabot product line up is built to convert plastic into filament for use in 3D printers. See https://www.filabot.com/.
[34] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4527617/
[35] https://www.pv-tech.org/news/engie-to-acquire-fenix-international-in-effort-to-spur-development-in-off-g

with 3D printing. Designing for developing countries is called designing for "the base of the pyramid" because it's designing for a lot of people with little money. This is the opposite of what 3D printers are good at –making a small number of parts at relatively high cost per part, but making them as unique as you like.

3D printing's greatest promise for developing nations is likely the same as in rich nations: empowering small businesses by lowering the barrier to manufacturing. Dozens of job shops, such as Shapeways[36] in the US and i.materialise[37] in Europe, 3D print small product runs that can help small companies or entrepreneurs get their business off the ground. If their products hit big, the companies shift to mass-manufacturing. Since 3D printers have no tooling costs, one printer can manufacture different parts for different companies – a few at a time, or a few hundred at a time. But for thousands or millions of parts, injection-molding is cheaper. Rather than consumers directly using 3D printers to make goods for themselves, small companies hire 3D printing shops for production runs too small to be economical for mass-manufacturing. Then the companies use earnings from small-run sales to finance expansion into mass-manufacturing. This does not replace supply chains, it replaces venture capitalists. Or at least it allows companies to make proof-of-concept sales to entice investors. Examples of 3D printing shops in developing countries are beginning to exist, such as the Indian start-ups 3DPD,[38] Divide By Zero,[39] and others[40]. These are not charities, but commercial firms. Bootstrapping small-run manufacturing can fund itself. [41]

Potential uses of 3D printing in the developing world:

CONSTRUCTION OF HOMES: There are over 1 billion people living in slums, under unsanitary conditions, and with little protection from extreme weather. In developing countries, traditional construction methods are expensive; time consuming and inefficient due to poor regulation. 3D printing might be used as a process to build entire homes. This process is known as "contour crafting."[42] Using this technology, floors, walls, plumbing, and electricity can be completed in as little as 20 hours. [43]

FOOD: At least 1 million malnourished children die each year. An additional 34 million children suffer from severe acute malnutrition. A major step toward ending world hunger is the ability to manufacture cheap, nutritious food. In 2013, NASA awarded an engineering firm based in Texas a six-month grant worth US$125,000 to create the world's first 3D food printer. This technology has the potential to be life-saving for the many malnourished children in the developing world. [44]

WATER AND SANITATION: Over 3.4 million people each year die from water- and sanitation-related issues; 99 per cent of these deaths occur in the developing world. Lack of clean water and proper sanitation kills children at a rate equal to a jumbo jet crashing every 4 hours. Engineers from the University of Washington are partnering with the charity "Water for Humans" to use 3D printing techniques to construct toilets and rainwater collectors. They plan to teach local entrepreneurs in developing countries how to use, build, and maintain these 3D printers. The first trial will take place in Oaxaca, Mexico.[4]

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[36] http://www.shapeways.com/
[37] https://i.materialise.com/
[38] http://www.3dpd.net/
[39] http://www.divbyz.com/services.html
[40] http://techcircle.vccircle.com/2014/06/04/excl-3d-printing-startup-biotz-close-to-raising-series-a-round-from-ncubate-others/
[41] https://sustainabilityworkshop.autodesk.com/blog/3d-printing-developing-countries-untapped-potential
[42] The Department of Engineering at the University of Southern California is at the forefront of testing this technology.
[43] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4527617/
[44] Ibid.

DISASTER RELIEF: 3D printers could be shipped to a disaster zone to produce medical supplies to help the injured. Advanced 3D printers can be configured to operate on solar power and used in areas where power lines have been cut.

SHOES: Kenya's University of Nairobi has advocated for the production of 3D-printed shoes to help solve Kenya's jigger problem.[45] Shoes would be produced from reused plastic and also be recyclable once they are worn out.

BLOCKCHAIN

Sharing electricity on the blockchain

In the future, thanks to blockchain, houses would be able to share energy between themselves, so that if a house produces excess energy, it can sell it to someone within its locality that needs more. This is where blockchain can transform decentralized power generation. If everyone in the same community is connected together at local level, when one owner produces more electricity because of excess production from their solar panels or less usage in the house, they can potentially sell it to a neighbour. The grids can be connected to each other on the cloud into a virtual micro-grid, with a real-time exchange of energy that guarantees local production is consumed locally as well. Blockchain allows transactions between these consumers to be settled through "i-contracts" (intelligent contracts) that can choose where customers buy excess energy from and how much they buy from each different producer; those transactions are registered on the blockchain. The transaction is available to all the people in the blockchain network and makes sure that two different people cannot claim the same unit of energy produced and the corresponding monetary compensation.

Source: Some villages are embracing the Fourth Industrial Revolution faster than cities. This is how, at https://www.weforum.org/agenda/2017/11/the-indian-villages-embracing-the-fourth-industrial-revolution

Blockchain has the potential to impact many sectors, from financial services to the public sector to healthcare and the media industry. The financial services industry is witnessing an increasing number of blockchain-based use cases that yield the potential to drive significant operational and client experience improvements.

At its simplest, a blockchain allows parties to co-create a permanent, unchangeable and transparent record of exchange and processing, without having to rely on a central authority. Where previous generations of digital technology have been about data and information and how to exchange it faster and more securely, blockchain is about the exchange of value and how to make it instant and decentralized. Blockchains will improve traceability, reduce or totally eliminate the need for a trusted middleman in many operations, be it a supply of certified renewable electricity coming from distributed energy generation, the verification of legal provisions, the establishment of a patent, or a simple payment.[46]

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[45] Jiggers are tiny parasites resembling fleas that are embedded in the hands and feet of animals and humans alike. They can elicit severe inflammatory reactions causing auto-amputation and may even promote secondary infection, such as tetanus.

[46] https://medium.com/world-economic-forum/still-dont-understand-blockchain-ded25f6cd24e; UNIDO (2017). Accelerating clean energy through Industry 4.0: manufacturing the next revolution.
Nagasawa, T., Pillay, C., Beier, G., Fritzsche, K., Pougel, F., Takama, T., The, K., Bobashev, I. A report of the United Nations Industrial Development Organization, Vienna, Austria., at http://www.unido.org/fileadmin/user_media_upgrade/Resources/Publications/REPORT_Accelerating_clean_energy_through_Industry_4.0.Final.pdf

II. IMPACT ON SECTORS

During the past 15 years, the internet revolution has redefined business-to-consumer (B2C) industries such as media, retail and financial services. It is expected that in the next decade, the IoT revolution will dramatically alter manufacturing, energy, agriculture, transportation and other industrial sectors. It will also foster new human-machine interactions.

The digitization of transportation has the potential to reduce many of these costs. It is breaking the mound of the entire automotive value chain as it creates greater efficiencies and cost savings. The rise of industry-leading platforms, supported by the explosion in the breadth and depth of data available, accelerates and amplifies the impact that digital technologies are having.

AUTOMOTIVE INDUSTRY

Growth in personal communication and the Industrial Internet of Things has accelerated the connected vehicle market. Globally, in-car technology has the greatest influence on purchasing decisions. However, developing connected vehicles requires an unprecedented ecosystem of players and presents new challenges for the value chain of automotive companies and original equipment manufacturers.

A study conducted by the World Economic Forum indicates that there is US$0.67 trillion of value at stake for automotive players and a further US$3.1 trillion worth of societal benefits as a result of digital transformation of the automotive industry up until 2025. Industry stakeholders should take notice and come together to prioritize digital transformation initiatives given the potential for three times more value to be created for society than for industry. According to the WEF, there are three digital themes driving this change in value throughout the automotive industry: (i) the connected traveler; (ii) autonomous vehicles; and (iii) the enterprise/ecosystem. The cycle of change begins with the ***connected and empowered consumer*** who is becoming more digitally conversant in all manner of electronic media. This, in turn, is driving a seismic change in all aspects of transportation and, by extension, society. It is a fact that, for many, access to affordable transportation is the most important factor in lifting themselves out of poverty.

Today's cars park themselves, cruise hands-free on highways and gain more autonomy towards becoming self-driving. In an optimistic future the roads would be congestion-free. People, especially the growing ranks of digital natives, see the vehicle not as a product to buy; rather, transportation is a mobility experience that might take them somewhere in a single vehicle or via multiple forms of transport. Today, there are real and substantial transportation costs. A driver in Moscow, Istanbul, Mexico City or Rio de Janeiro wastes more than 100 hours a year in congested traffic. Globally, transportation causes more than 200,000 premature deaths a year from air pollution, 1.25 million road deaths, and approximately 30 per cent of the carbon dioxide (CO_2) emissions behind climate change.

These shifts are disrupting business models for existing players, forcing them to fundamentally reconsider their businesses. To change at the pace of digital, players across the value chain will need to think about their structure, employee skills, hiring practices, how they collect and analyse data, and how they form partnerships inside and outside the ecosystem. They will need to consider their changing relationship with dealers and suppliers, and must effectively engage and maintain trust with consumers and their high expectations.[47]

[47] World Economic Forum White Paper Digital Transformation of Industries: Automotive Industry (2016) at: http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/wef-dti-automotivewhitepaper-final-january-2016-200116a.pdf

ELECTROMOBLITY (E-MOBILITY)

Electromobility is one of the keys to achieving sustainable mobility for the future. The first electric vehicles have been available on the market for years now. But high purchase prices and short ranges still keep many drivers from deciding in favour of an electric-powered vehicle. Fraunhofer researchers are currently working together with industry on new solutions for innovative batteries, cable-free charging and cost-efficient drive systems. These components are to help improve the performance of future generations of the electric automobile.

How industry 4.0 is influencing China's automotive industry

In China, there are big plans to move auto manufacturing up the value chain as part of the government's "Made in China 2025" initiative – a bid to avoid being squeezed by lower-cost countries on one side and high-end manufacturers on the other. Tianjin Economic-Technological Development Area (TEDA) is home to 124 auto companies, including five carmakers – Volkswagen, Toyota and Great Wall are the three biggest – and more than 100 component firms. The new Volkswagen plant, due to start operations in 2018, is expected to bring in a further 300 suppliers, doubling its own production value. Together, they form a complete industrial chain.

Some of the production lines are already set to benefit from the latest software systems. The Toyota joint venture with Chinese carmaker FAW has incorporated the carmaker's New Global Architecture system into its production line. The system tries to harmonize planning and components sharing to reduce costs and increase efficiency. In the welding process, high-performance robots are replacing humans, who do just 5 per cent of the work, boosting efficiency by 50 per cent. The company is also introducing a flexible assembly line, which sees software and real-time location tracking reduce the cost of large-scale customization and manage product variability without creating large quantities of waste or compromising product quality. Informatization – the use of new communication technologies to transmit, process and receive information – has been identified as a key pillar of Industry 4.0, and innovation parks such as TEDA are investing in IoT, collaboration and enterprise resource planning, cloud computing, and big data to create a holistic ecosystem for car manufacturers.

The combustion engine has been our main source of mobility for more than a century. However, climate change and the constantly growing world population are placing new demands on mobility. Today, cars, trucks, motorcycles, etc. are already responsible for approximately one fourth of the greenhouse gases emitted in Europe. What's more, noise, respirable dust and exhaust gas are a burden on the population at large. But not so with electric cars, which are quiet, emission-free, and which reduce dependency on petroleum imports. Another advantage is that if these cars are powered by electricity from renewable sources, they are much more environmentally sound than gasoline or diesel-powered vehicles.[48] When e-mobility meets Industry 4.0, state-of-the-art ICT technologies need to be applied to the task of integrating intelligent electric vehicles (smart cars) with intelligent energy systems (smart grids) and intelligent traffic infrastructures (smart traffic systems).[49]

AGRICULTURE 4.0

The global population is increasing, and, with it, global demand for agricultural products. Farmers are facing rising pressure to increase productivity per hectare in Germany, Europe, and around the world. This is compounded by climate change, as well as tighter regulation of, for example, pesticides and fertilizers. Digital technologies can support farmers and make their work easier by optimizing operating

[48] https://www.fraunhofer.de/en/research/current-research/electromobility.html
[49] https://www.bmbf.de/pub/HTS_Broschuere_eng.pdf

procedures and resource utilization, or by meeting the requirements for greater transparency in the agricultural value chain. Developments in digital technology mean that agribusinesses can improve the precision with which they monitor and feed livestock, or manage arable land and record production. This is made possible by innovations in, for example, sensor technology, digital positioning, visual detection systems or data visualization. The structural transformation in agriculture also makes introducing digital innovations more attractive, as potential savings or productivity increases are greater for large businesses.[50] Applying ICT is already proving quite effective in integrating, transforming, and upgrading agriculture value chains. It helps to dramatically reduce inefficiencies at all stages of the complex agriculture value chain, and to address negative externalities, such as pollution and food safety issues.

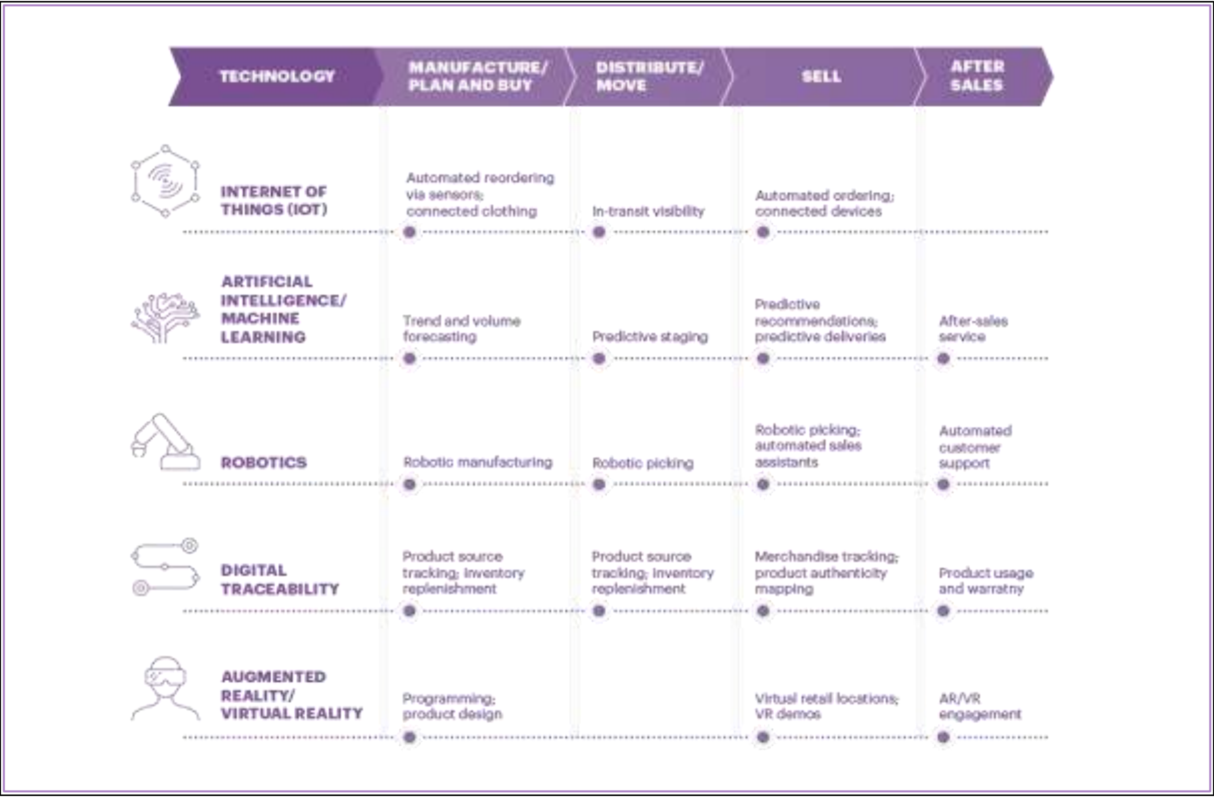
Agriculture 4.0

The concept of Agriculture 4.0 draws on the term "Industry 4.0" and refers to the increased integration of IT and communications technology with agricultural production. Smart, networked systems, combining various different types of data from multiple sources, promise to increase productivity and efficiency. Another feature is the increase in transparency along the value chain. It is not just agriculture that benefits, but also the environment and downstream economic activities right down to the end consumer. The model for the future is fully automated and autonomous agriculture.

RETAIL AND CONSUMER GOODS

Digital is blurring the boundaries among consumers, stores and brands, adding new channels for the customer experience, including virtual shopping for a personalized experience at their fingertips. Consumer packaged goods (CPG) companies need to address fast moving trends alongside the seasonality of products. In this segment, where high regulations are applied for ingredients, labelling and packaging, flexibility across the digital ecosystem is increasingly important. To address this, CPG leaders need to leverage shared digital strategies and technologies to enable a true consumer-centric approach. Those who will succeed over the next decade will bring a laser focus to which technologies increase the value-addition for consumers, weighing those benefits against their costs. There are eight key technologies that will impact all major areas of the value chain by 2025: (1) IoT; (2) autonomous vehicles/drones,; (3) AI/machine learning; (4) robotics; (5) digital traceability; (6) 3D printing; (7) augmented reality/virtual reality; and (8) blockchain. Five of these eight technologies will be at full readiness by 2020; some by 2018 (see Figure opposite). Companies that take the lead in the next era are now beginning to strategize, if they have not already, on applying digital to their value chains as rapidly as possible.

[50] 365FarmNet · White paper: Agriculture 4.0 – ensuring connectivity of agricultural equipment · January 2017



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

With slow-growing incomes in most digitally developed countries and a shift in consumer spending from products to services, the retail industry is likely to see greater value migration (from one company or business model to another) than value addition. While business models are in flux, traditional stores will undergo a metamorphosis to stay relevant when online purchases in most categories are growing. Omni-channel strategies will play an important role. Consumer products companies will also need to have effective strategies to compete in a flatter world, identifying ways to replicate and maintain the quality of consumer experience across channels. Despite continued growth in digital commerce, the physical store will continue to be the largest revenue producing channel until at least 2026. But, it is already evolving from a distribution channel to a customer experience platform. Technology is enabling frontline engagement with customers in store. We see more high engagement social interaction in bricks and mortar. For example, within six months of creating a digitally connected store, clothing designer Rebecca Minkoff saw a six- to seven-fold increase in ready-to-wear sales. As stores evolve, and online sales grow steadily, retailers will reduce their physical retail footprint – the overall number of stores and/or the typical store's respective size. As if the online/offline mix were not enough of a challenge, industry leaders are also already grappling with digitally-enabled business models, such as rental and secondary markets (the sharing economy), the personalization economy (curated subscriptions), auto replenishment and smart ordering via the replenishment economy, and the services economy ("do it for me."). Adapting business models to accommodate these new trends could be highly profitable, with US$2.95 trillion of potential value for the industry and consumers.[51]

[51] Donnely and Wright, Painting the digital future of retail and consumer goods companies, https://www.accenture.com/t20170628T051101Z__w__/us-en/_acnmedia/PDF-52/Accenture-Strategy-DD-Painting-Digital-Future-POV-v2.pdf#zoom=50

HEALTHCARE INDUSTRY

Digital is transforming companies across the life sciences industry. An increasing number of medical technologies, along with advanced methods to monitor patient's health, allow more opportunities for proactive efforts evolving the patient experience. Patients can be more informed in their decisions on diet, exercise, sleep patterns and medications, all affecting their overall health and wellness. The Connected Patient is changing the doctor/patient dynamic while evolving new business models are dramatically changing the healthcare industry.

ARTIFICIAL INTELLIGENCE IN HEALTHCARE

Advances of AI in healthcare are expected to help the treatment of human diseases and medicine by both helping to detect conditions early and – in combination with rapidly increasing flows of available medical data – by enabling precision and preventive medical treatments. AI helps detect medical conditions early through the use of image recognition on radiography, ultrasonography, computed tomography, and magnetic resonance imaging. For instance, IBM Watson and doctors from the University of Tokyo were able to diagnose a rare form of leukemia in a Japanese patient that doctors had not detected. In the area of breast cancer detection radiology, deep learning algorithms combined with inputs from human pathologists lowered the error rate to 0.5 per cent, representing an 85 per cent reduction in error compared to error rates achieved by human pathologists alone (3.5 per cent) or machines alone (7.5 per cent).

Advances in machine learning are also expected to facilitate drug inventions, creations and discoveries through the mining of data and research publications. Personalized healthcare services and life coaches on smartphones are already beginning to understand and integrate various personal health datasets. In the area of elderly care, natural language processing AI applications and visual and hearing assistance devices, such as exoskeletons or intelligent walkers, are expected to play an increasing role. [52]

MEDICAL USES OF 3D PRINTING IN THE DEVELOPING WORLD

For many of the non-profit medical clinics and academic centres in the developing world surviving on governmental support and/or private donations, the many advanced applications of 3D printing in medicine are just not feasible. Even the most basic supplies can sometimes be costly and the wait for simple items to be shipped from a distant city or even from overseas can take too much time. Despite this, numerous different uses of this technology have recently surfaced.

BASIC MEDICAL SUPPLIES: An illustrative example in this regard would be the invention of a 3D-printed finger splint. The commercialization of this invention would not only enable inexpensive production of splints but also override the need for developing countries to ship large supplies of splints from overseas. For small clinics located away from major cities, 3D printing will surely be practical when supplies run low. This is especially important in farming communities where patients from the nearby fields who come in with work-related injuries could be fitted with custom splints that are printed as needed. In Haiti, a 3D printing laboratory has been established that produces umbilical clamps for a local hospital.[53]

Having a medical 3D printer following a major disaster, such as hurricane or tsunami, will allow the production of crutches, splints, and whatever else is needed on the ground, instead of having to ship everything. Moreover, if a condition is not life threatening, triage teams can print out casts or splints for people with broken bones by simply inputting the required data into a system. Supplies would be available on a case-by-case basis without being wasteful.

VACCINATION AND MEDICATION: The concept of VaxBeads, which are 3D-printed beads that represent different vaccines, was named the winner of Michigan Technological University's Printers for Peace

[52] OECD Digital Outlook 2017.
[53] iLab Haiti, at http://www.ilabhaiti.org

Contest. The idea is for patients to wear these beads as a bracelet to serve as a visual medical chart. Each VaxBead string is personalized to the patient and is printed out with their initials, date of birth, and an identifying number. To take this idea a step further, it has been suggested that these "beads" also be representative of patient medications including dosages. Often, due to inaccurate record keeping or incomplete clinical files, patients in poorer countries may not be attentive to the exact name and dosage of the pills that they are taking. This finding can be especially dangerous when considering the many issues that antidiabetic or antihypertensive medications can cause.

LABORATORY EQUIPMENT: 3D printing has also been suggested for use in remote and underfunded medical clinics for the production of laboratory equipment. If a 3D printer can assemble de novo from 3D-printed parts, there are many uses that we are just discovering.

PROSTHETIC LIMBS: "Not Impossible" is a research firm that specializes in undertaking difficult healthcare challenges using low-cost, open-source methods. It has started to manufacture low-cost high-tech prosthetic limbs with controllable fingers using 3D printing in war-torn Sudan. Dr. Tom Catena, an American surgeon, who has long been involved in providing healthcare to patients in the developing world, has joined forces with the co-founder and CEO of "Not Impossible," Mick Ebeling, to set up a laboratory at a local hospital that utilizes consumer-grade 3D printers, which create low-cost prosthetic limbs, designed to be simple and affordable enough for anyone who needs one. A prosthetic arm produced at this laboratory takes 6 hours to make and costs US$100. Although refined versions of the original design may improve on its functionality, these limbs have already likely restored a significant measure of independence to amputees. [54]

FINTECH

The accelerating rate of technological change, combined with shifting customer preferences, is impacting the way in which financial services are structured, delivered and consumed, while the regulatory landscape itself is evolving in order to keep up with new financial regulatory transparency requirements globally, which also include anti-money laundering and anti-bribery obligations. This, against a backdrop of rising spend on technology worldwide and stronger confidence in the market, has led to an explosion in Fintech investment.

Fintech is rapidly changing many core aspects of the finance industry, with AI as one of the technologies with the most potential impact. AI technology has the capacity to both save the industry millions of dollars in regulatory costs and efficiency improvements and also potentially eliminate a significant portion of the financial services workforce.

> *Disruptive innovation is occurring across the industry value chain, in areas such as payments and billing technology, trading and clearing, lending, financial information services, retail and consumer banking, insurance, money transfer and remittance, blockchain, artificial intelligence and robotics technology, banking infrastructure, wealth management, security and investor protection, institutional investment tools, digital currencies, crowd funding, and investment platforms.*

Financial services have been dramatically impacted by the deep technology revolution. Transactions, including payments and trading, have become almost instantaneous, validated by electronic signatures. Financial services are available anywhere, anytime, accessible from cards or devices in customer pockets. As a result of all this "electronification," traditional bank "back rooms" and old-fashioned trading pits have disappeared, to be replaced by "clouds," iPhones, infrared beams, and so on. Customer data, once safe in the hands of bankers, is now frequently compromised in massive electronic breaches. We have no

[54] http://www.notimpossible.com/

way of knowing whether state agencies or criminals now hold this information in their possession. Seldom do financial firms attempt to deliver services on their own anymore; instead the end result is the result of behind-the-scenes collaboration among numerous market participants, the quality and capabilities of which varies widely. It is a world of the future present, with which we are only starting to come to grips. The automation of financial services is also having an impact on regulators: the newly emerging concept of 'RegTech,' which focuses on how regulatory monitoring and assessment can be automated.[55]

Emerging financial technologies have the potential to dramatically reshape many of our financial transactions, the ways in which we borrow, spend, share, and manage money. One of the emerging Fintech platforms is marketplace lending, already a multibillion dollar sector that promotes the potential to expand access to credit through innovative lending practices. Another emerging Fintech platform is peer-to-peer payments in crowdfunding platforms, which aim to greatly simplify and improve payments and project funding. The fintech sector is starting to use AI in several ways. For instance, the California-based robo-advisor, Wealthfront, has added AI capabilities to track account activity on its own product and other integrated services, such as Venmo, to analyse and understand how account holders are spending, investing, and making their financial decisions, in an effort to provide more customized advice to their customers. Sentient Technologies, which has offices in both California and Hong Kong, is using AI to continually analyse data and improve investment strategies. The company has several other AI initiatives in addition to its own equity fund. AI is even being used for customer service in banking. RBS has developed Luvo, a technology which assists its service agents in finding answers to customer queries. AI technology can search through a database, but also has a human personality and is built to learn continually and improve over time. The technology is being evaluated to understand its potential to directly interact with customers.[56]

E-COMMERCE FOR MANUFACTURING

A key theme among the industry changes described in Industry 4.0 is an increasing focus on clients and their needs. E-commerce provides manufacturers with a vital tool to improve customer services by automating purchasing processes tailored to B2B sales' requirements. Integrated systems are essential to make this possible.[57] E-commerce can help manufacturers provide a buying experience that meets or possibly even exceeds professional buyer expectations – expectations that are increasingly influenced by the consumerization of B2B sales. A webstore tailored to professional purchasing processes should be able to provide seamless support for the things that set B2B buyers apart from consumers. It should also offer all of the other elements that are to be expected from major B2C companies, such as clear navigation, good design, recognizable branding and responsiveness across all devices.

Where customer access was once constrained by minimum order sizes and the cost to serve in a particular market, e-commerce and web shops allow companies to reach customers they could never have reached before; hence cost to serve can be cut by 50 to 70 per cent. Online marketplaces such as Amazon Business and Alibaba virtually connect unlimited buyers and sellers, and established players like Grainger are leading the way with their own platforms, capitalizing on 2015's estimated US$1 trillion in B2B digital commerce sales in the United States.[58]

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[55] https://law.duke.edu/academics/course/581/

[56] https://www.forbes.com/sites/falgunidesai/2016/06/30/the-age-of-artificial-intelligence-in-fintech/#41f7b1585028

[57] https://www.hso.com/fileadmin/user_upload/sana-ebook-manufacturing-uk__2_.pdf

[58] https://www.mckinsey.com/business-functions/marketing-and-sales/our-insights/cracking-the-digital-shopper-genome

III. OPPORTUNITIES

DEVELOPED COUNTRIES AT THE FOREFRONT OF REVOLUTION: Developed countries are at the forefront of industrial revolution. Developed countries aim to boost labour productivity, offset high production costs and solve the issue of ageing populations by implementing Industry 4.0 concepts.

INDUSTRY 4.0 PROVIDES NEW OPPORTUNITIES FOR DEVELOPING COUNTRIES: Industry 4.0 could provide more opportunities for developing countries, such as Malaysia or China. By importing Industry 4.0 technologies and combining them with low costs of production factors emerging countries can leapfrog in the value chain and solve societal issues.

Sustainable Development Goals (SDGs) and Industry 4.0: Goal 9

Successful implementation of Industry 4.0 governance models would lead to more sustainable production and consumption patterns in developing countries, contributing to the implementation of the 2030 Agenda for Sustainable Development and the achievement of the SDGs. This is pertinent to Goal 9, to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation, which is central to the work of UNIDO. In a successful scenario, developing countries might benefit from the experiences of more advanced countries, and leapfrog into Industry 4.0. Developing countries might be able to achieve low-cost sustainable manufacturing through retrofitting manufacturing equipment.

COMPANIES TEMPTED BY EFFICIENCY GAINS AND NEW REVENUE STREAMS: Companies are expected to increase spending on Industry 4.0 solutions. Companies are tempted by promising efficiency gains and the possibility to re-adjust business models and create new revenue streams.

PLATFORMS WILL BECOME KEY IN THE LONG TERM: Manufacturers and IT companies are racing to develop industry platforms, as the need to integrate business ecosystems will increase in the future. Common Industry 4.0 platforms will create new revenue streams for platform owners and enable them to set new standards across many industries. [59]

CAN DEVELOPING COUNTRIES LEAPFROG?

The ICT revolution in the 1990s marked a third industrial revolution that created a new wave of manufacturing export-led growth. Vast absolute differences in unskilled labour wages between high-income economies and low- and middle-income economies, driven by differences in factor endowments, made cross-border production sharing profitable. These developments facilitated the opportunity to exploit the potential benefit of international production fragmentation, enabling the remote coordination of complex tasks at a relatively low cost. The ICT revolution brought about efficiency-seeking foreign direct investment (FDI) by multinational firms, which established operations under their ownership and

> *A key question will be whether Industry 4.0 and the continued rollout of Industry 3.0 will weaken the industrialization prospects across a broad range of developing countries or whether they will create new potential to boost manufacturing output and exports and leverage them for growth.*

managerial control in developing countries. With the departure from the "Fordist" production systems (entire goods were produced in one firm), the spread of global value chains (GVCs) provided developing countries with the opportunity to industrialize rapidly because offshore production diffused technology

[59] http://www.euromonitor.com/industry-40-the-future-impact-of-the-fourth-industrial-revolution/report

that took other countries decades to develop domestically – multinational firms combined high-tech ideas with low-wage workers in developing nations. The integration of developing countries into GVCs and the spread of FDI were also associated with reductions in transportation costs and lower tariffs on goods trade. This advent of global production fragmentation shifted the importance of economies in global manufacturing production. The resulting international division of labour meant that a low- or middle-income economy that was relatively abundant in unskilled labour would complete and export the relatively unskilled labour-intensive tasks involved in the manufacturing process, typically final assembly. At the same time, a relatively capital or skilled labour-intensive country would export intermediate products (such as capital goods) and services (such as design and R&D). Over time, countries can move into different parts of the value chain based on their changing comparative advantage.

(PREMATURE) DEINDUSTRIALISATION?

What is emblematic of the current global manufacturing landscape is the fact that the share of manufacturing value added in global GDP has been declining for decades, as services have grown relatively faster. Three-quarters of countries – including China – are experiencing a decline in the share of manufacturing in GDP. In many low- and middle-income countries, the peak shares of manufacturing in value added and employment were both lower and occurred at lower levels of development than in the past. This process has been referred to as "premature deindustrialization".[60] One interpretation is that countries are running out of industrialization opportunities sooner and at much lower levels of income than the early industrializers. Others have argued that "premature deindustrialization" could be an artefact of the fact that activities once classified as "manufacturing" are now "services," but the evidence for this is limited. On the other hand, upper-middle-income industrializers have shown evidence of "flying geese" – moving from labour-intensive to higher-skill manufactured goods – except for China, which remains a big player in the labour-intensive sectors too. Few lower income countries outside of Asia have a revealed comparative advantage in anything but labour-intensive tradable or commodity-based regional processing – although not all have passed even these thresholds.

Emerging technologies and their increasing rates of adoption are transforming manufacturing processes, and these are being rolled out in an evolving global setting. Industrial automation and advanced robotics, digitization and internet-based systems integration (industrial IoT), and additive manufacturing (3D printing) could significantly shift which locations are attractive for the production not only of advanced goods, but also more traditional manufactured goods. Globalization (freer cross-border flows in trade, capital, and ideas and the growth of GVCs) has been the main driver behind export-led manufacturing thus far, but its pace appears to be slowing. Many countries erect protectionist barriers by seeking to reindustrialize, upgrade, or industrialize their economies and manufacturing sectors. [61]

The prospects of the export-led development of manufacturing are further influenced by the disruptive technologies emblematic of Industry 4.0. For instance, nanotechnology, new materials, and biotechnologies may affect what materials are used and introduce a range of new products.

The Catch 22 for developing countries here is the fact that the production of these advanced manufactured goods (such as wearable tech, autonomous vehicles, biochips and biosensors, and new materials) are most likely to co-locate with R&D facilities in high-income economies. This mirrors the manufacture of certain capital goods and advanced inputs (such as semiconductors, doped wafers for semiconductors, and fibreoptic cables), which stayed in high-income economies during Industry 3.0. At the same time, the assembly of high-tech goods, such as laptops and mobile phones, moved to low- and middle-income economies with Industry 3.0. The same is unlikely to happen with the advanced manufacturing product lines associated with Industry 4.0 because of the likely skill and infrastructure requirements throughout the product's value chain. More than through these new advanced goods, however, the biggest impact on low- and middle-income countries is likely to be through new

[60] Rodrik (2016), "Premature deindustrialization," Journal of Economic Growth, vol 21(1), pages 1-33.
[61] Mary Hallward-Driemeier and Gaurav Nayyar (2017), Trouble in the Making? The Future of Manufacturing-Led Development, World Bank Group.

manufacturing process technologies that affect the production of traditional manufactured goods, such as robotics (AI-enabled); IoT (including sensor-using "smart factories" that may also be AI-enabled); and 3D printing. The more widespread use of labour-saving technologies in established global centres of manufacturing can challenge established patterns of comparative advantage. By reducing the relative importance of wage competitiveness, robotics and smart factories can change what it takes for locations to be competitive in the global market for manufacturing. One of the important challenges for developing countries would be the reversal of FDI flows.[62] While previously FDI followed cheap labour, labour cost differentials might no longer play such an important role with Industry 4.0. If high-income economies are reshoring production, this could affect current manufacturing exporters and stifle the potential entry of newcomers.[63]

Technological breakthroughs will also affect the range of goods for which 3D printing could be viable. Whereas plastic resins were initially the medium available, metal printing and mixed-materials printing are now available. And the printing of biological material (bioprinting) is under development. As 3D printing expands, there is still a question of the choice of location. ***While there is always the possibility of greater dispersion of production sites, many expect the development of 3D printing manufacturing hubs, particularly if the cost of 3D printers remains high and there are advantages of centralizing logistical support in transportation hubs.*** The expectation is that many firms may choose to locate in large consumer markets – or in lower-cost locations with easy access to these markets and where intellectual property rights and data flow issues can be reliably addressed.[64]

Much like IoT and smart factories, 3D printing emphasizes the increasing servicification of manufacturing. The technology eliminates the need to move manufactured goods over long distances from production centres and instead puts the premium on trade in services – primarily data flows – as part of the manufacturing process. For example, designs, data, and other information from a product designer/producer in an exporting country will be delivered digitally for printing in a target market.[65]

Some developing countries might be able to leapfrog thanks to their high-skilled, ICT heavy skilled workforce

Despite the common belief that only high-income countries and China will be adopting advanced processed technologies, such as robotics and smart factories, it is worth noting that several large emerging markets, including Brazil, India, Indonesia, Malaysia, Mexico, Thailand, and Turkey also, had nontrivial stocks of industrial robots in 2015. Smart production processes are also evident in these countries, for example, in the 3D printing of auto parts in India.

Many multinational corporations are increasingly locating high-skilled, ICT-heavy, and technical skill-based work in emerging markets, owing to the availability of technical and engineering talent at competitive wages. This is clearly an area where certain countries, such as India, have demonstrated a competitive advantage in terms of skilled and technical professional workers. Outward FDI from emerging markets for the acquisition of technology or other know-how from firms based in Europe and the United States might also accelerate the incorporation of Industry 4.0 technologies in these economies.

The potential for developing economies to boost their manufacturing exports in the future, and leverage them for growth, is affected by how emerging technologies change globalization patterns, and this could vary substantially across countries with different levels of development of the manufacturing sector. The faster diffusion of ICT and related developments in the IoT could strengthen the current structure of

[62] https://www.unido.org/fileadmin/user_media_upgrade/Resources/Publications/Unido_industry-4_NEW.pdf
[63] See supra note 61.
[64] Ibid.
[65] Ibid.

GVCs. But greater digitization in smart factories and advanced robotics might reduce the importance of low labour costs in determining comparative advantage, laying greater emphasis on skills, complementary services, and other aspects of firm ecosystems. Furthermore, 3D printing may make it feasible to produce in smaller batches with neither an emphasis on scale nor a larger ecosystem of suppliers, which may be particularly useful for countries that currently have limited manufacturing bases.[66]

The impacts of shifting technologies and globalization patterns might not be uniform across different manufacturing subsectors. The feasibility of continued opportunities for export-led manufacturing will depend on a subsector's magnitude of automation, the extent of trade in international markets, the degree of export concentration, and the importance of complementary services. For example, the adoption of robotics in the manufacturing of motor vehicles will reduce the labour intensity of production, while the 3D printing of medical equipment, if it reduces international trade, may diminish the scope for productivity growth through increasing specialization and technology diffusion.

Industry 4.0 technologies create the opportunity for developing countries to bypass traditional phases of industrial development

Mobile phones have already reduced the need for countries to lay expensive fixed landlines. and online and mobile banking is reducing the need to build networks of physical bank branches. While the infrastructure needs of most developing countries remain formidable, developments driven by Industry 4.0 suggest they could be lower. Localized renewable energy production, such as solar power coupled with new battery storage technology, could reduce the need for investing in expensive power distribution networks. Drones could help to deliver lightweight, high-value goods such as medical supplies to remote regions with poor transport infrastructure. While drones will not remove the need to build roads for the transport of heavy goods and people, they do offer the opportunity to design transport infrastructure in new ways and to reduce the need for "last-mile" road connectivity.

Source: WEF and ADB, ASEAN 4.0: What does the Fourth Industrial Revolution mean for regional economic integration?

[66] Ibid.

LEAPFROGGING THE STAGE OF HIGH FOSSIL FUEL CONSUMPTION FOR INDUSTRIAL DEVELOPMENT

UNIDO's report "Accelerating clean energy through Industry 4.0: Manufacturing the next revolution" looks into two development pathways towards more sustainable energy: developed countries could retrofit their systems to improve energy efficiency, while developing countries could industrialise in a more sustainable manner by jumping from older technologies to very modern ones, such as smart factories and decentralised microgrids. Industrialised countries are now operating within established industries and infrastructure that enabled considerable economic growth but led to high energy consumption with detrimental effects to the environment. Connecting Industry 4.0 and sustainable energy initiatives could stimulate major opportunities in carbon intensive industries via digitisation, automation and optimisation.

But today's developing countries have access to energy technologies that did not exist when current industrialised countries were at similar stages of their own growth. This could allow them to avoid passing through a stage of high fossil fuel consumption for industrial development. ICT, and advanced technology in general, could play a key role in helping them cope with some of the most pressing challenges, such as energy access and connectivity, while avoiding carbon lock-ins. To successfully realise this potential the digital divide needs to be bridged through investments in the development of ICT literacy, skills and infrastructures.

According to the report, the private sector should play a large role in driving technology standards, financial solutions and targeted incentives to accelerate improvements, while the public sector should be responsible for creating enabling policy environments. Financial institutions (both private and public, including international) would provide the financial frameworks for unlocking large resource pools for high capital projects. [67]

CHANGES FOR COMPANIES

Industry 4.0 is expected to accelerate over the next 2-3 years, transforming manufacturing processes on the way. Industry 4.0 will make supply chains and production processes more interconnected, efficient and flexible, allowing mass-customization and virtual production. This will be made possible through the following processes:

- Bringing products to market faster;
- Machines perform independent quality checks so errors can be detected and remedied faster;
- Smarter resource management based on energy data leads to optimized equipment maintenance;
- Improved stock management via using chips and sensors;
- Improved prediction for demand through data mining, which leads to improved supply chain and inventory management.

[67] UNIDO (2017). "Accelerating clean energy through Industry 4.0: manufacturing the next revolution." Nagasawa, T., Pillay, C., Beier, G., Fritzsche, K., Pougel, F., Takama, T., The, K., Bobashev, I. A report of the United Nations Industrial Development Organization, Vienna, Austria., at http://www.unido.org/fileadmin/user_media_upgrade/Resources/Publications/REPORT_Accelerating_clean_energy_through_Industry_4.0.Final.pdf

How Industry 4.0 is delivering revenue, cost and efficiency gains

ADDITIONAL REVENUE FROM	LOWER COST AND GREATER EFFICIENCY FROM
Digitizing products and services within the existing portfolio	Real time inline quality control based on big data analytics
New digital products, services and solutions	Modular, flexible and customer tailored production concepts
Offering big data and analytics as a service	Real time visibility into process and product variance, augmented reality and optimization by data analytics
Personalized products and mass customization	Predictive maintenance on key assets, using predictive algorithms to optimize repair and maintenance schedules and improve asset uptime
Capturing high-margin business through improved customer insight from data analytics	Vertical integration from sensors through MES to real-time production planning for better machine utilization and faster throughput times
Increasing market share of core products	Horizontal integration, as well as track-and-trace of products for better inventory performance and reduced logistics Digitization and automation of processes for smarter use of human resources and higher operations speeds System based, real-time, end-to-end planning and horizonal collaboration using cloud based planning platforms for execution optimization Increased scale from increased market share of core products

Source: PwC Industry 4.0: Building the Digital Enterprise

ENTREPRENEURS, SMES AND START-UPS

Initiatives have been launched in many industrialized countries to help SMEs make the digital transition. In Europe the initiatives carry names like "Industrie 4.0" in Germany, “Factory of the Future” in France and Italy, and “Catapult” in the United Kingdom. The common goal of these programmes is to increase digitalization and ensure that European manufacturers are part of the new industrial revolution. In China, as mentioned, the government is pushing for more digitalization via a series of activities under its Made in China 2025 initiative. In the United States, a whole range of federally funded programmes have been initiated to promote advanced manufacturing – and they also benefit SMEs.[68]

[68] https://www.siemens.com/customer-magazine/en/home/industry/one-step-closer-to-industrie-4-0/introducing-smes-to-industrie-4-0.html

In the countries of the European Union (EU) plus Norway, SMEs account for around two-thirds of total employment and contribute more than half of value added. In the United States, SMEs provide 55 per cent of all jobs and account for 54 per cent of all sales in the country. Statistics are similar in other parts of the world. If this sector falls behind, the consequences could be dire. [69]

Initiatives have been launched in many industrialized countries to help SMEs make the digital transition. These programmes aim to encourage companies to make greater investments in digital technologies. A starting point for many SMEs on the digital path is cloud solutions. According to KPMG research, more than 50 per cent of German companies already report using this. **In industrial settings, cloud solutions can be used for predictive maintenance, energy data management, or resource optimization.** All these applications have a proven ability to help manufacturers save money.

The SMEs will have to adapt to new Industry 4.0 standards and methods in order to remain competitive and to remain linked into existing value chains and production networks. If certain big companies exploit their first-mover advantage to set industry standards, they may be able to compel SMEs to adopt these standards.

Besides these external incentives, the expected improvements in productivity, enhanced innovation capability, and the modern image Industry 4.0 may convey are strong drivers for SMEs to engage with Industry 4.0. This raises the question as to how SMEs can utilize the benefits of Industry 4.0 and ensure they are not left behind by larger firms. On one hand, there are strong arguments for an optimistic scenario: a blurring between information and physical worlds along with a new focus on mobile manufacturing units and open production sites (smaller than present-day plants) and 3D printing may lower entry barriers for SMEs. Equally, as value chains become increasingly fragmented, there are more entry points for newcomers, for example with regard to design, processing, handling customer data, etc., and more generally new ways of creating value and novel business models. Industry 4.0 might also provide start-ups and small businesses with the opportunity to develop and provide downstream services and to thus integrate themselves into new value chains.

To sum up, the expected benefits for SMEs' participation in Industry 4.0 are manifold: cost savings due to more efficient processes; enhanced competitiveness through intelligent production systems and networked processes; customized products and services; innovation through more flexible production; new sales channels; a more extensive market; and customer analysis through the use of big data.

Beyond these potential benefits for SMEs, there are some changes to the business paradigm that SMEs face that may not necessarily be viewed as entirely positive: product portfolio aspects, financing considerations, customer relations will all be affected, as will the operational and strategic independence of the enterprise, posing new challenges to SMEs.[70]

SMEs face some major challenges as regards the take-up of digital technologies in their operations. The risks in this regard are manifold: data security and the costs of investments required to ensure it; stability of technical infrastructure and vulnerability of it systems; increased competition; higher investment requirements; and difficulty of recruiting skilled IT staff.

These are the most common obstacles faced by SMEs to participation in the supply chain of Industry 4.0:

- Lack of awareness about advanced technologies and the potential benefits of applying them in production processes;

[69] Ibid.
[70] http://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf

- Ability to buy required technology and invest sufficiently in research and development where technology is not readily available – this, in turn, requires easy and swift access to finance;
- Capacity to run pilot projects to test out Industry 4.0 mechanisms and potentially limited access to facilities to test advanced solutions;
- Availability of highly skilled specialized (IT) staff needed to integrate and use advanced machine tools and the ability of SMEs to attract such skilled labour;
- Big companies may take advantage of their market position to first test and then patent new technologies – raising entry barriers for followers;
- Industry 4.0 may make internationalization of production more pertinent than ever – this will be easier to execute for big corporations than for SMEs, which in turn may increase the dependency of SMEs on bigger firms as their customers.

It has been argued that these obstacles can be overcome by adopting a multi-pronged strategy:

- By integrating into existing supply chains with Industry 4.0 "champions" and benefitting from their know-how;
- By focusing on developing niches within a more dispersed production system and marketing these in more localities internationally; and
- By embracing technologies, such as 3D printing, which make it easier to produce on a more decentralized basis.

Moreover, it will be key for SMEs to make use of data they already collect in their enterprise resource planning and customer relationship management databases but do not fully utilize yet.[71]

For the above, publicly-funded programmes that support SMEs engagement in Industry 4.0 are extremely important. An illustrative example in this regard is the Digitizing European Industry initiative, where the European Commission is focusing a €500 million investment from Horizon 2020 on digital innovation hubs, which is an important step. As a pilot, the Commission will support a network of technology centres to provide services to SMEs in advanced manufacturing for clean production. More networks and innovation hubs in advanced technologies will follow.[72] Another example in this regard is the SME integration to Industry 4.0 Thematic Platform led by the Joint Research Centre of the European Commission. This initiative aims to increase the SMEs' absorption of specialized digital services. The partners will develop common projects based on an open source platform and reinforce cooperation, together with SMEs and other stakeholders (sectorial clusters and competence centres), along European value chains, surveying both the demand and supply side and providing demonstrational and development services in order to accelerate and catalyze the process of matchmaking within the European value chain. [73]

SUSTAINABILITY AND CIRCULAR ECONOMY

Industry 4.0 could represent a step forward towards more sustainable industrial value creation, mainly characterized as a contribution to the environmental dimension of sustainability. The allocation of resources, i.e. products, materials, energy, and water, could be realized in a more efficient way on the basis of intelligent cross-linked value creation modules. [74]

A circular economy is essential to achieve inclusive and sustainable industrial development and the 2030 Agenda for Sustainable Development. This is where economic and environmental benefits join hands, creating jobs while reducing the environmental impact. The lifetime of biological and technical materials

[71] Ibid.
[72] https://www.europeanfiles.eu/industry/industry-4-0-an-opportunity-for-sme
[73] http://s3platform.jrc.ec.europa.eu/sme-integration-to-industry
[74] https://www.nature.com/news/the-circular-economy-1.19594

and products is extended as they are designed for durability, reusability and recyclability. Pursuing the most effective ways to produce, with renewable energy saving energy by reusing materials, is one of the primary tenets of the circular economy. New business models, such as products as services, repairing, refurbishing, and recycling also help create new jobs. A circular economy is focused on the reprocessing of goods and materials. This could generate jobs and save energy while reducing resource consumption and waste. For instance, vehicle owners can decide whether to have their used tires repaired or regrooved or whether to buy new. Rather than being dumped, used tires are collected by waste managers and sold to the highest bidder. Conventional waste management is driven by minimizing the costs of collection and disposal – landfill versus recycling or incineration. In a circular economy, the objective is to maximize value at each point in a product's life. New jobs will be created and systems are needed at each step. [75] The concept of the circular economy also places greater emphasis on the establishment of partnerships with and between private sector, research, development, and innovation communities, as well as with the financial sector.[76]

Connectedness (Industry 4.0) might act as enabler of many of the circular economy innovations. Changing any one of the following parameters: products themselves; how they are designed; who designs them; and/or the industrial context that brings them into existence through supply and demand, has the potential to remove or reinforce existing barriers to the realization of a circular economy and to present new opportunities and complications for its future implementation.

The circular economy is part of a trend towards intelligent decentralization. The various technologies under the umbrella of Industry 4.0 could serve as a major enabler of circular strategies. The contribution to a circular economic model gives the development of Industry 4.0 purpose and momentum. The following examples show how this may occur in practice:

CREATING POSITIVE SUSTAINABILITY IMPACTS ALONG THE WHOLE VALUE CHAIN: This can be done through increases in efficiency by facilitating circular economy solutions, enabling transparency, and traceability through the customization of products. Products that are connected to the IoT allow manufacturers to control and analyze their performance at a distance and collect usage data. This provides a foundation for many circular business models: (i) car sharing platforms require data about the whereabouts, the usage, and the condition of each car; (ii) in Products-as-a-Service (PaaS) models, manufacturers retain ownership and the responsibility for the flawless operation of their equipment. They can only do so when they are able to monitor and analyses performance at a distance. In addition, PaaS models allow capacity to be tailored to fluctuating demand, and provide manufacturers an incentive to produce goods that are durable, which should help to reduce waste; (iii) circular strategies like recycling, remanufacturing and parts harvesting likewise require the collection and analysis of data about the usage and condition of parts.

Advances in AI would allow manufacturers to employ smart machines in an increasing number of applications, thereby potentially increasing yield and reducing waste, as well as extending product life times.

AUTOMATED DISASSEMBLY: One of the challenges in designing for a circular economy is the need to design products that are both desirable and durable during use and easily and economically disassemble at end of life. Due to the high labour costs associated with manual disassembly, relative to the material value in waste products, recyclability is often neglected in favour of product aesthetics, functionality and reliability. However, one of the developments associated with Industry 4.0 is that of smart, automated product manufacturing,[77] in which an embedded RfID tag coordinates a product's construction as it moves through the production process. Should it be possible to run this process in reverse, smart and

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[75] Ibid.

[76] https://www.unido.org/tedxtalksthecirculareconomy.html

[77] https://www.boschrexroth.com/en/xc/trends-and-topics/industry-4-0/best-practices/smart-automation-demonstrator/smart-automation-demonstrator-1

automated product disassembly could reduce or eliminate existing design trade-offs between product durability and recyclability.

SMART PRODUCTS: IoT enables everyday objects to become connected and networked devices could also present opportunities for sustainable product design. The live feedback of data from consumer products could provide designers with valuable insights into product life cycles beyond the point of sale, including during use and end-of-life phases. Designers would then be able to monitor failure points, use and maintenance practices, and final disposal routes, and then make the necessary adjustments to their designs to improve product circularity and sustainability.

Additionally, in the case of smart products, it may be possible to design software updates to improve functionality or aesthetic appeal without the need to replace the physical objects themselves.

Whilst these examples are certainly not exhaustive, they highlight Industry 4.0's relevance to the circular economy. As Industry 4.0 is still in development, the foresight of both the possible opportunities and challenges it presents are needed so that preparatory actions can be taken to ensure a sustainable future.[78] Where Industry 4.0 and the circular economy meet, the waste of value might be prevented, and the value of waste might be recovered, if certain preconditions are met.[79]

On the flip side, Industry 4.0 can possible lead to increases in consumption and create negative sustainability impacts. Data centres waste an average of 90 per cent of the energy that they consume (30 billion watts, equivalent to the output of 30 nuclear power plants), and account for 17 per cent of technology's carbon footprint. Although the circular "business case" looks remarkable (global management consultants McKinsey and Company estimate that it could add US$2.6 trillion to the European economy by 2030), the fact that business remains central to the vision is a vulnerability. The growth economy impedes sustainability. In 2014, for instance, Chevron and a number of other big oil companies retreated from investments in renewables because of poor returns. Business competitiveness and "disruption" can hinder the collaboration that is central to eco-design. UK design engineer Chris Wise has noted that the practice of using "least materials" is at odds with the construction industry's prime aim of selling more materials. The "rebound effect", in which designed efficiency leads to greater use or consumption, is a related conundrum.[80]

SMART CITIES

Urbanization and technology have become closely interrelated, to the point where technology now directly influences where and how urbanization happens. Cities are the engines of modern society; they power the global economy, consume vast amounts of resources, house the majority of the world's population, and create much of the pollution and emissions that have scientists concerned about the future.[81]

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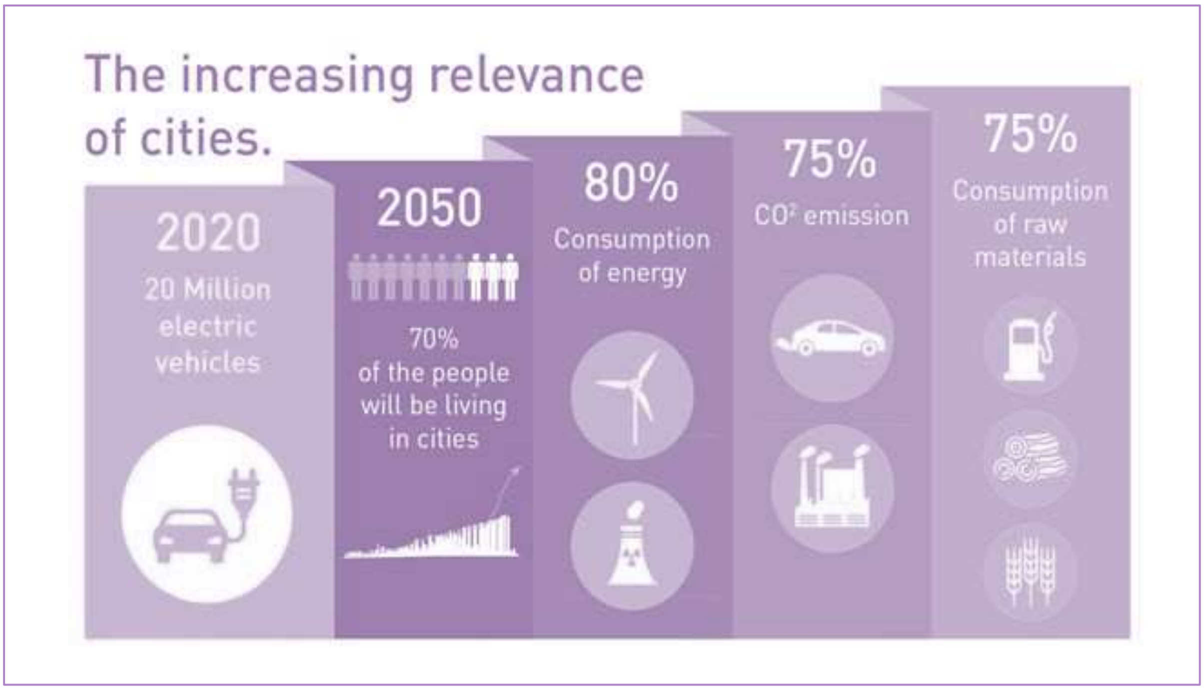
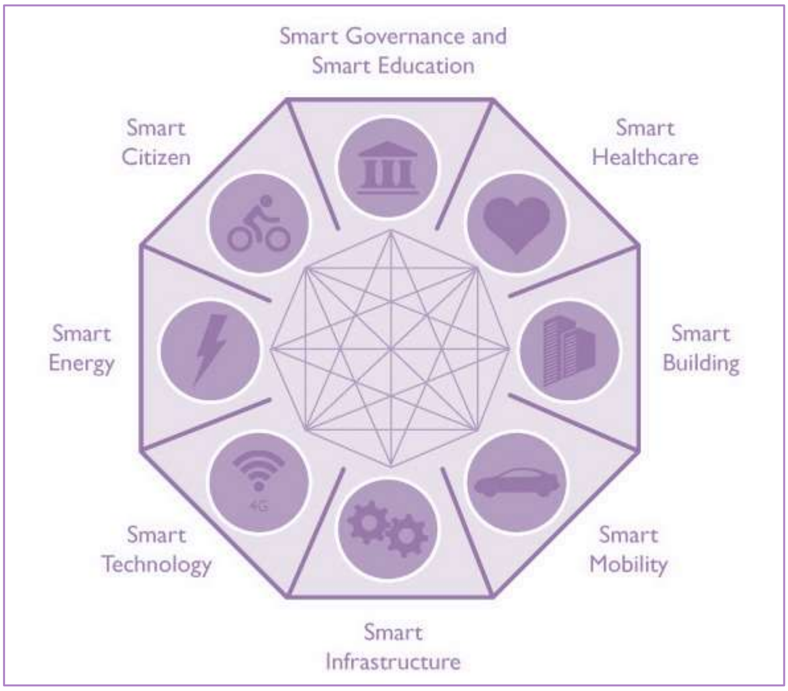
[78] http://wastelessfuture.com/design-sustainability-and-the-4th-industrial-revolution/
[79] http://pwc.blogs.com/sustainability/2017/06/industry-40-as-an-enabler-of-the-circular-economy.html
[80] https://www.nature.com/nature/journal/v531/n7595/full/531443a.html; C. Wise et al. Nature 494, 172–175; 2013 at http://dx.doi.org/10.1038/494172a
[81] https://www.weforum.org/agenda/2017/09/this-is-how-the-worlds-smartest-cities-are-being-built



Source: Visual Capitalist

The increasing availability of broadband internet, along with the rise of IoT, have accelerated the roll-out of smart and connected infrastructure across cities, regions and entire countries. Roadways, energy grids, water and sewage systems, public buildings and facilities, communications networks, cars and homes, etc. are becoming "smarter" every day. There were over 6.4 billion connected devices in 2016; estimates are five to ten times that number just in the next four to five years. This smart infrastructure, and the massive amount of real-time, geo-specific data it generates, provide both the engine and the fuel for AR in the public sector. This is being borne out across the globe as evidenced by the significant "smart city" initiatives and challenges being launched in the EU, India, China, the US and most recently in Canada.[82]



Source: Visual Capitalist

[82] https://www.weforum.org/agenda/2017/02/augmented-reality-smart-government/

IV. CHALLENGES

Industry 4.0 could be more challenging for emerging economies because the risks could be potentially bigger than opportunities. The impact will vary according to the answers to these questions: (i) What are the main obstacles to the full realization of Industry 4.0 in developing countries? (ii) When will these advanced manufacturing technologies be widely adopted? (iii) What public policies will be necessary to deal with this new species of economic development?[83]

In order for Industry 4.0 to take off successfully, certain preconditions should be met, such as robust technological infrastructure, a workforce with the required digital skills, work systems with the required levels of security, and adequate governance structures. These are all significant risks that should be considered by both public policymakers and enterprises when embarking on Industry 4.0 initiatives.[84]

Main obstacles to full realization of Industry 4.0 in developing countries

- A stable electricity network and a good internet or telecommunication network are often required. There is a risk that Industry 4.0 disruptive technologies will increase the gap between countries with good electronic infrastructure and countries with less developed networks.
- A risk of reinforcing loops whereby the countries with developed Industry 4.0 eco-systems will have developed adequate education and an available skilled workforce that will lead to further development of Industry 4.0 (and the opposite with countries with less developed eco-systems in this regard). Disruptive technologies might reinforce the inequalities between countries.
- As AI devices respond to commands that are either in English or in program languages, the use of such device is out of reach of populations with low education levels.
- In countries with poor governance, the regulatory framework enabling the development of Industry 4.0 may not exist and this creates a vicious circle: the regulatory framework does not exist because there are no Industry 4.0 activities and there is no Industry 4.0 activity because there is no regulatory framework.
- Industry 4.0 can create a new dependencies for countries if they develop an activity based on a specific product which they need to import and which the producing country may decide to discontinue or no longer share the available technology.

INFRASTRUCTURE IN DEVELOPING COUNTRIES

Investing in infrastructure for energy, transport, information and communication technologies, and irrigation is a crucial step towards creating empowered communities in any country. A lack of adequate infrastructure is a major barrier to social and economic development. The biggest impact of inadequate infrastructure can be seen in African countries whose productivity is influenced the most. It is proven that a good-quality infrastructure results in an increase of productivity and improvements in health and education. This positive correlation between infrastructure on the one hand, and economic and social goals on the other, should serve as an incentive for future efforts and investments.

[83] https://www.weforum.org/agenda/2017/01/designing-iinnovation-policies-in-emerging-economies/
[84] http://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf

Rapid technological advances in renewable energy, fuel efficiency and energy storage not only make investments in these fields increasingly profitable, boosting GDP growth, but they also contribute to mitigating climate change, one of the major global challenges of our time.

In the era of Industry 4.0 the quality of infrastructure and logistics and other backbone services, regulatory requirements, the density of the supply base, and information flow about markets are becoming increasingly important for better connectivity, which will be key in reducing time to market and raising responsiveness to changing customer needs. The ease of doing business will warrant greater attention to support a production model reliant on highly differentiated tasks.

ENERGY 4 INFRASTRUCTURE

Many developing countries have yet to enjoy the full benefits of even the second industrial revolution. A number still lack access to electricity; for those who have it, it remains highly unreliable.

Energy 4.0 is instrumental regarding the possibility for leapfrogging. Renewable energy decentralizes access, displacing grid infrastructure reliance. Smart microgrids distribute power efficiently across a number of homes. Energy 4.0 also opens up new opportunities for high-value-added, high-efficiency industries that could drive the rise of income levels. Renewable energy, smart grids, and electric mobility integration form a major green field with mature technology manufacturing and distribution, among other huge investment opportunities. Modernizing developing countries' businesses and enabling them to compete in global markets are thus imperative.

ICT INFRASTRUCTURE

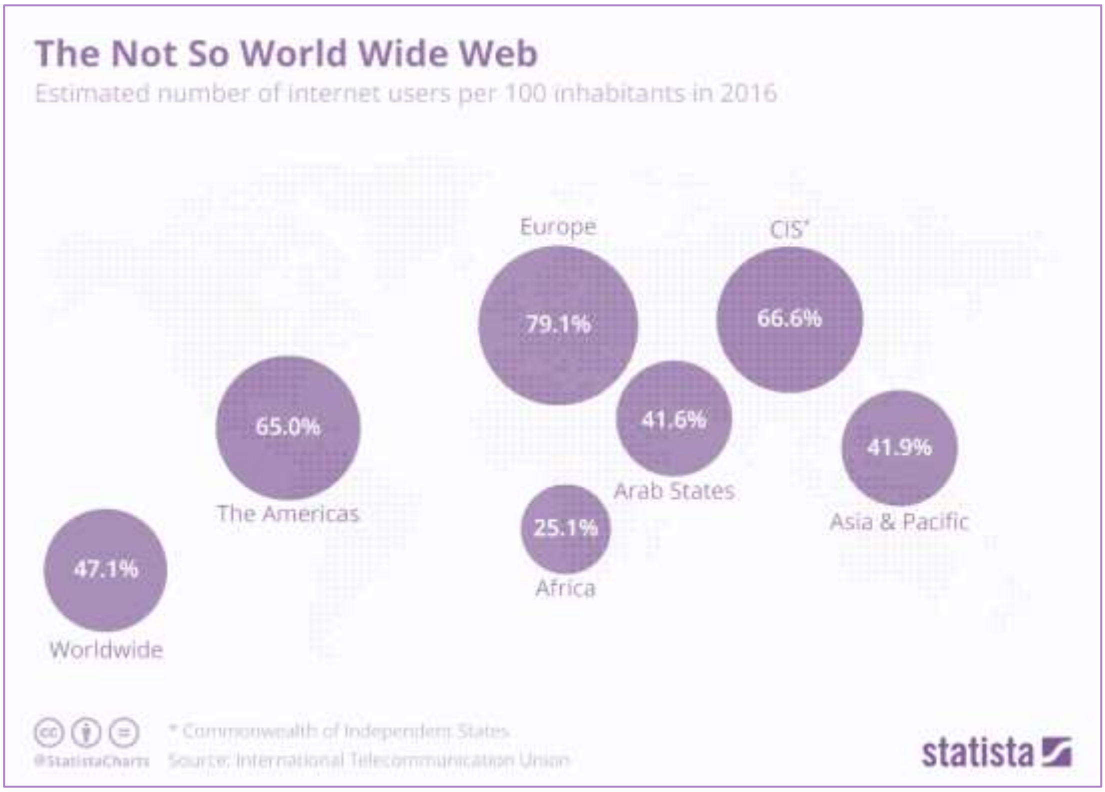
In a time in which most of us have a feeling that having an internet connection is a commodity, more than a half of the world's population (more than 4 billion people) still lack access to the internet. 90 per cent of people without an internet connection live in developing countries. In order to ensure the equality of making knowledge and information available, it is crucial to bridge this digital gap. At the same time, around 2.5 billion people in the world lack full access to electricity, and about 800 million lack access to water. Even though mobile phone services are spreading quickly, allowing people to be included in the universal information network, this twenty-first-century phenomenon has still not reached the point of universal utilization. This is a proof that a massive share of rural areas remains disconnected, and that this issue should be addressed in the near future.[85]

Digital infrastructures, including efficient, reliable and widely accessible broadband communication networks and services, data, software, and hardware, are the foundations on which the digital economy is based. It is essential that governments promote investment in digital infrastructures and competition in the provision of high-speed networks and services, ensuring that key complementary enablers are in place, e.g. fibreoptic backhaul, sufficient spectrum and increasing uptake of Internet Protocol version 6 (IPv6) internet addresses. Individuals, businesses and governments need reliable and widespread access to digital networks and services to benefit from digital opportunities.[86]

[85] http://www.mn.undp.org/content/mongolia/en/home/sustainable-development-goals/goal-9-industry-innovation-and-infrastructure.html

[86] OECD digital outlook 2017

However, even 25 years after what some call its inception, the World Wide Web is not nearly as universally available as its name suggests. According to the latest estimates by the International Telecommunication Union,[87] a UN agency specializing in information and communication technologies, only 47 in 100 world citizens use the internet. While internet access in regions such as North America and Europe has become a commodity not unlike electricity and running water, people in less developed regions often still lack access to what has arguably become the most important source of information of our times. The following chart shows how widely internet penetration still varies across different world regions.



[87] http://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx

JOBS, SKILLS AND EDUCATION IN DEVELOPED AND DEVELOPING COUNTRIES

Industry 4.0 is at its nascent stage and is characterized not by any singular technology, but by a networked connection of the digital and the material world through the integration of CPS. Like the major industrial developments that have preceded it, it is expected to result in significant, disruptive changes to the way in which products are produced, consumed and designed. Thus, business models and the industrial architecture that supports the production and consumption of products will also be forced to evolve and adapt. Even though it is impossible to anticipate its precise societal impact, in general there are three big areas of concern: inequality, security, and identity. Advances in AI and robotics are rapidly consuming jobs and widening the economic inequality gap around the world even further. The World Bank estimates that increasing automation will put 57 per cent of the jobs in the 35 countries in OECD at risk, including 47 per cent of US jobs and 77 per cent of the jobs in China. While many existing jobs will be eliminated or transformed – especially manual and routine jobs that are easily automated – new kinds of jobs that require different skillsets will emerge. By one estimate, 65 per cent of children entering primary school today will have to prepare for jobs in categories that don't yet exist.[88]

The composition of the workforce will need to change to match the digital skills required to support Industry 4.0. Entire industries will need to adjust, meaning most occupations will undergo a fundamental transformation. Some jobs will become redundant; demand for other jobs will grow rapidly. Many of the jobs of today will go through a change in the skillsets required to do them. By introducing smart sensors, intelligent assistant, and robots, the Industrial Internet will also increase the need for new types of skills and ultimately change the labour landscape. Lower-skilled jobs will be replaced by machines, and new, highly-skilled jobs would be created, such as medical robot designers and grid optimization engineers. As these trends take hold, and new skills are required, people will increasingly rely upon smart machines for job training and skills development.[89]

The WEF research shows that the broad adoption of the Industrial Internet in many industries will lead to a structural shift in employment and skills. An increase in the use of smart products and AI will transform the desirable skillset of the human labour force in the future. Companies will use machines and network systems to automate tasks that can be done at lower costs and higher quality levels. This would enable humans to focus on tasks such as creative problem solving and collaboration. The optimistic scenario is that, in the long run, the Industrial Internet would enable the creation of a blended workforce, where it is no longer humans *versus* machines but humans *with* machines (the concept of "human-cantered automation").[90]

WEF: job families that will experience the most growth owing to these drivers of change

In descending order of demand, they are computing and mathematical (e.g. data scientists, analysts, programmers), architecture and engineering, management, and sales roles. On the other hand, installation and maintenance, construction and extraction, and manufacturing and production are predicted to experience negative growth.

[88] https://www.weforum.org/agenda/2017/01/4-ways-to-close-the-inequality-gap-in-the-fourth-industrial-revolution

[89] http://reports.weforum.org/industrial-internet-of-things/executive-summary/

[90] http://reports.weforum.org/industrial-internet-of-things/4-shift-towards-an-integrated-digital-and-human-workforce/

Compounded by the effects of globalization, workforce transformation will create many new opportunities in some regions, yet there will be a significant dislocation of jobs elsewhere. This will not occur in an even fashion, as transformation will be specific to the industry, region and occupation in question, not to mention the varying ability of employers to manage such significant change. Ongoing business model innovation and industry transformation will become the new normal, such that the skills employers need will constantly change. New technologies will begin replacing specific tasks of existing jobs, allowing these workers to focus on higher-level and more complex tasks. Some lower level, repetitive jobs will be completely displaced. According to the WEF 2016 Future of Jobs Survey, there is "a modestly positive outlook for employment across most industries, with jobs growth expected in several sectors ... accompanied by high skills instability across all job categories". The combination of net job growth and skills instability will result in most businesses facing major recruitment challenges and talent shortages.[91]

Using Industry 4.0 to overcome infrastructure problems

Some developing nations, such as Indonesia, the Philippines and Malaysia, are archipelagic and physical connectivity has long been a concern for economic development. Also, some Asian countries have large rural populations in remote areas that have yet to benefit from Industry 1.0 and Industry 2.0. In Cambodia and Myanmar, only about half of the population has access to electricity.

Using Industry 4.0 technologies distributed structures for services that can overcome geographical limitations can be developed. People can be linked to electricity through new renewable energy technologies that are generated locally rather than in centralized power plants. 3D printing will enable people to manufacture products at small scale as required, subject to the availability of raw materials, right next to where they are needed, and so overcome resistance by distributors to serve remote regions.

Investments in high-speed broadband, 3D printers and local power hubs could provide a faster way to connect people than investments in roads, shipping and electricity grids. Drone delivery also offers an opportunity to provide improved access to vital supplies, such as vaccines, to remote areas.

Skills provide an important safeguard against the risk of automation. Fewer than 5 per cent of workers with a tertiary degree are at a high risk of losing their job due to automation, on average, compared to 40 per cent of workers with a lower secondary degree. Indeed, looking at the type of jobs gained and lost over the last fifteen years, most job growth has been on the high-skill end. This is true in the United States, Japan, as well as in Europe as a whole. Similarly, jobs in the middle of the skills distribution have declined in absolute terms in all countries. "Soft" skills are also likely to grow in importance in the new world of work. Evidence from the United States shows that the ability to work in teams, problem-solving, and communication skills will be particularly sought after.[92]

Industry 4.0 requires new skillsets, for instance in mechatronics, digital medicine, precision agriculture, robot design, and smart grid design, as well as management. These skillsets cannot be created overnight, and require changes in education and vocational training. The following is an example of the required shift in job profiles for the connected factory, illustrated by McKinsey and Company.[93]

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[91] http://www3.weforum.org/docs/WEF_FOJ_Executive_Summary_Jobs.pdf

[92] http://www.oecd.org/employment/Going-Digital-the-Future-of-Work-for-Women.pdf

[93] https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/digital-in-industry-from-buzzword-to-value-creation

Example of required shift in job profiles for connected factory

	From...	...To
Worker (production)	Carries out production tasks, large share of manual tasks	Exception handler in production line, operator in automated environment
Maintenance expert	Troubleshooter and exception handler	Overseer of predictive maintenance, planning and steering based on data-driven analysis
Quality specialist	Inspects parts and controls quality standards after the fact	Smart engineering of process to online control for quality issues
Production planner	Top-down planning and steering of linear processes (50 percent build-to-stock)	Supply-chain planner • Develops flexible self-steering value stream (100 percent build-to-order) • Becomes a planner on a fully integrated supply chain from order to delivery
Logistics planner	Plans supply in segmented approach (inbound, line delivery, outbound)	
Team leader	Focus on leading people based on visible waste on shop floor	Leads team based on identified digital waste, brings insights to action

McKinsey&Company | Source:McKinsey analysis

IMPACT ON DEVELOPING COUNTRIES

Given new technologies and shifting globalization patterns, cheap labour as a source of competitive advantage is increasingly giving way to more demanding ecosystem requirements for countries to compete, while still using technologies associated with Industry 2.0. Technological change will raise the requirements for high quality education to meet changing demands for skills (shifting from operators to engineers). Moreover, the increasing "servicification" of manufacturing will also raise the bar on what is feasible, thereby placing a premium on increasing the productivity of services embodied and embedded in manufacturing.

Despite all of these changes, there is still scope for countries using Industry 2.0 technologies to compete if the costs of doing business are substantially reduced. For example, if countries in Sub-Saharan Africa add massively to their labour pools, while also substantially improving their business environments, this might slow down the adoption of labour-saving technologies in the high income countries. The alternative – using Industry 4.0 technologies to produce traditional manufactured goods – has a higher bar, too. New technologies place higher demands on the availability and reliability of ICT services, the data ecosystem, skills, and logistical services. To the extent that they involve more embodied and embedded services, links to these services will be important. And if the time to market matters that much more and links with suppliers need to be that much more seamless, then the feasibility of using these new production processes depends on the ecosystem as well as the technical requirements. It may be particularly challenging for firms in countries with a less established manufacturing base to leapfrog into using new technologies, having not already established certain processes, skills, and networks using more accessible technologies. Inability to participate in the use of new technologies may therefore become a source of increased polarization across countries.

LEGAL IMPLICATIONS FOR DEVELOPED AND DEVELOPING COUNTRIES

Besides offering a plethora of opportunities, Industry 4.0 could also be seen as a public concern for the many risks present where decisions are made by computers and not by humans. The disruptive technologies of Industry 4.0 require access to vast amounts of data. Poorly drawn laws and government policies can hinder beneficial access without reducing the risks presented by Industry 4.0. The disruptive technologies also raise important ethical and privacy concerns that could erode trust if not addressed thoughtfully.

Attempting to marry something as technical as Industry 4.0 with robust regulation presents new challenges. For instance, there is dislocation between the need for transparency in regulation and the impenetrability for the majority of people of the inner workings of an AI system. The more advanced certain types of AI become, the more they become "black boxes", where the creator of the AI system does not really know the basis on which the AI is making its decisions. Thus, ensuring accountability and compliance in AI behaviour becomes very difficult.

The far-reaching societal, economic, environmental and geopolitical implications of Industry 4.0 necessitate a debate today to chart the course for the future and reap the many benefits but avoid the risks. This is not a trivial task given the many interdependencies and uncertainties and the fact that many challenges transcend the spheres of decision makers, across both technologies and borders. Regulators face the dilemma of designing regulatory systems that are predictable enough for companies, investors and scientists to make rational decisions, but unambiguous enough to avoid a governance gap that could jeopardize public consent or give too much room to non-state actors. Against this backdrop, evolving and adaptive regulatory systems should be designed in a flexible manner to take into account changing socio-economic conditions, new scientific insights, and the discovery of unknown interdependencies. The regulatory systems and structures of the future should be able to adequately supervise and control the risk in deploying Industry 4.0-based products, services and approaches. These risks, and the ability to manage them, are a challenge both for the firms concerned and the regulators tasked with protecting consumer interests and the integrity of the regulatory and legal system.

Regulators tend to take a technology-neutral approach to rule-making (at least in Europe), focusing on activities and outcomes rather that the means of delivery. Thus, in principle, methods of performing existing activities or achieving existing outcomes should fall neatly within existing legal and regulatory frameworks. If this approach works, then there should be no need for new laws or regulations, just new understandings of business models, or risks, and of the effectiveness of risk management responses. However, the introduction of autonomous non-human actors in Industry 4.0 decision-making processes could give rise to more complex questions regarding liability and responsibility for risks, especially when risks turn into harm.

DATA SECURITY, PROTECTION AND PRIVACY

Since the Industrial Internet is in its nascent stage, there are numerous risks and challenges associated with it. Due to increased connectivity and data sharing, sustainable governance models will need to focus on cybersecurity and data privacy issues. New security frameworks will have to be devised that span the entire cyber physical stack, from device-level authentication and application security, to system-wide assurance, resiliency and incidence response models.

A predictable legal framework is a *sine qua non* in order to realize the full economic potential of digitization. One way to protect data is to not process it in the first place. However, in the Industry 4.0 context, data processing necessarily takes place. Not having reliable and adequate legal infrastructure in place might hamper investment and adaptation of the latest technologies. Given the inherent international nature of data flows, in areas such as supply chains or 3D printing, national governance needs to be complemented by a functioning international legal framework. However, the current regulatory regime is underdeveloped and lacks the necessary legal certainty in areas such as privacy, transparency, interpretability, encryption control, the effect of intellectual property regimes on data that cross borders, and the impact of proprietary data on competition. Moreover, the physical infrastructure for data exchange, such as undersea cables, could also become a target in international conflict or terrorism.[94]

Data security means protecting data from destructive forces (both intentional and unintentional), and from the unwanted actions of unauthorized users. The ultimate goal of data protection is to ensure the privacy of customers and employees (in case data of persons are processed) and confidentiality (in case data on business secrets are processed). If data is not protected adequately, companies could be faced with court proceedings and ultimately high fines. Furthermore, data breaches could lead to a decrease in customer trust which ultimately leads to further losses.

INTELLECTUAL PROPERTY

The concept of intellectual property rights as we know it today would be challenged in the era of Industry 4.0. One field where this is already happening is AI. A key consideration for companies seeking to use AI in their business is how they can protect and exploit their investment into AI. When we talk about IP protection in the field of AI, we think of not only algorithms on which the AI model is based, but also any ideas or inventions that are created by AI.

PATENTS: The algorithms and AI processes that sit behind AI may be patentable inventions, though this varies from jurisdiction to jurisdiction. IBM claim that in 2016 they were granted more than 2700 patents relating to AI, cognitive computing and cloud computing (this amounts to 25 per cent of IBM's patents granted in 2016). The downside of patent protection is that the applicant is required to disclose the patentable material, which might be disadvantageous, giving competitors an opportunity to design around the invention.

COPYRIGHT: Most jurisdictions will also protect the expression of the algorithm and AI process in the form of software through copyright. However, there is more of a challenge where the AI continues to "learn" and so make changes to its own software structure. How should regulators respond in this regard: should they recognize copyright in works created by AI, and the ownership of these works?

For instance, the concept of computer authorship is already legislated in UK law: if the work is computer generated, the author will be the person by whom the arrangements necessary for the creation of the work are undertaken. This definition is acceptable when an engineer designs a simple algorithm and actively inputs a given set of data with the express purpose of eliciting the creation of a new computer program. However, how do you stretch this wording for more complex scenarios that involve multi-faceted models capable of learning and expanding their input and output without human supervision? What happens when we reach a point where human "arrangement" is many steps removed, and perhaps not capable of being traced? This impacts questions of ownership, responsibility, and accountability.

TRADE SECRET PROTECTION: Where it is not possible to establish from the AI output how the AI model works, then perhaps the best protection is to protect the confidentiality of the algorithms and the AI model. Thus, the best investment in protecting a valuable AI asset may be in enhancing the organization's conventional and cyber security protections and procedures.

LICENSING OF INTELLECTUAL PROPERTY RIGHTS: Like most intangibles it is possible to license a proprietary AI model to others. How this licensing will be structured depends on the type of AI and its use If the AI model is static and is not continuing to be trained, this is similar to licensing any other software product. However, if it is anticipated that the AI model will continue to be trained after deployment, and where the benefit of this training is expected to be shared with licensees, then another licensing approach is needed – e.g. how to feed back any improvements?

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[94] http://www3.weforum.org/docs/GRR/WEF_GRR16.pdf

LIABILITY

Issues pertaining to civil and criminal liability would become increasingly important in fields such as operability, environmental protection, and health and safety.

OPERABILITY: With the increasing interoperability of networks linking processes and machines, data security is more challenging but crucial to secure functionality (of machines) and operability (of the company as such). For instance, if through criminal intention a bug enters the network of a smart company, it could lead to great damage since potentially all machines linked to the network could be infected and stop functioning. Furthermore, if a hacker can get into the production environment (which is not usually associated with security systems) he/she can retrieve sensitive data, manipulate the production process, or even sabotage the entire production environment. The damage from this type of attack can be much higher than that of conventional hacking. Therefore, data security is not only important to ensure the protection of privacy and intellectual property, but also for the operability of the company.

ENVIRONMENTAL PROTECTION: Companies might deal with substances that are environmentally hazardous. If the handling of those substances is determined by smart machines data and network, security might also be important to safeguard the environment (e.g. avoid the manipulation/malfunction of networks leading to misuse/wrong use of these substances).

HEALTH AND SAFETY: When smart machines and humans interact in the same workspace it is important to be able to precisely predict the machines' actions to avoid danger to health and safety. If networks and machines can be manipulated due to insufficient data security machines could interact differently to how they were originally programmed.[95]

ETHICAL IMPLICATIONS OF INDUSTRY 4.0 TECHNOLOGIES

The anticipated business dynamics of Industry 4.0 poses questions of wealth and power distribution as well as of competition and barriers to entry. The rapid evolution of disruptive technologies could challenge existing competition policies and raise questions on the potential impacts of these technologies on income distribution and of who will control them. On the economic side, there is the potential that a few technology companies with access to large amounts of data and funding could end up controlling this technology, with access to its super-human intelligence and gathering most of the benefits yielded from AI.

As with some other digital and data markets, the AI market may exhibit "winner-takes-most" characteristics because of network effects and scale effects. With the disruptive business models of highly innovative digital multinationals unfolding transnationally, the accumulation of wealth and power by a limited number of private AI actors could cause tensions within and between countries. Some stakeholders highlight risks of digital giants acquiring start-ups before they can become potential competitors and the consequent risks of resource concentration in the field of AI.[96]

BLACK BOXES

If you look three decades ago, you can think of a software being programmed. But the way to think about it in terms of shifting to an AI environment is that the software is not programmed anymore, it is trained. And this is crux of the difference – it is between programming and training. Now, we are dealing with networks of information that often have surprising capacities. AI is a truly disruptive technology that offers a plethora of benefits, especially for developing nations. But it also comes with inherent risks, which, if not addressed and managed properly, might raise ethical and privacy concerns.

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[95] http://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf
[96] OECD Digital Outlook 2017.

It is very difficult to "marry" something so technical as AI to a robust regulation. On one hand, most governance systems require transparency, on the other most lay people do not understand how AI works. The more advanced certain types of AI become, the more they become "black boxes", where the creator of the AI system does not really know the basis on which the AI is making its decisions. Accountability, foreseeability, compliance and security are questioned in this regard.

BIAS

The biggest ethical concern related to Industry 4.0, big data and AI is "bias". While it is tempting to think that computers can be programmed to be completely objective, in fact, machine learning displays very human biases. AI may permanently codify human biases and cognitive investing errors. How do biases get into the system?

INTENTIONAL BIAS. The example with Volkswagen is illustrative in this regard. There was an effort to intentionally undermine regulatory objectives by putting code in systems that allowed the cars to identify when test conditions were occurring and to go into a separate mode that altered the emissions profile of the car. This was an effort to intentionally embed bad code to defeat regulatory oversight. Here the bias can enter technical systems in a way that is extrememely difficult for the public and regulators to understand.

BIAS REGARDING DESIGNER VALUES OR DESIGNER PROCESS. This is the example with Jeep Cherokee. Charlie Valasek and his colleague were able to remotely take over a car, control the air conditioning, and, most importantly, the gas and the brake on a highway. And this was not because Jeep does not care about security, Computation and connectivity is becoming embedded in devices, particularly in big ones that move about, and the engineers in these companies have not historically been focused on computer security, cybersecurity, and so this a blind spot. Chrysler announced a recall for 1.4 million vehicles after a pair of hackers demonstrated to WIRED that they could remotely hijack a Jeep's digital systems over the internet. For Chrysler, the fix was embarrassing and costly.[97]

We have to be concerned about the ways in which systems might just reflect the institutions or the individuals that are building them. The data used in filling out automatic forms can introduce sources of bias. *What data is considered relevant?* In the intake forms the data that is requested and used about clients varies. There are some standard pieces that appear to be required, but there is a lot of variation. *How is data cleaned?* This can be very important. People are often very focused on what data is there. But if you are a data scientist, one of the most important decisions you make after what data you use is how you clean it. *Sampling bias?* Who is poorly represented in the training data from which the models are built? For instance, many financial services are being targeted at millennials, and yet these are people who have historically not been a big part of the financial system. By building models based on data that does not represent them, what are some of the risks that we might be introducing?

COMPLEXITY BIAS. Data, algorithms, interactions, and personalization are all features of Industry 4.0. There are multiple parties engaged. And there are lots of opportunities for bias to come into systems in very complicated ways that require such things as game theory thinking.

One of the trickiest parts about algorithmic bias is that engineers do not have to be actively racist or sexist to create it. In an era when we increasingly trust technology to be more neutral than we are, this is a dangerous situation. As the tech industry begins to create artificial intelligence, it risks inserting racism and other prejudices into code that will make decisions for years to come. And as deep learning means that code, not humans, will write code, there is an even greater need to root out algorithmic bias. Put simply, the best case against AI is that it learns from us (humans) and we are awful! Thus, the ongoing diversity and inclusion efforts in this area are of great importance.[98]

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[97] https://www.wired.com/2016/08/jeep-hackers-return-high-speed-steering-acceleration-hacks/

[98] https://www.wired.com/2017/02/keep-ai-turning-racist-monster/

V. HUMAN CENTERED GOVERNANCE MODEL IN INDUSTRY 4.0

Industry 4.0 represents a new chapter in human development, enabled by extraordinary technology advances that are merging the physical, digital and biological worlds in ways that create both huge promise and potential peril. Industry 4.0 is about more than just technology-driven change; it is an opportunity to help everyone, including leaders, policymakers, and people from all income groups and nations, to harness converging technologies in order to create an inclusive, human-centered future. The real opportunity is to look beyond technology, and find ways to give the greatest number of people the ability to positively impact their families, organizations, and communities.

It is clear that Industry 4.0 has put pressure on businesses and governments to adjust business models and regulatory frameworks. Other challenges that need to be faced include a lack of data, inadequate skillsets, a lack of physical and digital infrastructure, and limited connectivity. This is especially true in developing countries. Several steps need to be taken at policy and business level in order to respond to these challenges, and boost the kind of inclusive and sustainable industrial activity that leads to higher employment and economic growth. These include the following:

JOINT ACTIONS ARE NEEDED IN ORDER TO SUCCEED

Governments, technology providers and manufacturers will have to cooperate in order to succeed in Industry 4.0 implementation. Collaboration of three parties would set required physical IT infrastructure, common rules, speed up exemplary projects, and pinpoint areas on which to focus R&D. The aforementioned factors would create a sound basis to successfully develop and implement Industry 4.0 solutions.

In light of the complexities and rapidly changing nature of emerging technologies, governance should be designed in such a way as to facilitate dialogue among all stakeholders. For regulators, dialogue with researchers at the cutting edge of developing these technologies is the only way to understand the potential future implications of new and highly-technical capabilities. For the scientific community within and across certain fields, a safe space is needed to coalesce around a common language and have an open discussion around both benefits and risks. At the same time, given that risks tend to cross borders, so must the dialogue on how to respond. And given the power of public opinion to shape regulatory responses, the general public must also be included in an open dialogue about the risks and opportunities of emerging technologies through carefully-managed communication strategies. Governance would be more stable and less likely either to overlook emerging threats or to stifle innovation unnecessarily, if the various stakeholders likely to be affected are involved in the thinking about potential regulatory regimes and given the knowledge to enable them to make informed decisions.

The absorption of an emerging technology into society is a complex, open-ended, unpredictable and oftentimes disruptive process. The long-term impact of the emerging technologies, their risks and side-effects can only be known through experience, and by that time the effects may be irreversible due to their magnitude or entrenchment into societal infrastructures or human culture. Thus, the political and regulatory actions have to include an element of anticipation, acting upon sociotechnical imaginaries, i.e., narratives that imagine the future of science, technology and society and their interactions. Sociotechnical imaginaries have real influence on research practice and policy, and they can be an object of governance. The production of sociotechnical imaginaries has been dominated by scientists, innovators and investors. Lately, however, many European governments, the European Union, and the USA have devoted efforts into "soft governance" in order to democratize the processes of agenda setting for research and innovation. Sociotechnical imaginaries can also be taken as early (and uncertain) signals and early warnings. They may warrant monitoring schemes. They may also be taken as worst-case scenarios that warrant regulation, such as with human cloning (prohibition) or xenotransplantation (comprehensive safety scheme).

While the desire to innovate leads emerging technologies to develop at a galloping pace, it is important to remember that they can lead to unpredictable results in the absence of clear regulations, laws and ethical guidelines in the relevant industries. This risk is increased by the fact that, unlike in the past, new technologies can be used by private individuals or non-state actors more easily. For example, while brain-computer interfaces – the possibility to interact with computers through thought alone – could benefit many patients, especially those paralyzed by spinal cord injuries or neurodegenerative diseases, these technologies can have damaging repercussions in the field of cyber security as hackers could easily find ways to access sensitive and critical data, hijack systems, or manipulate devices.

Some technologies might progress independently of political support. Nonetheless, good governance and examinations of dual-use risks and ethical considerations must still remain guiding posts at all times. Ultimately, how we approach the regulation of emerging technologies will inevitably have wider impact, not only for security and ethics, but for our definition of human dignity, solidarity and the equality of individuals.

GOVERNMENTS WILL HAVE TO RETHINK EDUCATION SYSTEMS

Industry 4.0 will create disruptions in the labour market by eliminating some of the low-skilled and/or repetitive jobs, at the same time increasing the shortage of talented and highly-skilled workers. Countries will have to rethink educational systems and encourage lifelong learning in order to make human resources competitive and succeed in the fourth industrial revolution.

Workers need help in building the right skills for the future

On the one hand, initial education, including early education, should equip all students with solid literacy, numeracy, and problem-solving abilities, but also with basic ICT skills and soft skills (e.g. the ability to communicate, work in teams, lead, self-organize, etc.). On the other hand, those already in the labour market need better opportunities to maintain their skills, up-skill and/or re-skill throughout their working lives.

Paradoxically, the low skilled are the most likely to be affected by the ongoing changes, but also the least likely to receive training. In fact, they typically encounter additional barriers to training due to their higher risk aversion, more severe credit constraints and reduced access to information. Moreover, employers are less likely to provide training to low skilled workers. Devising policy solutions that reduce barriers to training and encourage employers to provide training more widely is a crucial step in preventing further increases in inequality.

Policies to get people back to work and social protection measures should be updated to help people face disruptive changes and facilitate labour mobility

An effective activation framework should motivate jobseekers to: actively pursue employment; improve their employability (e.g. through training); and expand the set of opportunities to find and remain in appropriate jobs (e.g. through job-search assistance). Activation measures should be pro-active, taking into account the likely risk of job loss in different sectors and providing workers with adequate information and re-employment support ahead of potential job losses (e.g. during the notice period prior to a mass redundancy).

Welfare benefits should be designed to provide workers with adequate protection, while minimizing disincentives to work. One way to ensure that all workers are protected, no matter what industry or occupation they belong to is to link entitlements to individuals rather than to jobs, so that they are portable from one job to the next. Some countries are experimenting with the idea of replacing existing social protection systems with a basic income guarantee, i.e. an unconditional income transfer that would replace other forms of public transfers without any means testing or work requirement.

However, unless taxes are increased considerably, the level of such basic income is likely to be too low to lift people out of poverty. In addition, the switch from the current regimes to one with basic income would generate many losers, mainly among current beneficiaries of targeted benefits, raising doubts on the viability of the new system.

Dealing with structural change can be achieved more easily and effectively if social partners work closely together in a spirit of cooperation and mutual trust

Together, social partners can play an important role in: adapting labour market regulation, training and social security systems to new challenges; finding compromises between employers' need for flexibility and workers' desire for security; achieving an equitable distribution of productivity gains; and helping individuals displaced by technology or trade get back into work.[99]

Skills policies should strengthen initial learning; anticipate and respond better to changing skill needs; increase the use of workers' competences; and improve incentives for further learning along with greater recognition of MOOCs (massive open online courses) and OERs (open educational resources).

Being open-minded and making sure that one remains open to learning and using new skills is likely to be the best attitude to adopt.[100]

Diversifying education and credentialing system

Changes in educational and learning environments are necessary to help people stay employable in the labour force of the future. A central question about the future, then, is whether formal and informal learning structures will evolve to meet the changing needs of people who wish to fulfil the workplace expectations of the future.[101]

It is expected that the education marketplace – especially online learning platforms – would continue to change in an effort to accommodate the widespread needs. Some predict employers will step up their own efforts to train and retrain workers. Many foresee a significant number of self-teaching efforts by jobholders themselves as they take advantage of proliferating online opportunities.

It is expected that a new education and training ecosystem will emerge in which some job preparation functions are performed by formal educational institutions in fairly traditional classroom settings. Some elements are offered online, some are created by for-profit firms, some are free, some exploit augmented and virtual reality elements and gaming sensibilities, and a lot of real-time learning takes place in formats that job seekers pursue on their own.

The best education programmes will teach people how to be lifelong learners. Accordingly, alternative credentialing mechanisms will arise to assess and vouch for the skills people acquire along the way.

Nurturing unique human skills that AI is unable to replicate

These should be the skills developed and nurtured by education and training programmes to prepare people to work successfully alongside AI. Workers of the future will learn to deeply cultivate and exploit creativity, collaborative activity, abstract and systems thinking, complex communication, and the ability to thrive in diverse environments.[102]

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[99] https://www.oecd-forum.org/users/62601-andrea-salvatori-and-paolo-falco/posts/19894-poles-apart-how-technology-globalisation-have-affected-the-global-workforce

[100] http://www.oecd.org/els/emp/Skills-for-a-Digital-World.pdf; http://oecdinsights.org/2016/12/21/the-future-of-work-a-world-of-new-and-changing-skills/

[101] http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf; https://obamawhitehouse.archives.gov/blog/2016/12/20/artificial-intelligence-automation-and-economy; https://www.nap.edu/read/24649/chapter/1

[102] http://www.pewinternet.org/2017/05/03/the-future-of-jobs-and-jobs-training/

RELIABLE PHYSICAL AND DIGITAL INFRASTRUCTURE NEEDED

Reliable physical and digital infrastructure needs to be made widely accessible. At the moment 3.9 billion people – which corresponds to slightly more than half of the world's population – have no or minimal access to the internet. The huge digital divide between developed and developing regions needs to be addressed in order to reap the full benefits of Industry 4.0.

Both small and large enterprises need to find new, creative ways of organizing traditional manufacturing processes. They need to move from a "centralized" to a more "decentralized" production, in which a product might use intelligent machinery to communicate what needs to be done, instead of simply being "processed". Businesses and governments need to adapt to a new reality, in which workers collaborate and coexist with machines (co-bots), and in which new industry sectors, such as digital medicine and precision agriculture, emerge.

The cost of access to digital networks remains too high in some countries. There is also typically a gap between small and large companies in internet use, with a higher proportion of large businesses operating websites, selling online and accessing broadband, regardless of a country's level of income. Given the great potential ICT holds for small companies – notably in connecting with global value chains – and the predominant role that SMEs play in developing countries' economies, ensuring smaller companies can reap the benefits is critical. Similarly, there are significant digital divides between urban and rural areas. To make the most of digital innovations, and ensure that their development benefits all, a number of core conditions needs to be in place.

All individuals, businesses and governments need reliable and affordable access to digital networks and services. The priorities should be wide digital coverage and targeted measures to help disadvantaged people, companies, and regions. However, mere access to networks does not ensure effective use. Policy will need to help equip people with the skills they need, not just specific information technology skills, but also basic literacy, numeracy, problem-solving and socio-emotional skills. Complementary investments that help companies adjust their internal processes, and sound macroeconomic and regulatory conditions that support healthy business dynamics, are other critical ingredients.[103]

STANDARDISATION AND INTEROPERABILITY ISSUES NEED TO BE ADDRESSED

Another potential challenge related to Industry 4.0 is the issue of standardization, i.e. lack of interoperability among current operational technology systems. A fully functional digital ecosystem requires seamless data sharing between machines and other physical systems from different manufacturers. The drive towards seamless interoperability will be further complicated by the long lifespan of typical industrial equipment, which would require costly retrofitting or replacement to work with the latest technologies.

The key role of standardization for Industry 4.0 is reflected in the ongoing international initiatives as follows:

- Intensive work is being carried out at ISO/IEC and in various forums and consortia (e.g. W3C, IEEE). This work will include developing standards that ensure resource and environmental efficiency and effectiveness.
- A proposal for the neutral reference architecture model has been made in Germany: RAMI 4.0, with the objective of setting a comprehensive framework for the conceptual and structural design of Industry 4.0 systems; and the organization of standard resource and environmental data.

103 https://asia.nikkei.com/magazine/20170810/Viewpoints/Angel-Gurria-Making-the-digital-age-work-for-ASEAN?page=2

National standardization activities need to be harmonized with those at international level. This would include issues such as identifying which standards' organizations and which standards' projects are relevant, as well as who is to be responsible for what. SMEs need to be more involved in the standardization process and some pilot cases should be initiated and supported. There should also be an agreement on a uniform reference architecture model for structuring further standards work. Flexible standardization combined with open source implementation should be used to ensure further strategic, conceptual, and organizational developments. An interoperable and safe IT architecture model, based on international standards, should be set up. Reaching an agreement on Industry 4.0 standards is also important for the secure exchange and storage of big data, security and privacy, as well as for ethics guiding the relation between machinery and the workforce.

MEASURES OF TECHNOLOGY UPGRADING AND INCLUSIVENESS IN INDUSTRY 4.0

There is a dearth of empirical studies which explore various dimensions of technology upgrading of emerging and transition economies. Studies that are based on R&D and patent data dominate. Also, the dominant matrices of relevance for technology upgrading, like the Global Innovation Index, the EU Innovation Union Scoreboard or the Global Competitiveness Index, capture only a part of the complexity of technology upgrading. These matrices do not capture a range of facets of technology activities which are present in middle-income economies as they relate, for instance, to production capability, firm organizational capabilities, low value-added activities in high-tech sectors, diffusion of management practices, engineering activities, etc.

WEF INCLUSIVENESS INDEX

Based on GDP and other measures of well-being, humanity has never been better off. The number of people living in absolute poverty has fallen fourfold since 1980. Fewer people die today from violence or conflict than any prior era. Individuals generally live longer and more comfortably than any prior generation. Yet inequality within countries is rising, and in some cases, has hit historic highs. Incomes have stagnated for the middle class in advanced economies. Recent surveys indicate that trust in key social institutions – business, government, media and even non-governmental organizations – has been falling.[104]

Too little has been done in recent decades in too many societies to address the human impact of technological disruption, international economic integration, domestic deregulation and privatization, and migration. The Fourth Industrial Revolution threatens now to exacerbate this social frustration. AI threatens to create a substantial new disruption to labour markets, testing social cohesion still further. If public policy stakeholders want to ensure that the increased prosperity and opportunity enabled by technology and globalization are widely diffused, they will need to place social inclusion at the heart of economic policy.[105]

The WEF has issued a new Inclusive Growth and Development Report defining 15 areas of domestic policy and institutional strength that determine how well economies are able to translate economic growth into broad-based improvement in living standards. Each is a potential source of both stronger growth and wider social inclusion. Together, they constitute the implicit income distribution system of modern market economies. To help governments rebalance their policy priorities, the WEF has created an alternative measure of national economic performance - the Inclusive Development Index. Rather than simply measure an economy's annual production of goods and services (GDP), this new global index

[104] https://www.weforum.org/agenda/2017/06/toward-a-human-centered-model-of-economic-growth/
[105] Ibid.

combines GDP with 11 additional measures of the extent to which an economy is generating broad-based and sustainable progress in living standards.[106]

The Fourth Industrial Revolution will require governments to move beyond reactive measures aimed at efficiency and short-term growth, to proactively chart a course that mitigates the social risks of new technologies and strengthens the positive feedback between growth and inclusion in an economy, through a stronger emphasis on certain key domestic institutions. A new approach to technology cooperation and structural economic reform is what is required to place people and their living standards at the centre of economic policy.[107]

INDUSTRY 4.0 AND SUSTAINABILITY PERFORMANCE INDICATORS

Policymakers should use "resource-miser" indicators, such as value-per-weight and labour-input-per-weight ratios, rather than GDP. Policies should focus on performance, not hardware; internalization of external costs, such as emissions and pollution, should be rewarded. IoT and Industry 4.0 will boost such a shift, but also demand a policy review that considers questions of ownership and liability of data and goods.[108] Moving towards 2030, there will be growing product/service/technology design, development and innovation opportunities driven by increasing sustainability considerations. For example, there will be new policy initiatives focused on product circularity (e.g. repair, refurbishment, remanufacturing,) leading to opportunities for, for example, smarter materials that enable dis-assembly ("green industries"); implementation of climate change and air pollution policies driving the development of technologies to store solar power and new monitoring and control technologies related to air pollution ("green industries"); and re-utilization of waste materials in new products.[109]

A concept for industry 4.0 that includes the sustainability and lifestyle perspective needs to be developed. These should form an integral part of the strategy for Industry 4.0 and not be regarded as a by-product. A participative approach, which includes various stakeholders from different industries but also from research and civil society, will help create a larger impact and develop sustainable Industry 4.0 solutions. There is a need for more cross-sector collaboration in order to develop a concept for Industry 4.0 that includes the sustainability and the sustainable lifestyle perspective. There are various unresolved issues around data including ownership, clear and transparent handling, privacy, and security. There is an overall need to better understand the challenges and risks that new technologies have on society as a whole and how they will shape our lives in the future. The public policy creators need also to understand that the Industry 4.0 consumers are turning into prosumers and creators. This changing role may be a shift to develop more sustainable lifestyles and will influence industry players, creating new opportunities for their products, services, and business models. [110]

THE ROLE OF INTERNATIONAL ORGANIZATIONS AND UNIDO

The role of UNIDO and other international organizations in assisting developing countries to build their harvesting capabilities for Industry 4.0 is instrumental. In the case of UNIDO, this includes its capacity to serve as a knowledge-sharing and project development platform, its ability to enable transformation and leapfrogging processes, and its experience in establishing partnerships with the private sector.

UNIDO stands ready to work with international fora, governments, and businesses to realize the potential that Industry 4.0 and ICTs have for the achievement of the SDGs. UNIDO and ITU recently made a commitment to strengthen collaboration in the areas of Industry 4.0, digital transformation and

[106] Ibid.
[107] Ibid.
[108] https://www.nature.com/news/the-circular-economy-1.19594
[109] https://curtiswyss.com/article/article/9
[110] http://ten.scp-centre.org/wp-content/uploads/2016/07/workstudio_4.pdf

broadband infrastructure, capacity building, and the development of new international ICT standards in order to connect the unconnected, and to enable people worldwide to reap the benefits of the fourth industrial revolution.[111]

UNIDO can be instrumental in assisting developing countries to harvest the benefits of Industry 4.0 by:

- Organizing awareness-building knowledge events about the impacts of Industry 4.0 on inclusive and sustainable industrial development (ISID). Specific and well-designed workshops are needed to better understand the key essence of Industry 4.0 and the core technologies that are available, affordable, transferable, and also make sense for the respective markets. Automation should be evaluated from a societal, environmental, and ethical aspect;
- Assisting developing countries in formulating innovation management standards for leapfrogging into Industry 4.0. These guiding frameworks would be relevant for all types of organizations, including SMEs;
- Assisting in the establishment of multi-stakeholder knowledge-sharing platforms to create awareness on Industry 4.0 opportunities and challenges for pursuing ISID in developing countries;
- Sharing available tools and methods for innovation management;
- Designing training curricula for new workforce skills requirements;
- Exploring methods and best practices to support SMEs' digital transformation and bridging the gender digital divide;
- Offering technical assistance on capacity building and technology transfer and absorption;
- Building awareness among policymakers and industry associations on the issues of new infrastructure, standards and policies that need to be developed or mainstreamed to correspond to the new technologies.

THE WAY FORWARD

The governance regimes that could mitigate the risks associated with the abuse of emerging technologies, from formal regulations through private codes of practice to cultural norms, present a fundamental challenge that has the following main aspects:

Insufficiency of the current regulatory framework

The current regulatory framework is insufficient. Regulations are comprehensive in some specific areas of emerging technology, while weak or non-existent in others, even if conceptually the areas are similar. Consider the example of two kinds of self-flying airplane: the use of autopilot on commercial airplanes has long been tightly regulated, whereas no satisfactory national and international policies have yet been defined for the use of drones.

Spatial issues with respect to the regulatory framework: Where to regulate?

Spatial issues include where to regulate, whether at the national or international level. The latter is further complicated by the need to translate regulations into rules that can be implemented nationally to be fully enforceable. Undesirable consequences have the scope to cross borders, but cultural attitudes differ widely. For example, public attitudes are more accepting of genetically-modified produce in the United States than the European Union; the EU has institutionalized the precautionary principle, while there is more faith in the US that a "technological fix" will be available for most challenges. Safeguards, regulations and governance need to combine consistency across countries with the strength to address the worldwide impacts of potential risks and the flexibility to deal with different cultural preferences.

[111] http://news.itu.int/ict-infrastructure-crucial-achieving-sdgs-era-fourth-industrial-revolution/

Time issues with respect to the regulatory framework: When to regulate?

Decisions need to be taken today for technologies that have a highly uncertain future path, the consequences of which will be visible only in the long term. Regulate too heavily at an early stage and a technology may thus fail to develop; adopt a laissez-faire approach for too long, and rapid developments may have irrevocable consequences. Different kinds of regulatory oversight may be needed at different stages: when the scientific research is being conducted, when the technology is being developed, and when the technology is being applied. At the same time, the natural tendency to think short term in policymaking needs to be overcome. Compared with internet technology, notably the physical and life sciences have longer cycles of development and need governance regimes to take a long-term approach. History shows that it can take a long time to reach international agreements on emerging threats – 60 years for bio-weapons, 80 years for chemical weapons – so it is never too early to start discussions.

Who regulates?

The question of who regulates becomes significant when it is unclear where a new device fits into the allocation of responsibility across existing regulatory bodies. This is an increasingly difficult issue as innovations become more interdisciplinary and technologies converge. Examples include Google Glass, autonomous cars and M-healthcare: while all rely on internet standards, they also have ramifications in other spheres. Often no mechanism exists for deciding which existing regulatory body, if any, should take responsibility for an emerging technology. Striking a balance between precaution and innovation is an overall dilemma. Often potentially-beneficial innovations cannot be tested without some degree of risk. For example, a new organism may escape into the environment and cause damage. Weighing risks against benefits involves attempting to anticipate the issues of tomorrow and deciding how to allocate scarce regulatory resources among highly technical fields.

When a gap in governance exists, it may create a vacuum of power that could be filled by religious movements and action groups exerting more influence and potentially stifling innovation. With that risk in mind, industry players in emerging technologies where institutions are weak or non-existent may seek to respond to a governance gap by demonstrating their responsibility through self-regulating – as the "biohacker" community is attempting in synthetic biology. Another example of a private player highlighting a governance gap is the way Facebook effectively exerts regulatory power in online identity management and censorship, through policies such as forcing users to display their real names and removing images that it believes the majority of users might find offensive.

A fundamental question pertains to societal, economic and ethical implications. While emerging technologies imply the long-term possibility of a world of abundance, many countries are struggling with unemployment and underemployment, and even a temporary adjustment due to technological advancement could undermine social stability. Governance regimes for emerging technologies are strongly influenced by the perceptions, opinions and values of society – whether people are more enthusiastic about a technology's potential benefits than fearful about its risks. This is very domain-related, and not always rational or proportional: it can lead to some technologies being over-regulated and others under-regulated. Many biological technologies that touch on beliefs about religion and human life, for example, are regulated relatively stringently, as evidenced by the worldwide prohibition on human cloning. On the other hand, the human propensity to anthropomorphize means that robotic prototypes in some empathic form of assistive technology (such as Paro, a baby harp seal lookalike robot assisting in the care of people with dementia and other health problems) easily capture public sympathy, which may ease safety, ethical or legal concerns. In other areas, such as lethal autonomous weapons, it would probably be easier to get close to unanimous public support to prohibit them as has been the case for landmines. As such, these societal implications constitute an important risk in themselves, as it is difficult to anticipate their impact on the use and path of emerging technologies.

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