



# THE FUTURE OF MANUFACTURING

BUILDING THE FUTURE THROUGH AGILITY AND INNOVATION

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## BUILDING THE FUTURE THROUGH AGILITY AND INNOVATION

May 2016

PREPARED BY:

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## INTRODUCTION



*Technology is disrupting our lives and changing how the world functions. The manufacturing industry is undergoing massive transformation, becoming more agile and adaptable as it responds to the demands of the world's growing population.*

**The Future of Manufacturing** presents Future iQ's analysis and insights into key trends that are impacting the global manufacturing sector. Manufacturing products and processes have witnessed a near-constant evolution over the last three hundred years. Beginning with the first organized mass production of textiles in Europe in the early eighteenth century to the currently developing innovations, such as the Internet of Things and robotics, the global economy has become increasingly defined by the trade of goods produced in factories of all sizes. Success in the development of an advanced manufacturing sector has been synonymous with a nation or state ascending to "first-world" status, but is now even more critical to maintain that standing.

Rapid globalization has developed complex global networks, allowing companies and people to design, source materials and manufacture products from virtually anywhere, while providing products to customers almost anywhere. **The Future of Manufacturing** examines many of these trends and describes the ways in which they are changing companies and communities throughout the world, and how they may shape manufacturing industries in the long-term.

Future iQ believes that manufacturing is on the verge of a fourth industrial revolution driven by a series of shifts in consumer driven markets, technology, workforce and sustainability. To prosper, manufacturers, and associated economies must continue to grow and adapt at ever increasing speed and intensity. Many of the innovative processes and practices outlined in this report will prove pivotal to future success.



**David Beurle**

CEO  
Future iQ  
May 2016

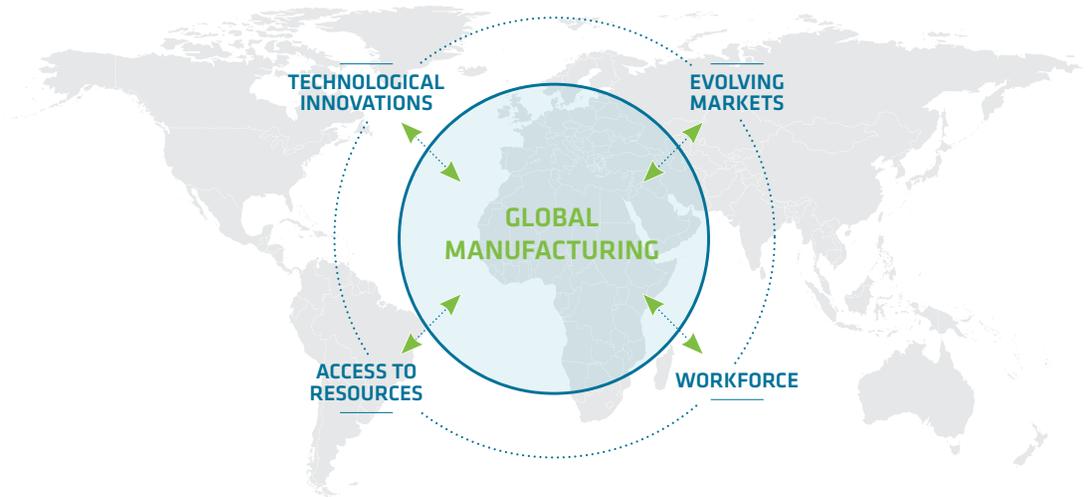


# FORCES OF CHANGE

*A range of powerful mechanisms is reshaping world of manufacturing, as well as where and how products will be made.*

## 2.0 FORCES OF CHANGE

Manufacturing is a large part of the world economy. It is estimated that more than one in every four global jobs has a first or second-order connection to manufacturing processes.<sup>1</sup> It also accounts for 32 percent of all traded goods,<sup>2</sup> and 16% of the global GDP.<sup>3</sup> The industry is undergoing a massive transformation which is changing how and where things are made, as well as what is manufactured and what materials things are made from.



**The Future of Manufacturing** explores an array of catalysts that we believe are driving change in the sector. While this list is not comprehensive, the material presented in this publication represents those trends that Future iQ believes are currently having the most impact in shifting the industry, and are most likely to transform manufacturing into the future. This report draws on research from a wide variety of sources to explore the trends, challenges and opportunities shaping the manufacturing industry.

# SMART MANUFACTURING - THE TECHNOLOGY REVOLUTION

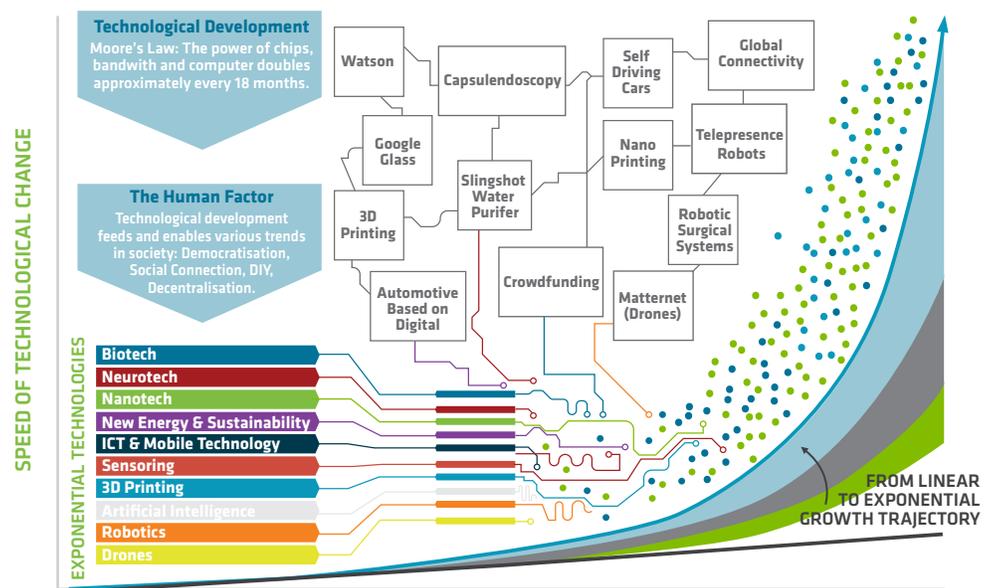


How will new manufacturing technologies and processes transform the future of production?

## 2.1 SMART MANUFACTURING - THE TECHNOLOGY REVOLUTION

The Future of Manufacturing can be defined both by what is produced and how it is made. The future of production technology is being shaped by a number of innovations that will impact the industry in the next ten years.

The most prominent among these are the Internet of Things, additive, agile and modular manufacturing, nanotechnology, and sustainability. These advances are changing the way we use materials, stay connected, and the speed of production. All are focused on shrinking the distance between design and production, and from plant to customer. These innovations are being implemented globally at all scales, thereby changing the face of manufacturing in a rapid and profound way.



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

**“Manufacturing in 2050 will look very different from today, and will be virtually unrecognisable from that of 30 years ago. Successful firms will be capable of rapidly adapting their physical and intellectual infrastructures to exploit changes in technology as manufacturing becomes faster, more responsive to changing global markets and closer to customers.”**

*Foresight. The Future of Manufacturing: A new era of opportunity and challenge for the UK. The Government Of ce for Science, London, 2013.*



# SMART MANUFACTURING - THE TECHNOLOGY REVOLUTION

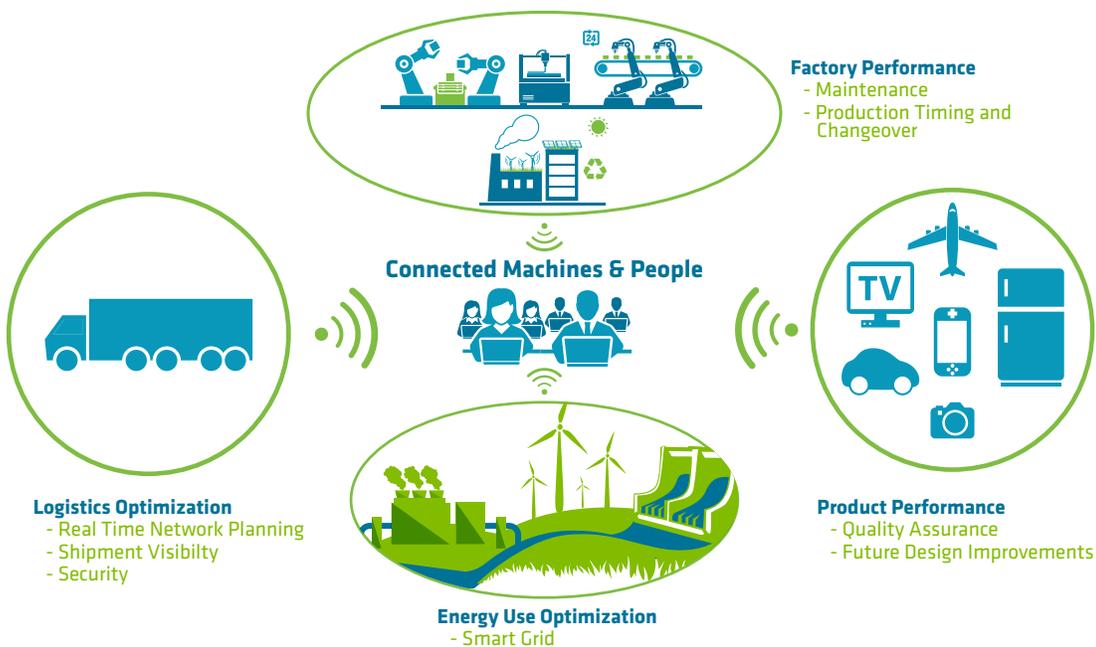


*The Internet of Things and technological developments are rapidly increasing digital connectedness. How is this transforming the manufacturing industry?*



## 2.1.1 INDUSTRIAL INTERNET OF THINGS

Today, there is estimated to be between 8 and 16 billion objects connected to the Internet of Things, which is expected to increase to between 25 and 100 billion by 2020.<sup>1</sup> This increase is expected to accelerate into the future, and will allow businesses to establish global networks through sensors and other devices that incorporate their machinery, warehousing systems and production facilities as Cyber-Physical Systems (CPS) in which facilities are able to exchange information and control each other independently.<sup>2</sup>



The evolution of these systems will allow vertical networking of production systems to be integrated with an individualized and customer-specific production operation. Additionally, horizontal integration will create a new global value-creation network, including business partners and customers, allowing new business and cooperation models across countries and continents.<sup>3</sup> These advances will affect all areas of manufacturing, including, maintenance, waste management, energy efficiency, supply and demand management, logistics, production, marketing, lifecycle management, and product improvements, and will facilitate real-time optimization, transparency and adaptability.

*“...the Internet of Things (IoT) is not merely about creating savings within current industry models. It’s about upending old models entirely, creating new services and new products. There is no one sector where the Internet of Things is making the biggest impact; it will disrupt every industry imaginable, including agriculture, energy, security, disaster management, and healthcare, just to name a few.”*

*Daniel Burrus, Wired Magazine, November, 2014.*

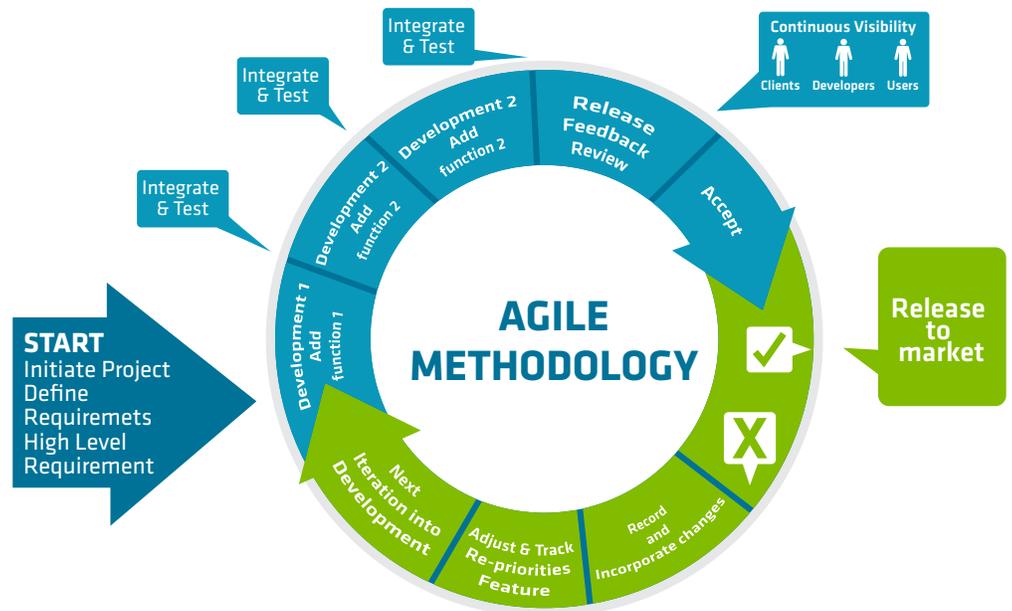
# SMART MANUFACTURING - THE TECHNOLOGY REVOLUTION



Manufacturing developments in the previous 30 years were driven by improvements in efficiency and productivity. How will it change with a shift to the driving forces being end user requirements and adaptability?

## 2.1.2 AGILE MANUFACTURING

Agile manufacturing, as exemplified by Six Sigma and other continuous efficiency-based improvement methodologies, represents a next generation advancement beyond the concept of Lean manufacturing that has dominated much of the discourse on manufacturing productivity. The Lean approach has created efficiency gains, and American manufacturing firms in the last decade have increased output by more than 23 percent, and similar gains have been observed globally.<sup>4</sup> However, the emergence of new technologies is creating a wave of massive transformation in the manufacturing industry, and the impetus for change is coming from the marketplace, demanding fast product improvements and customization.



Source: All Management PowerPoint Diagrams and Slides. 2016.

Successful firms will be those that generate rapid and continuous innovation with a focus on providing value to the customer. Manufacturers using the traditional process of slow-moving, multi-year product cycles will find it difficult to adapt to the rapidly shifting marketplace.<sup>5</sup> Agile manufacturing is focused on the goal of continuously delivering increasing value to customers and delivering it faster.

*“Many established manufacturers will find themselves flat-footed and ill-prepared for the transformation. That’s because traditional manufacturing is typically slow to innovate... traditional manufacturing processes are inherently slow because processes are expensive to change. For instance, if engineers want to redesign a car door, they often need to wait years to pay off the existing multi-million door mold before making a new one.”*

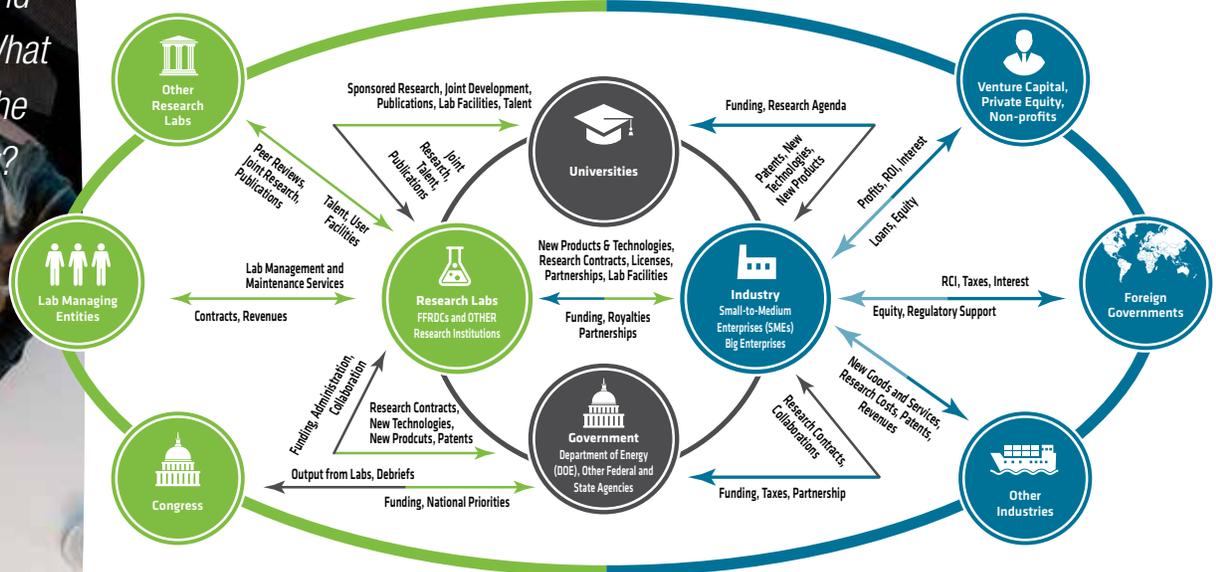
Steve Denning, Forbes Magazine, August, 2012.

# SMART MANUFACTURING - THE TECHNOLOGY REVOLUTION

— (?) —  
*The Internet of Things, new technology and development of an open source mindset are shifting how ideas and innovations are shared. What are the implications in the manufacturing industry?*

## 2.1.3 INNOVATION DIFFUSION

Manufacturing growth depends on the effective delivery of new ideas and innovations to market, as well as the incorporation of innovations within the manufacturing processes. Innovations spread through direct replication or improvements upon the idea. A change in the collective mindset to a more open source perspective has allowed new partnerships to develop, and manufacturers, suppliers, partner companies, and customers now frequently collaborate and share resources to reduce the cost burden.<sup>6</sup>



Source: Advanced Technology Initiative, Deloitte and the Council on Competitiveness

Government and institutional resources further support these collaboration networks with funding, infrastructure and expertise (e.g. EU targets 3% GDP public and private R&D investment by 2020<sup>7</sup>; Canada provides funding for 48 Business-Led Networks of Centres of Excellence<sup>8</sup>). New technologies such as additive manufacturing, allow prototyping and manufacturing at a smaller scale, and the industrial Internet of Things further facilitates the sharing of ideas and solutions.<sup>9</sup> Intellectual property rights continue to evolve in many countries, but the global trend is towards further liberalization and information sharing through private-sector partnerships and a globalized knowledge-based, networked world economy.<sup>10</sup> Through the combination of these developments, the future of manufacturing will see the pace innovation and diffusion accelerate.

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

*Secretary Penny Pritzler, U.S. Department of Commerce, March, 2015.*

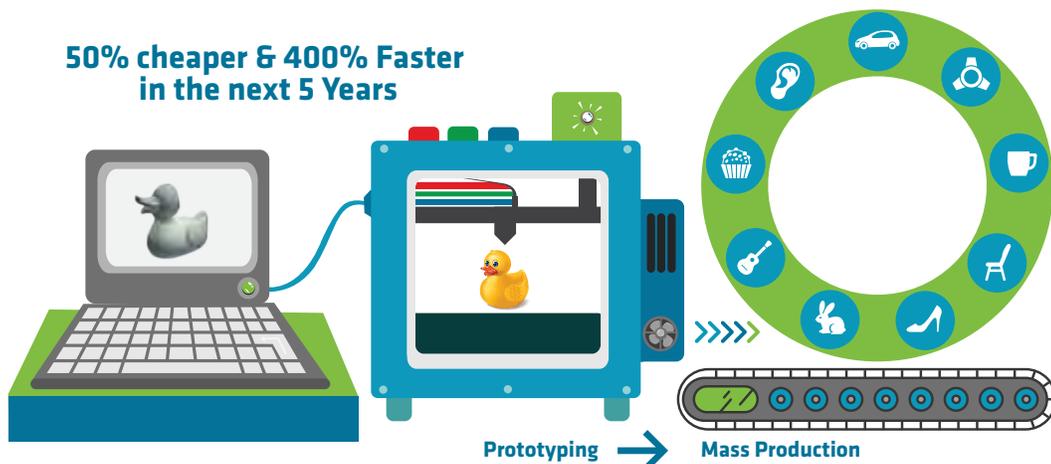
# SMART MANUFACTURING - THE TECHNOLOGY REVOLUTION



*New processes are being developed in manufacturing. How will new technologies such as additive manufacturing (3-D printing) revolutionize the way we make things?*

## 2.1.4 ADDITIVE MANUFACTURING

Additive manufacturing is the process of building components and products layer-by-layer rather than cutting them from larger stock or casting them in pre-formed molds. This leads to decreases in weight and variability, coupled with increases in strength and speed of production.<sup>11</sup> The future of manufacturing will see this technology proliferate in scale and scope, moving from prototyping and design to full-scale production. The worldwide 3-D printing industry is expected to grow from \$3.07B in revenue in 2013 to \$12.8B by 2018, and exceed \$21B in worldwide revenue by 2020.<sup>12</sup> What is currently used for the production of small-batch or complex components will become more ubiquitous, sparking creativity and spurring increased productivity.



Source: Siemens. 2016. 3-D Printing: Facts and Forecast.

Additive manufacturing is now accepted as an industry standard for rapid prototyping. Companies in the aerospace and electronics industries are among the most advanced in using processes to shape metal products.<sup>13</sup> As our understanding of nanotechnology increases, additive processes will be of critical importance in applications ranging from construction to pharmaceuticals. The United States and Germany are currently among the world leaders in the development of large-scale additive processes. The cost of entry into additive manufacturing has decreased by more than 30% since 2010.<sup>14</sup> Continued cost decreases will make the technology both more attractive and more widely adopted globally.

***“...while 3-D printing for consumers and small entrepreneurs has received a great deal of publicity, it is in manufacturing where the technology could have its most significant commercial impact.”***

*Martin LaMonica, MIT Technology Review, 2013.*

# SMART MANUFACTURING - THE TECHNOLOGY REVOLUTION



As new technology, such as additive manufacturing, is developing, how are materials for use in manufacturing evolving?

## 2.1.5 MATERIALS SCIENCE

Development and discovery of new materials and processes is another critical evolution in manufacturing processes. Materials science is creating new products from the macro to the molecular level, including nano crystals, nano coatings, electric ink, thermoelectric materials, and biologically inspired materials such as plastics and fungal foams.<sup>15</sup> Global demand for nanomaterials (e.g. metal oxide, metals, chemicals and polymers, nanotubes) is anticipated to surpass US\$ 5 billion in revenues by 2016, fueled by demand from construction and energy storage industries, and future growth is expected in the development of materials for food packaging, aircraft structures, and healthcare.<sup>16</sup>

### EXAMPLES OF MODERN - DAY APPLICATIONS EMPLOYING NANOTECHNOLOGY



Computer Chips



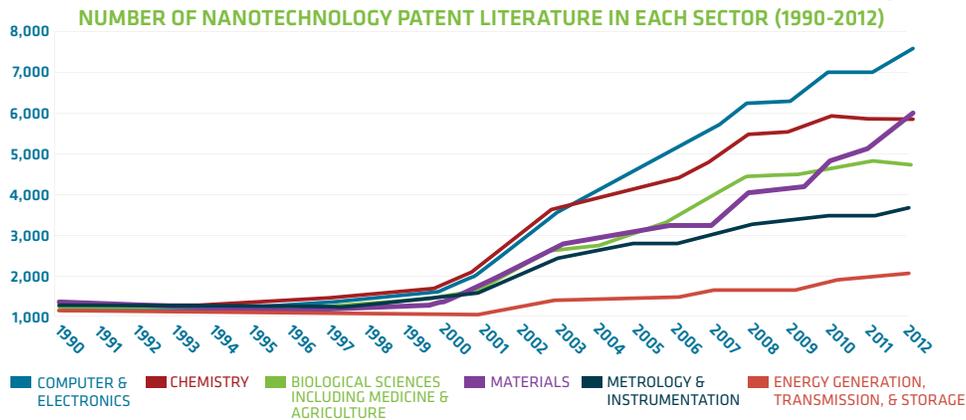
Water Filtration Systems



Solar Panels



Food containers that minimize growth of bacteria in order to keep food fresher longer



Source: Column Five, *Nanotechnology Patents in the United States and Beyond*.

Individual atoms and molecules can be manipulated with nanotechnology and rearranged to create useful materials, devices, and systems. The impact of nanotechnology on society has been compared to the invention of electricity or plastic—it is transforming nearly everything we use today. Products can be made with fewer imperfections and more durability, drugs can be more efficient and have fewer side effects, and energy sources can be cleaner and more cost-effective.<sup>17</sup>

**“A policy paper by the National Academy of Agricultural Sciences (NAAS) describes nanotechnology as modern history’s “sixth revolutionary technology,” following the industrial revolution in the mid-1700s, nuclear energy revolution in the 1940s, green revolution in the 1960s, information technology revolution in the 1980s, and biotechnology revolution in the 1990s.”**

*Maria Doyle, Nanotechnology Gains Momentum in Manufacturing.*

*Product Lifecycle Report, August 18, 2014.*



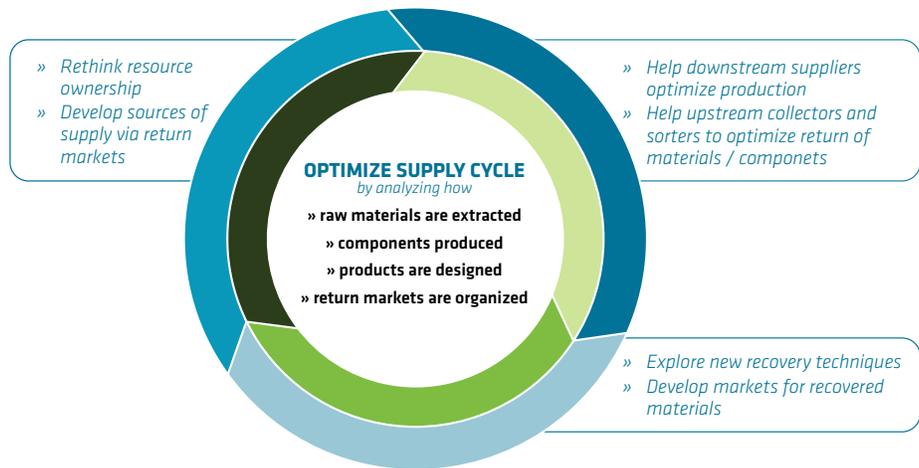
# ACCESS TO RESOURCES



How will we supply manufactured goods to 9 billion people without exhausting our supply of natural resources and raw materials?

## 2.2 ACCESS TO RESOURCES

Over the next 20 years, the middle class is expected to increase by an additional 3 billion people, to nearly 5 billion, primarily within the developing world.<sup>1</sup> Feeding the demand of these growing markets will place additional strain on already limited resources, such as land, water, energy, minerals, oil and biomass. As these resources become scarce, competition between companies and nations increases and access becomes more volatile and costly.



Source: S. Mohr, K. Somers, S. Swartz, and H. Vanthourmout. 2012. *Manufacturing Resource Productivity*. McKinsey & Company.

Traditionally, resource use in manufacturing has been a linear process of cradle to grave. However, predictions of passing peak production and looming shortages of many raw materials, such as oil and rare earth metals, as well as increasing costs of sourcing or developing “new” resources, are forcing the industry to examine its manufacturing processes and improve resource productivity. Shifting from a linear path of production to a circular process will improve resource productivity, and allow goods to be manufactured while maximizing the efficient use and reuse of materials and energy, and minimizing the costs, as well as the environmental and social impacts of resource extraction and processing.

***“They [manufacturers] will have to dedicate as much effort to optimizing resources in the future as they did to lean and other improvement initiatives in the past, while at the same time rethinking their business models to capture the value residing in resource ownership. If they get it right, the effort will enable them to increase the stability of supply and manage their costs while developing new products—and even lines of business—that generate sustainable bottom-line value.”***

*S. Mohr, K. Somers, S. Swartz, and H. Vanthourmout. Manufacturing Resource Productivity. McKinsey Quarterly, 2012.*

# ACCESS TO RESOURCES



As the production of many resources passes global peak production, will manufacturers respond to future scarcity with new innovations?

## 2.2.1 BEYOND PEAK, WHEN RESOURCES BECOME CONSTRAINTS

With growing consumer demand, there is increasing pressure on the raw materials required for manufacturing. By 2050, up to three times the minerals, ores, fossil fuels and biomass per year could be consumed (140 billion tons).<sup>2</sup> Scientists have been speculating over the past thirty years as to whether a number of mineral sources ranging from petroleum to bauxite are not inexhaustible, and have reached “peak” production.<sup>3</sup> Surpassing peak availability, combined with increasing demands is resulting in increased prices, stockpiling and volatility, but also spurring technological innovation.



### IF DEMAND GROWS...

Some key resources will be exhausted more quickly if predicted new technologies appear and the population grows.

Source: New Scientist.

Efficiency of use, materials sciences, searching for alternatives to replace diminishing resources, and reclaiming and recycling from products that are past their useful life are all part of the solutions to shortages of past-Peak materials.<sup>4</sup> Those companies and nations that can manufacture their products with fewer inputs from virgin sources, will be more resilient to the volatility of resource availability.<sup>5</sup>

*“... the size of today’s challenge should not be underestimated as we enter an era of unprecedented growth in emerging markets. Our recently completed research on the supply- and-demand outlook for energy, food, steel, and water suggests that without a step change in resource productivity and a technology-enhanced expansion of supply, the world could be entering an era of high and volatile resource prices. Nothing less than a resource revolution is needed.”*

*R. Dobbs, J. Oppenheim, and F. Thompson. Mobilizing for a resource revolution. McKinsey Quarterly, January, 2012.*

## ACCESS TO RESOURCES

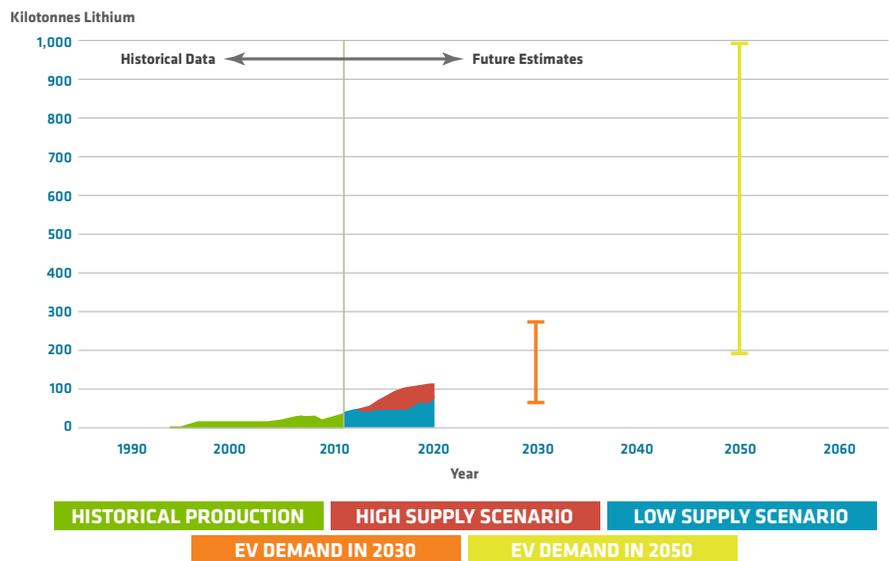


How will manufacturers respond to diminishing availability and increasing costs, as demands on many scarce resources, such as rare earth minerals exceeds available sources?

### 2.2.2 CHASING SCARCE MATERIALS

The increasing global scarcity of rare earth minerals is of particular concern, due to the limited number of supplying regions, and their growing importance in technological innovations.<sup>3</sup> Extraction of many of these resources has slowed over the past decade in response to global economic fluctuations, political uncertainty in countries with many of the largest reserves, and environmental concerns.<sup>6</sup> However, emerging economies are growing, such that demand of rare earth minerals could be up to 5 times what it is today by 2050, which will be impossible to meet solely with existing resource reserves.<sup>7</sup>

#### A COMPARISON OF HISTORICAL LITHIUM PRODUCTION, FUTURE SUPPLY ESTIMATES AND FUTURE ELECTRIC VEHICLE (EV) DEMAND ESTIMATES



Source: Els, F. 2014. Giant gap between future lithium supply. Mining.com.

To address shortages of scarce raw materials, a two pronged solution is needed, reclamation and reuse of materials from products that are past their useful life,<sup>4</sup> and seeking new sources. As global prices for minerals, ranging from europium to yttrium, have reached historic highs, a mini-revolution in mining technology is occurring, for example, firms such as Nautilus Minerals have turned to the floor of the world's oceans as a potential source of minerals.<sup>5</sup> The extraction technology remains in its infant stages but it has the potential to increase availability, and to slice world prices for many of the most scarce minerals by as much as 50 percent from current highs.

**"In an economy where the use of rare earths is growing, you cannot recycle your way out of trouble. Eventually, there will have to be new mines."**

*Alex King, Critical Materials Institute, 2016.*

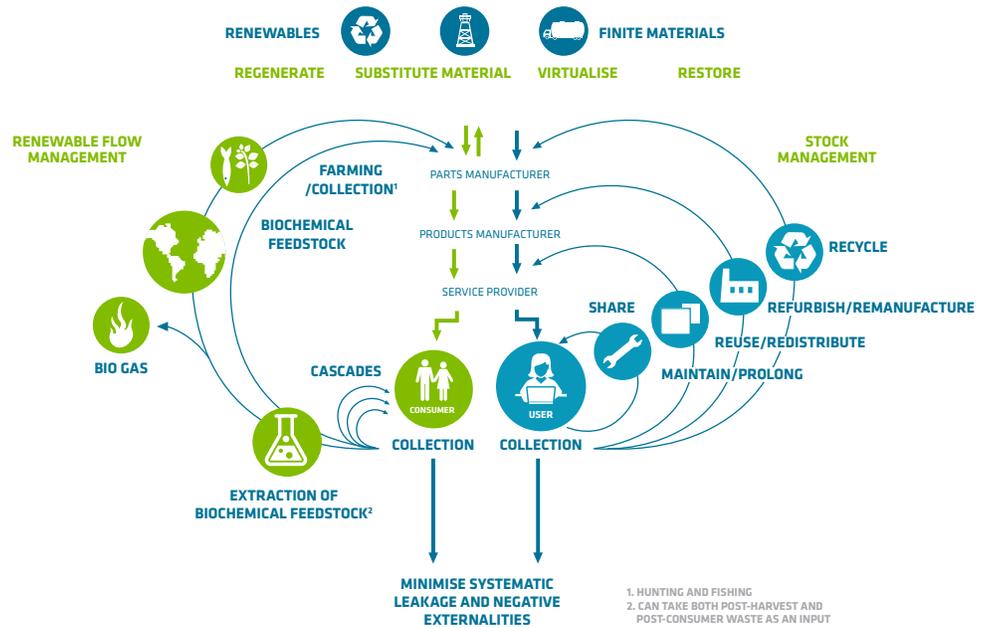
# ACCESS TO RESOURCES



Is the potential of a circular economy the solution to the predicted raw materials shortages?

## 2.2.3 CLOSING THE LOOP

In 2015, more than 1.6 billion tons of steel was produced and utilized in 28 percent of all manufactured goods. This represents a 16 percent increase since 2010, while market prices have increased by more than 48 percent.<sup>9</sup> Similar increases in production and costs have been observed in the production of aluminium, lumber and wood products, as well as other mined and harvested commodities. As the availability of many new or “virgin” sources of materials either become scarce or economically infeasible to extract, the industry is seeing recycling of post-consumer sources as a way of reclaiming raw materials in a circular economy model.



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

The circular economy incorporates the sustainability concepts of recycling, closed loop, cradle-to-cradle, and zero waste, and is built on four principles: designing products with their entire life cycles in mind; maximizing product life cycles; recycling materials from end-of-life products; and reusing materials across diverse industries and value chains.<sup>10</sup> This strategy increases resource productivity, allowing increased production, with cost savings. What was formerly the domain of aluminium cans and plastic milk jugs will become common in manufacturing of metals, woods, and even consumer electronics.<sup>11</sup>

**“A circular economy is one that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times.”**

Ellen MacArthur Foundation

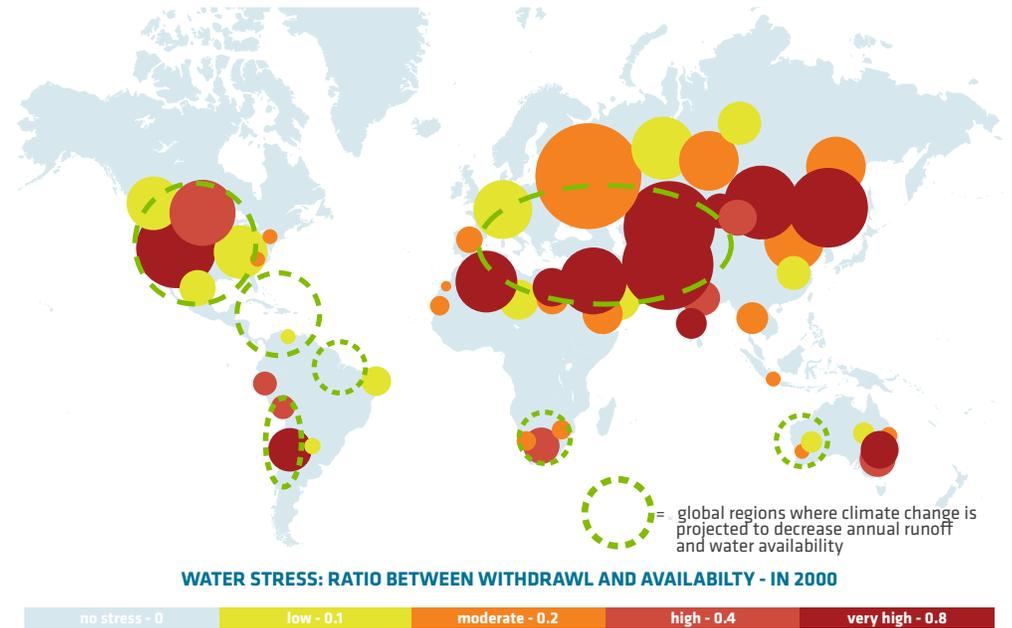
# ACCESS TO RESOURCES



How can manufacturing adapt to use less water, while meeting growing demands for goods?

## 2.2.4 GROWING IMPORTANCE OF WATER

Global water demand is projected to increase by 55% by 2050, due to growing demand from manufacturing (+400%), thermal electricity generation (+140%) and domestic use (+130%).<sup>12</sup> With water shortages projected in many parts of the globe, particularly in regions where populations and manufacturing are both expected to grow, competition between users will increase costs, and create volatility in water availability.



Source: Land Commodities Research, 2014.

To ensure consistent water availability, manufacturers must look at opportunities to reduce overall water use, reclaim and recycle water within their own systems and processes, and, where available and of a suitable quality, to use waste water from outside processes or sources (e.g. treated wastewater or outputs from other manufacturing processes). Where it is possible to reclaim, treat and reuse water repeatedly, there will be the best possibilities to maintain consistent, quality supplies for all water users.

***“Around the world, cities, farmers, industries, energy suppliers, and ecosystems are increasingly competing for their daily water needs. Without proper water management, the costs of this situation can be high – not just financially, but also in terms of lost opportunities, compromised health and environmental damage.”***

*OECD. Environmental Outlook to 2050: The Consequences of Inaction, 2012.*

# ACCESS TO RESOURCES

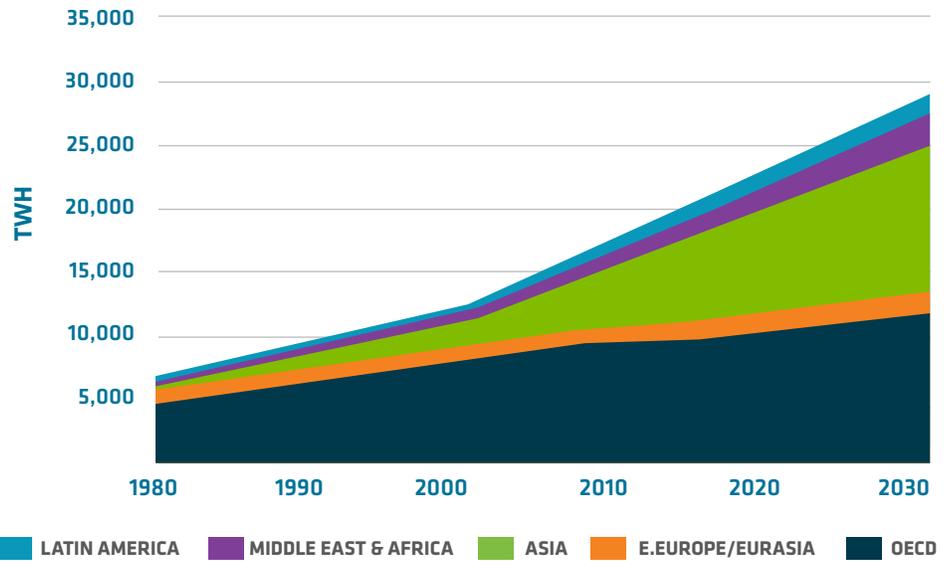


As energy demand soars and prices rise, how will the manufacturing industry adapt?

## 2.2.5 ENERGY DEMANDS AND SHORTAGES

World energy demand is expected to grow by 50 percent by 2030 according to the International Energy Agency.<sup>13</sup> Demand and cost of energy will only continue to increase with future population growth and emerging economies. Economic development tends to be tied to growth in manufacturing, and energy use is growing, especially in the industrial sector. Manufacturing energy consumption currently accounts for close to 1/3 of total energy consumption worldwide, and is expected to grow 50% by 2035, with 70% of that growth driven by emerging countries.<sup>4</sup> Energy efficiency and developing new energy sources is critical to ensure that demand does not outstrip supply.

### WORLD ELECTRICITY CONSUMPTION BY REGION



Source: OECD World Energy Outlook – Reference Scenario

Manufacturers are seeking new processes to remain competitive, including energy efficient buildings, product designs, operations and logistics.<sup>4</sup> As fossil fuel based energy sources become increasingly expensive and unstable, affordable, clean, renewable energy strategies and effective energy policies will serve as important differentiators of highly competitive countries and companies.<sup>13</sup>

***“This is a time of unprecedented uncertainty for the energy sector. Energy demand will continue to increase. The pressure and challenge to develop and transform the energy system is immense.”***

*World Energy Council, 2013.*

# ACCESS TO RESOURCES

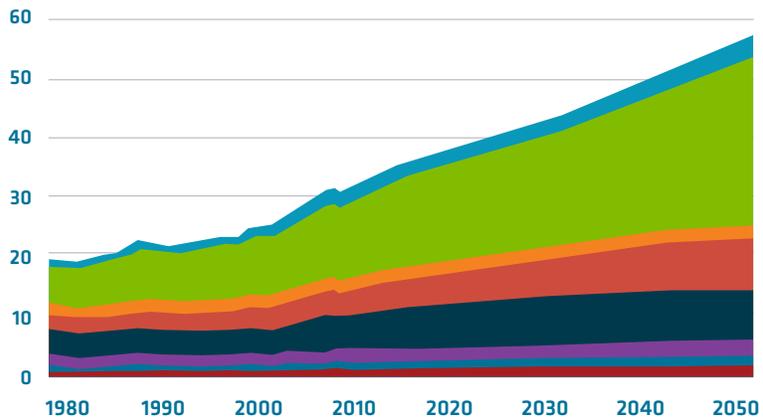


What effect could a changing climate have on manufacturing, and what can the industry do to address climate change?

## 2.2.6 IMPACT OF CLIMATE CHANGE

If the global energy mix remains as it is now, the OECD estimates that fossil fuels will supply about 85% of energy demand in 2050, resulting in a projected increase of 50% in greenhouse gas (GHG) emissions.<sup>12</sup> GHGs are the major cause of climate change, and as a substantial user of natural resources, such as water and biomass, manufacturing will be affected by the changing availability of these resources due to the changing climate. Additionally, the effects of climate change will likely also interrupt supply chains through extreme weather events and sea level rise.<sup>14</sup>

GLOBAL CO<sub>2</sub> EMISSIONS BY SOURCE: BASELINE, 1980-2050



INDUSTRIAL PROCESS | POWER GENERATION | ENERGY TRANSFORMATION | TRANSPORT | INDUSTRY | RESIDENTIAL | SERVICES | OTHER SECTORS

Source: OECD, 2012. OECD Environmental Outlook to 2050

Manufacturing accounts for approximately 35 percent of global electricity use and 20 percent of CO<sub>2</sub> emissions,<sup>15</sup> which means that it has the potential to significantly impact GHG reductions. Manufacturers can reduce GHGs by reducing energy consumption through improved efficiency of equipment, sourcing externally or self generating renewable energy (e.g. on site solar, reclaiming heat energy) and by reducing emissions in industrial processes (e.g. switching fuels for equipment that generate less CO<sub>2</sub>, and producing products from materials that are recycled, rather than raw materials).<sup>16</sup> Reducing GHGs in manufacturing is part of the solution for climate change mitigation, and will also help to improve air quality conditions. In the long term it will improve the stability of some resources, and provide cost savings to manufacturers through improved efficiency.

**“One truth is evident across all these industries: companies that ignore climate-related risks are likely to feel the consequences. Those that identify the most pertinent risks, think through how they relate to one another, and then put in place appropriate measures can begin to manage the challenges ahead. These companies will not only put themselves in position to ride out the storm; they could rise above it.”**

H. Engel, P. Enkvist, and K. Henderson. *How companies can adapt to climate change*. McKinsey & Company, 2015.

# MARKETS DRIVING MANUFACTURING

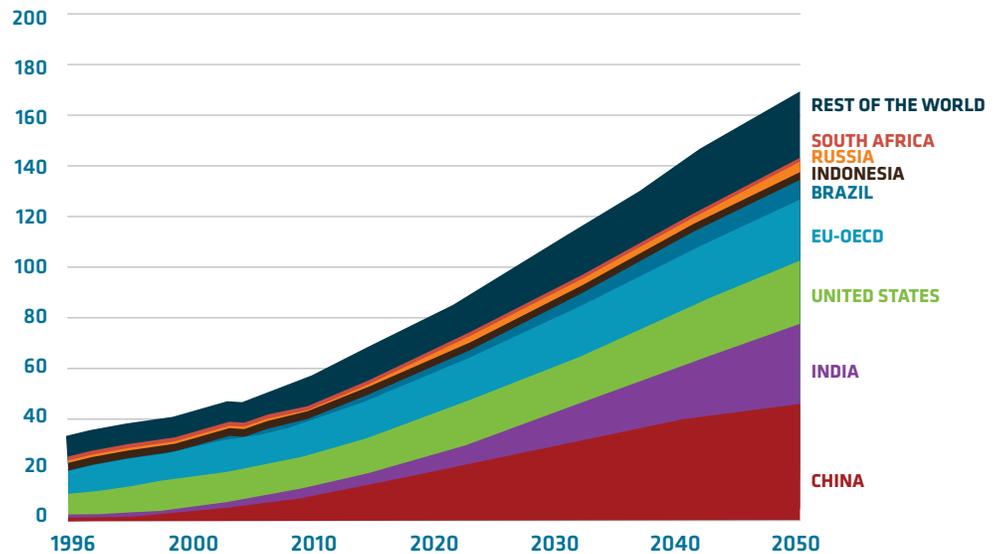


With population growth and developing economies, how will new and established markets shape the manufacturing industry?

## 2.3 MARKETS DRIVING MANUFACTURING

Population growth and emerging economies are the most significant drivers of the demand for manufactured goods. Consumer markets are expected to expand from \$6.5 trillion in 2001 to a forecasted \$30 to \$45 trillion by 2021.<sup>1</sup> This rapid expansion is occurring within developing economies and these new markets are shaping the future of manufacturing in terms of what is produced and where it's made.

GROSS DOMESTIC PRODUCT (TRILLION 2005 USD PPP)



Sources: European Environment Agency, 2015. Continued economic growth? Based on OECD Long-term Baseline Projections 2014 data; Siemens, 2015. The Future of Manufacturing; World Bank. The Data Catalog, 2016.

Additionally, as markets mature in developed nations, they are creating demand for specialized products, such as desire for locally produced or customized items. Manufacturers of all stripes have felt these changing consumer demands, regardless of whether their products are consumer facing or marketed towards other manufacturers.

**“Global spending by the middle class may grow to \$56 trillion by 2030 from \$21 trillion today—and, again, more than 80% of this growth in demand is expected to come from Asia.”**

E. Kerschner and N. Huq, Asian Affluence: The Emerging 21st Century Middle Class. Morgan Stanley Smith Barney, Global Investment Committee, 2011.

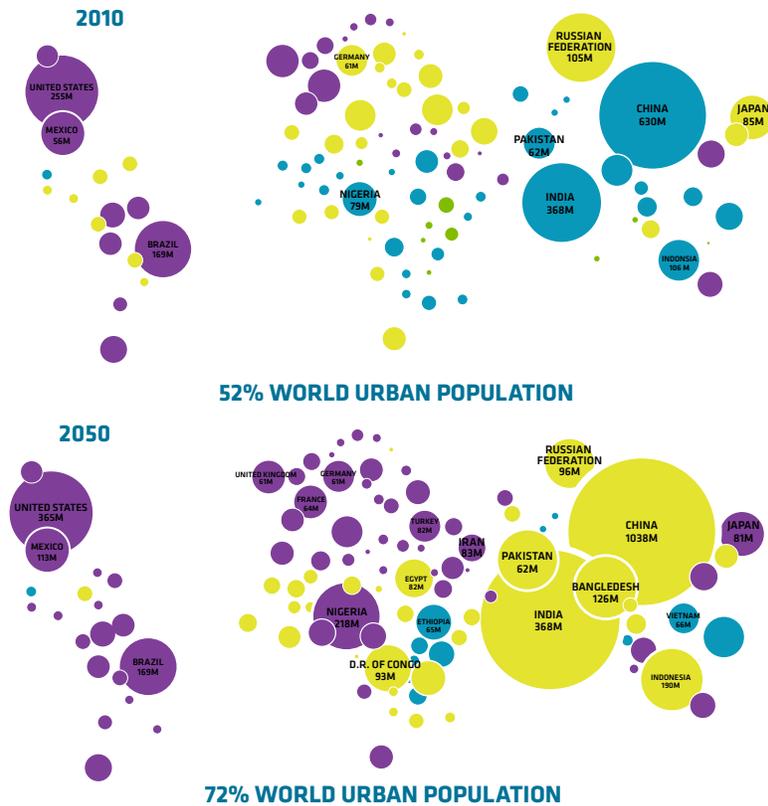
# MARKETS DRIVING MANUFACTURING



As population centers continue to shift towards the developing world and urban centers, how will this change what is made and where?

## 2.3.1 MORE PEOPLE; MORE THINGS

Global population has grown exponentially over the last 100 years with projections indicating that it could grow from 2.5 billion in 1950 to more than 9.8 billion in 2050.<sup>2</sup> The majority of this growth is occurring within less developed nations. Overall growth is accompanied by rapid urbanization in the developing world, in 2013, the global urban population surpassed the rural population. It is forecasted that approximately 70 percent of the global population will be living in cities by 2050.<sup>3</sup>



THIS GRAPHIC DEPICTS COUNTRIES AND TERRITORIES WITH 2050 URBAN POPULATIONS EXCEEDING 100,000. CIRCLES ARE SCALED IN PROPORTION TO URBAN POPULATION SIZE.

Source: UNICEF, 2012. Urban Population Map.

These two trends are intensifying the need for manufactured goods, and are changing where economic centers and markets are located, presenting opportunities for manufacturers to access large new markets.

*“Urbanization has the potential to usher in a new era of well-being, resource efficiency and economic growth. But cities are also home to high concentrations of poverty. Nowhere is the rise of inequality clearer than in urban areas, where wealthy communities coexist alongside, and separate from, slums and informal settlements.”*

United Nations Population Fund, 2016.

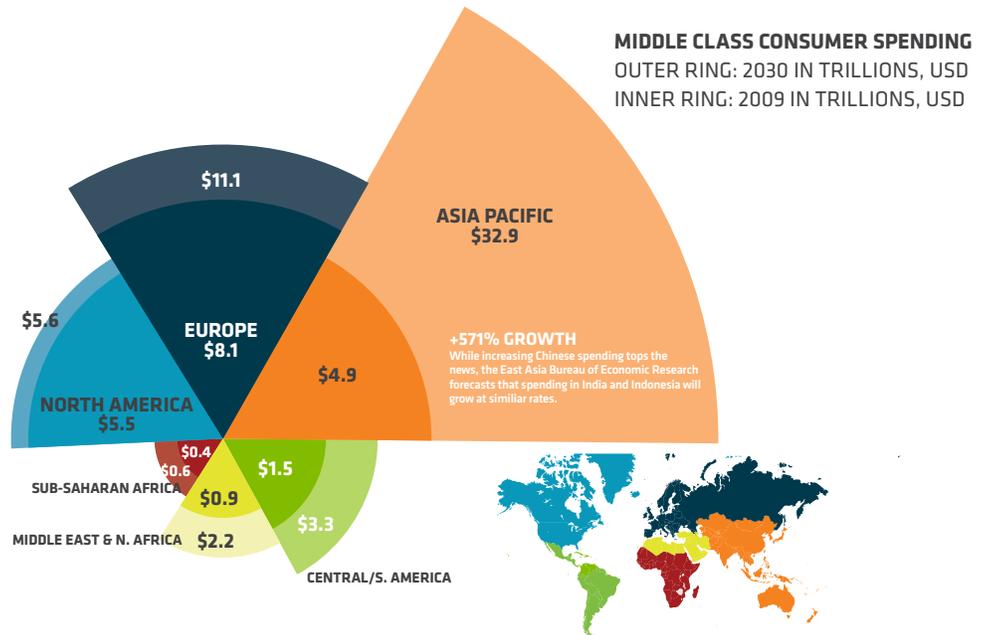
# MARKETS DRIVING MANUFACTURING



With an increase in prosperity in developing economies, how will the manufacturing industry adapt?

## 2.3.2 SPENDING POWER OF THE EMERGING MIDDLE CLASS

In recent decades, developing nations have been used by manufacturers for low-cost labor, however, many of these emerging economies are developing their own innovations and manufacturing capabilities. As these economies advance, wages and costs are rising following the path set by previously developed nations. Increased wages and prosperity are driving the ability and desire to consume, creating a new, emerging middle class.<sup>4</sup>



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

The global middle class is being reshaped and resized by millions of newly affluent people in emerging economies. The global middle class will grow from 2 billion to almost 5 billion in 2030, with most of that growth coming from developing countries.<sup>5</sup> The consuming power of this emerging middle class, is opening up new, competitive market opportunities for local manufacturers and established multinationals.

**“However, as businesses turn their attention to these new consumers, they’re also finding that the past strategies of exporting affordable, scaled-down versions of successful products or services often do not work. The new middle class consumers are overall poorer, live in different countries, and are less familiar to global companies, and may need different products and services than their middle class counterparts in other nations.”**

*Kelly, E. and G. Goldman. Emerging markets: How to reach the new middle class, Deloitte, October 5, 2015.*

# MARKETS DRIVING MANUFACTURING

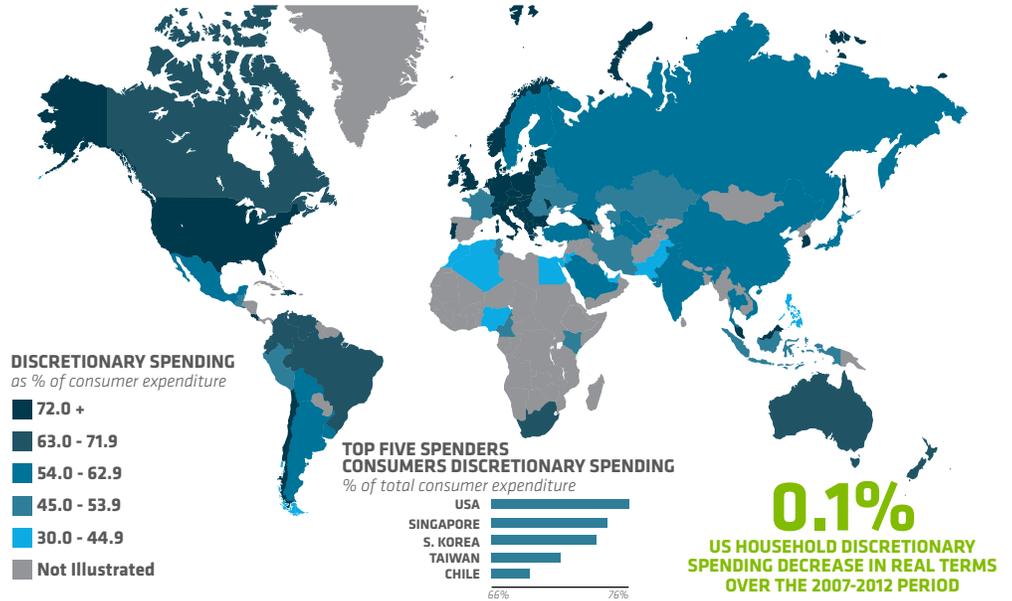


How will manufacturers react as growing consumer demands drive calls for innovation and change?

## 2.3.3 DISCRETIONARY SPENDING POWER

Within established economies, the largest developing market is a new, younger middle class who has greater connectedness and digital literacy. As group of consumers, they are more fragmented and seek to drive the market.<sup>6</sup> They have a high percentage of their income that is discretionary, and therefore, are willing to spend more for exactly what they want.

### DISCRETIONARY SPENDING AS A PROPORTION OF CONSUMER EXPENDITURE



Source: EuroMonitor Research, 2013. Emerging Markets Drive Growth in Discretionary Spending.

They are demanding products that are high quality and highly customized, as well as ethically sourced and manufactured, and environmentally responsible.<sup>7</sup> As this market continues to diversify, manufacturing firms will need to anticipate changing consumer tastes within multiple, small market channels to be competitive. This also suggests that smaller, more boutique firms will thrive in both consumer facing and business-to-business markets.

*“Meanwhile, in established markets, demand is fragmenting as customers ask for greater variation and more types of after-sales service. A rich pipeline of innovations in materials and processes—from nanomaterials to 3-D printing to advanced robotics—also promises to create fresh demand and drive further productivity gains across manufacturing industries and geographies.”*

*McKinsey & Company. Manufacturing the future: The next era of global growth and innovation, 2012.*

# MARKETS DRIVING MANUFACTURING



*How will manufacturers maintain an innovative edge when every product can be customized and consumers are also designers?*

## 2.3.4 MASS CUSTOMIZATION

The culmination of new manufacturing technologies and processes, globalized value chains, and agile philosophies is the advent of mass customization and personalized manufacturing.<sup>8</sup> What has previously been offered only to high-value customers will become more commonplace. The end customer will be able to define a variety of characteristics of any product from materials to features to finish.<sup>9</sup>

### ●●● CROWD DATA ●●●

Aggregated data from the crowd are used to inform the design and delivery of goods and services.

### ●●● ADAPTIVE

Customer insights enable a strong feedback loop between organizations and end user, who are keen to shape the process. This allows for the creation of highly personalized experiences.

## CORE CAPABILITIES OF PERSONALIZED MANUFACTURING

### SENSING ●●●

Crowd data, digitalization, sensors, and analytics allow for unprecedented capabilities to gather and assess evidence from ecosystem participants.

### ●●● BEHAVIOR ●●●

Consumer behavior is monitored in real time. Analytics is used to understand, predict, and shape ongoing customer interactions.

Source: William Eggers and Paul Macmillan, *Deloitte Review*, Issue 16, January 26, 2015.

Manufacturing lines will be able to produce multiple models or variations of the same product through the use of RFID chips, sensors, new materials and multi-tooled machinery.<sup>10, 11</sup> The result of highly flexible, individualized, and resource efficient mass production is that customized products will be produced in the same timeframe as a standard product at a marginal increase in cost.

***“Instead of being at the end of the value chain, customers and citizens are engaged as cocreators throughout—and often act as both supplier and customer in the same value exchange. This idea was first articulated decades ago by futurist Alvin Toffler, who in his 1980 book *The Third Wave* coined the term “prosumer,” a consumer who takes part in the production process as well. Toffler argued that pure consumers are a phenomenon of the Industrial Age and that they will be replaced by prosumers, who will coproduce many of their own goods and services.”***

*William Eggers and Paul Macmillan, Deloitte Review, Issue 16, January 26, 2015.*

# MARKETS DRIVING MANUFACTURING

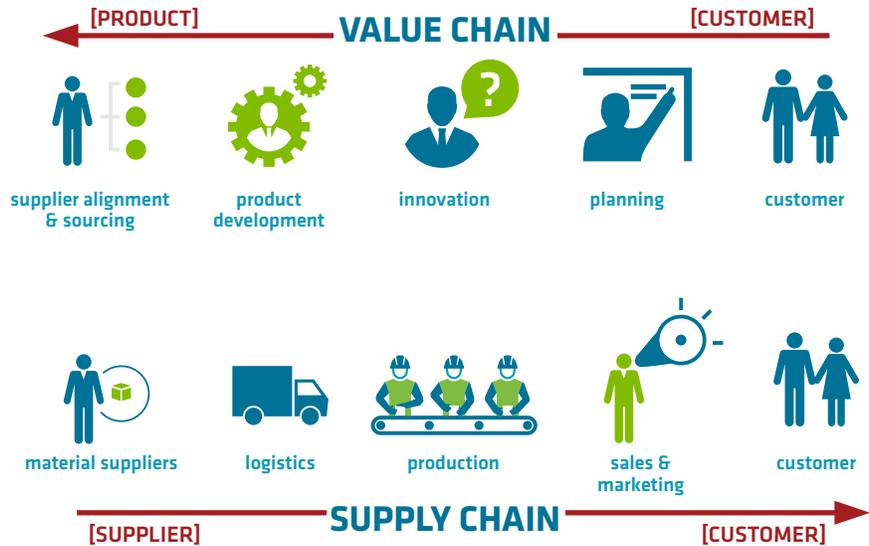


Is the next frontier of manufacturing profitability to be found in the development of an agile value chain?



## 2.3.5 MOVING FROM SUPPLY CHAINS TO VALUE CHAINS

Success in manufacturing has always depended on the firm's ability to source inputs from a variety of suppliers. Our understanding of supply chain dynamics has improved significantly with the current data revolution, as complex trade flows spanning multiple countries can now easily be mapped using network analysis algorithms. Production is more efficient and scheduled to seamlessly source inputs from multiple vendors timed to arrive when needed.<sup>12</sup>



Source: T. Weiner. 2015. *How to Develop an Efficient Value Chain*. Manufacturing Extension Partnership (MEP) Supply Chain Optimization Initiative and California Manufacturing Technology Consulting.

In the future, supply chains will evolve into value chains where firms involved in both production and service activities will be connected as vital linkages in the primary process flow, and feedback comes from all parts of the chain from suppliers through to customers. The move to a value chain model also offers development opportunities for a number of countries who excel in providing services such as design or distribution but have few domestic manufacturing industries.<sup>13</sup> The value chain model will also introduce a number of core dependencies between unrelated firms, changing cost structures and spurring further competition between niche service firms.

*"Over the years, supply chain management has become a more sophisticated discipline. The fundamental vision has been to create an integrated approach to a company's end-to-end supply chain, from the furthest upstream suppliers to its end customers, with participants working in concert toward common goals. Through practices such as lean manufacturing, outsourcing, and supplier consolidation, companies have made tremendous progress in achieving that vision. For many companies—and their customers—these efforts have led to lower costs, higher quality, shorter time to market, and increased business agility."*

*Deloitte Consulting LLP, 2011.*

# MARKETS DRIVING MANUFACTURING



*Will the innovations in autonomous technology and distributed systems be sufficient to support developments in the global value chain?*

## 2.3.6 MULTIMODAL LOGISTICS

Manufacturing has long played a dominant role in the definition and development of global transportation networks. Cities and production facilities have been established around the fundamental needs to bring resources into production and products to market. As the manufacturing footprint and supply chain have expanded globally since World War II, multimodal solutions combining road, rail, water, and air transportation have become increasingly more vital. In the future, the physical distance between production and marketplace will shrink through distributed manufacturing. This will again create the need to develop new smart transportation solutions.



Source: Tristan Wiggill. 2015. *Global Megatrends and The Future of Urban Logistics*.

Solutions are already emerging in a number of developed countries as large shipping companies such as DHL are investing hundreds of millions of dollars to upgrade facilities to connect rail and road shipping options.<sup>14</sup> Advances in capacity, efficiency, and routing, such as the expansion of the Panama Canal, have transformed the commercial shipping industry and generates an additional \$400 million annually.<sup>15</sup> Continued developments in logistics will see further evolution of the traditional multimodal system, as well as manufacturers shipping a higher volume of products through Intelligent Transportation Systems, including semi-autonomous and autonomous means such as drones and driverless vehicles.<sup>16</sup>

***“The industry will start to operate more on the level of multi-way interactivity between suppliers of different tiers, transport providers and retailers. This is one reason why any transport system which companies choose should be on an industry-standard or open platform, so that doors can later be built between it and whoever they wish to share data with.”***

*Lombard. The Future of Logistics, 2015.*

# MANUFACTURING WORKFORCE OF THE FUTURE

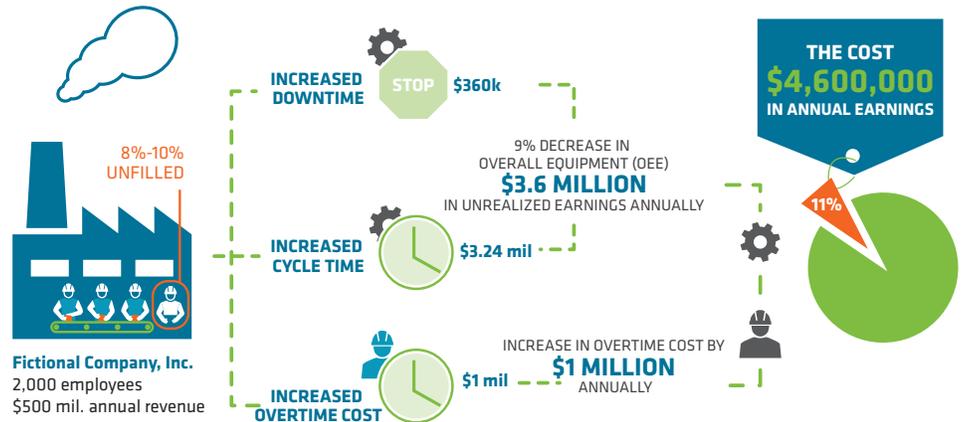


Technological advances have progressively replaced humans for centuries. Will people become obsolete in manufacturing?

## 2.4 MANUFACTURING WORKFORCE OF THE FUTURE

The Future of Manufacturing will likely be increasingly automated, complemented by a small, but highly skilled workforce, and will be less dependent on the use of large numbers of physical laborers than in the past.

This will not necessarily be true in the context of all countries or in all manufacturing industries, but decreasing labor availability associated with aging populations in North America, Western Europe, and Japan is, and will continue to impose significant labor constraints in most manufacturing industries.<sup>1</sup> This, in turn, is increasing the premium tied to advanced skill sets in science, technology, engineering, and math.<sup>2</sup> Automation advances will also greatly increase worker productivity.



Source: Accenture, and Manufacturing Institute. 2014. Accenture 2014 manufacturing skills and training study.

As a consequence, the manufacturing workforce may be smaller in number in the future, but it will be the most highly skilled and productive in history.<sup>3</sup> The current and projected skills gap in workers, may limit growth until employers, governments and institutions develop strategies to attract new workers and increase skill levels.

***“As talent becomes increasingly difficult to find, we are heading toward a global employability crisis. Employers must reconsider their work models and people practices, and develop a robust workforce strategy that in a sense “manufactures” the talent they need to execute their long-term business strategy.”***

*Manpower Group. The Future of the Manufacturing Workforce – Report One: Technology and the Workforce, 2013.*



# MANUFACTURING WORKFORCE OF THE FUTURE

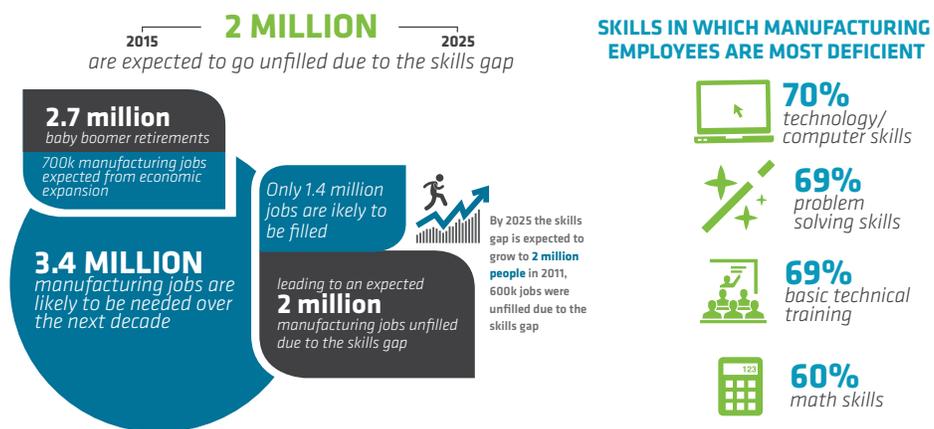


Advanced technologies are driving productivity growth and enhancing value added industries. How will the manufacturing workforce transform alongside?



## 2.4.1 SKILLS AND SPECIALIZATION

In the past 60 years, labor intensive activities have shifted to developing nations to take advantage of low cost labor. However, manufacturing is seeing a major shift based on technological advances and the workforce will continue to evolve to increasingly rely on intellectual capacity rather than physical labor.<sup>4</sup> The success of technological advances that are driving the future of manufacturing will be based on the availability of highly-skilled labor to harness its potential.



Source: Deloitte and Manufacturing Institute. 2015. The skills gap in U.S. manufacturing 2015 and beyond. Deloitte analysis based on data from U.S. Bureau of Labor Statistics and Gallup Survey; Manpower Group. 2013. The Future of the Manufacturing Workforce – Report One: Technology and the Workforce

However, shortages exist, particularly in skilled production workers, technologists, scientists and design engineers. Competition between developed countries and developing countries has traditionally been fought between the availability of a relatively small number of high-skilled, high-value added workers in the developed world and larger numbers of semi- and unskilled workers in the developing world. This balance is shifting with the development of new technologies and investments in education globally. This has also sparked interest in on-shoring activity in the United States and elsewhere.<sup>5</sup> It also makes the development of domestic talent pools even more critical.<sup>6</sup>

*“As a general principle, the American people would be well served by the active pursuit of effective policies to support longer-run growth in productivity. Policies to strengthen education and training, to encourage entrepreneurship and innovation, and to promote capital investment, both public and private, could all potentially be of great benefit in improving future living standards in our nation.”*

*Janet Yellen, Chairwoman Federal Reserve Bank, July, 2015.*

# MANUFACTURING WORKFORCE OF THE FUTURE

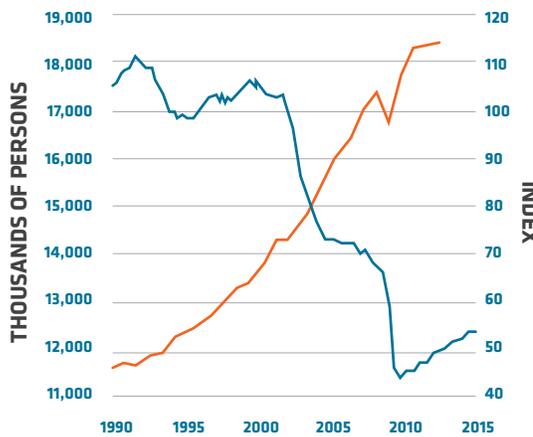


*Will the accelerating pace of innovation and adoption of new robotic technology spark a new productivity revolution?*

## 2.4.2 AUTOMATION AND ROBOTICS

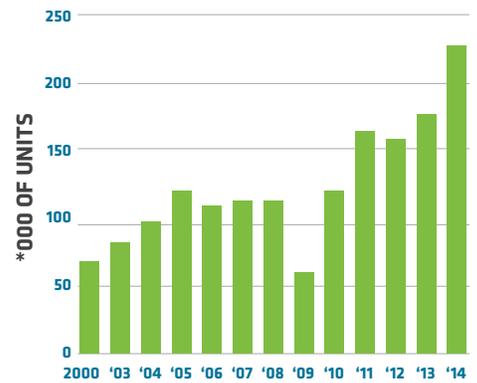
Basic manufacturing processes have become more automated over the last forty years, beginning with advances in the apparel and automotive industries. The use of robotics and other automation technologies are now more widely dispersed with Asia, Europe, and North America all having strong footholds in robotics and software development.<sup>7</sup> In the future, automation technologies will become more prevalent, as machines are designed to be able to learn skills, adapt, replicate and exceed the precision and specialization of high-skilled workers. The World Economic Forum estimates that we could see an increase in productivity of 40% per worker by 2025 due to increased automation. The image of human teams working alongside robotic production lines will become commonplace.

■ ALL EMPLOYEES: MANUFACTURING (LEFT)  
 ■ MANUFACTURING: OUTPUT PER HOUR OF ALL PERSONS, 2007 = 100 (RIGHT)



Source: FRED Economic Data, 2015. Economic Research, Federal Reserve Bank of St. Louis.

ESTIMATED WORLDWIDE ANNUAL SUPPLY OF INDUSTRIAL ROBOTS



Source: International Federation of Robotics, 2015.

The increase in automation has prompted concerns regarding whether these technologies will bring an end to work as we know it.<sup>8</sup> There is not enough evidence in many industries to conclude whether this will be the case. What is more likely is that manufacturers of all sizes will adopt automation technologies at a variety of scales in order to maximize the productivity of their workforce, take over routine tasks, and ultimately lead to a rapid increase in production. This will bring a revolution in "smart working" where the skillsets of workers are matched to the technology that can optimize them.<sup>9</sup>

***"Few can deny the benefits that these advances have brought to society since 2000. The economics is straightforward: Automation allows people to complete tasks faster with fewer errors at cheaper costs. This increases productivity, which means people don't have to spend as much time or money to accomplish tasks, which generates new wealth for society."***

*Stephen Gould, The Future of Work, Industry Week, May 12, 2015.*

# MANUFACTURING WORKFORCE OF THE FUTURE



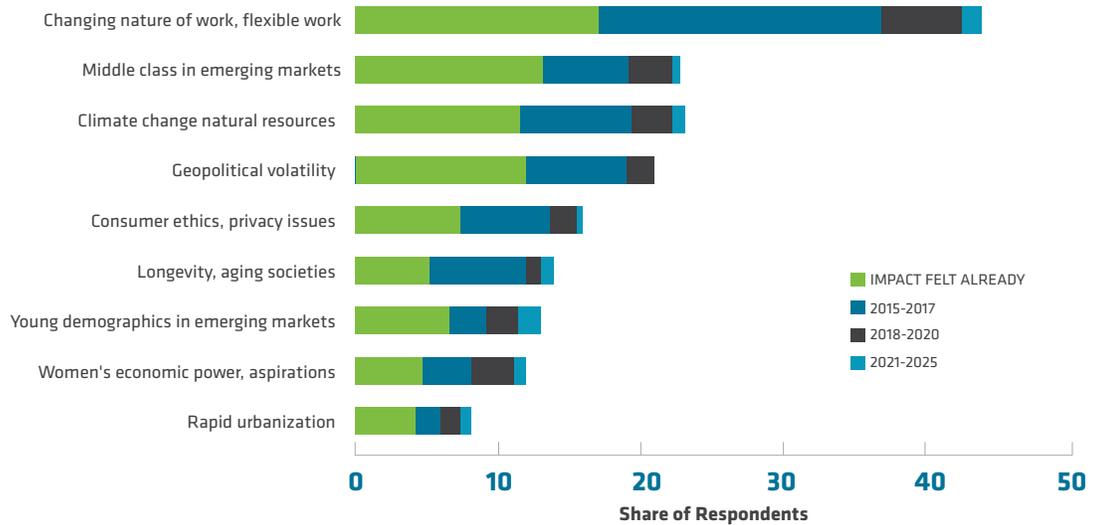
*How will the aging population affect the manufacturing workforce of the future?*



## 2.4.3 IMPACT OF DEMOGRAPHICS

There is a current and progressive decline in the number of prime-age workers in developed countries due to the aging and retiring baby boomer population, increasing life expectancy, and declining birth rates.<sup>10</sup> The demographic transition is a long-term phenomenon that can be observed on a global scale on different time horizons. The aging workforce means there are and will continue to be fewer workers available and labor shortages. We have already observed significant concerns in the United States, Western Europe and Japan.<sup>11</sup>

### DRIVERS OF CHANGE, TIME TO IMPACT ON EMPLOYEE SKILLS



Source: World Bank calculations, based on data from UN 2015. *Global Monitoring Report 2015/2016 Development Goals in an Era of Demographic Change*. A joint publication of the World Bank Group and the International Monetary Fund.

Additionally, because fewer young workers are entering the manufacturing industry, the manufacturing workforce in most advanced countries is aging far more rapidly.<sup>12</sup> For example, in the United States, 25% of the manufacturing workforce is over the age of 45, where less than 10 percent is under the age of 25.<sup>13</sup> This share has been gradually decreasing over the past fifteen years. Increasing demographic pressures in many developed countries will lead to a larger focus on skills and productivity in combination with technological support, such as automation. This has also fostered national debates in a number of countries regarding the proper role of migrant labor.

***“As many as one in every five workers in developed countries will exit the workforce in the next decade, placing further pressure on companies to replace both skills and experience.”***

*World Economic Forum. The Shifting Geography of Global Value Chains: Implications for Developing Countries and Trade Policy, 2012.*



# MANUFACTURING WORKFORCE OF THE FUTURE



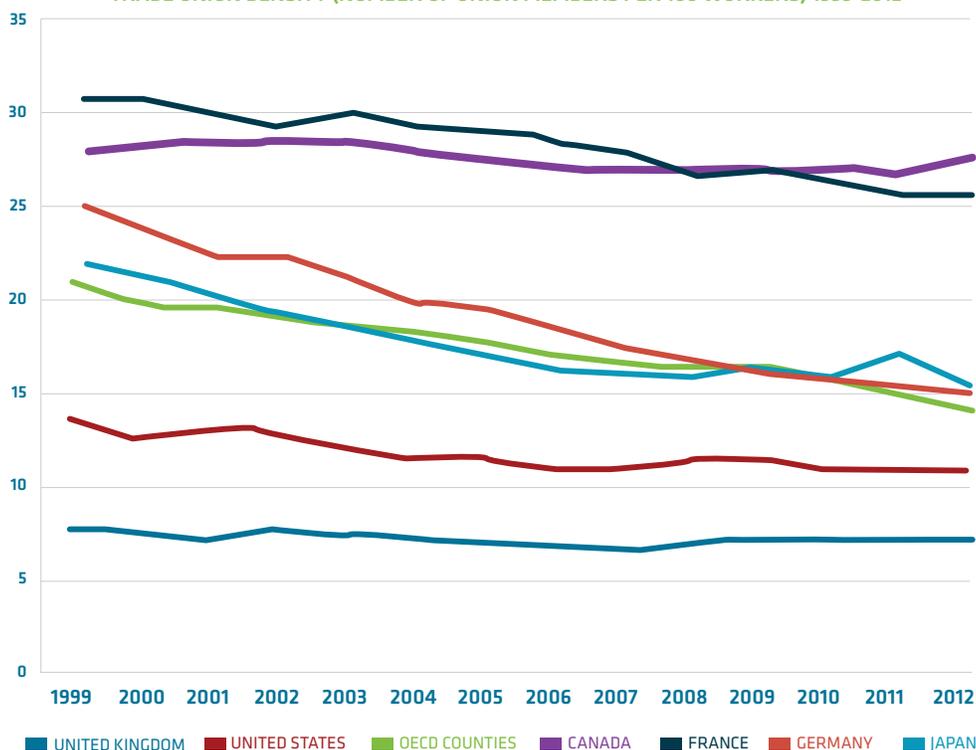
How does a gradual decline in union membership affect future manufacturing prospects in the developed world?



## 2.4.4 CHANGING UNION ENVIRONMENT

One of the fundamental influences that drove manufacturing growth for much of the 20th century is the growth and recent decline in trade unions. While the history of unionization stretches further back in history, its influence in manufacturing has been most strongly felt in Europe and North America in the post-World War II era.<sup>14</sup> Union membership has been slowly declining as the manufacturing workforce has globalized.<sup>15</sup>

TRADE UNION DENSITY (NUMBER OF UNION MEMBERS PER 100 WORKERS) 1999-2012



Source: Organization for Economic Cooperation and Development. 2016. Trade Union Density from OECD.Stat.

As questions about income inequality are rising to the forefront in many countries, along with the possibility of shifting production, we can predict that the role that unions play in driving future wage growth and productivity will also be of critical importance. This has been demonstrated historically as wages for all workers more than doubled during the period of highest union membership in the United States.<sup>16</sup>

***“If we want a better economy, then, we need a better story about how the economy works, in which a union worker is not a cost but a customer. The weakness of labor is everyone’s problem — and its revival everyone’s opportunity.”***

*Eric Liu, Time Magazine, January, 2013.*

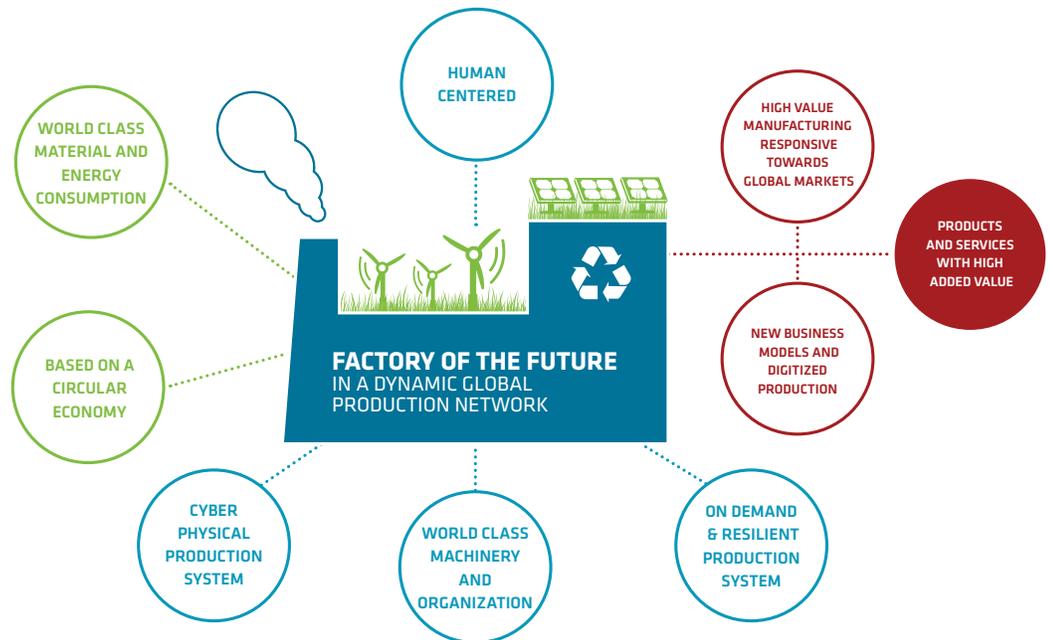
# FACTORY OF THE FUTURE



How will factories adapt to changing markets, technological innovations, and raw materials and workforce availability?

## 2.5 FACTORY OF THE FUTURE

The defining image of manufacturing's past and present in many communities is the presence of large factory buildings with their hallmark loading docks and smokestacks. These factories dominate the skylines of communities large and small throughout the world. However, innovative building practices, materials, and design principles are changing the way that the factory of the future will both look and function.



Source: Made Different. 2016. What is Factory of the Future 4.0?

*“Manufacturing has traditionally been considered to be a process that turns raw materials into physical products. Nowadays, though, the physical part of production is at the center of a much wider value chain. Manufacturers are increasingly generating revenue from other activities, many of which are categorized as services.”*

*The Economist, Schumpeter Business and Management. The factory of the future. October 30, 2013.*



# FACTORY OF THE FUTURE

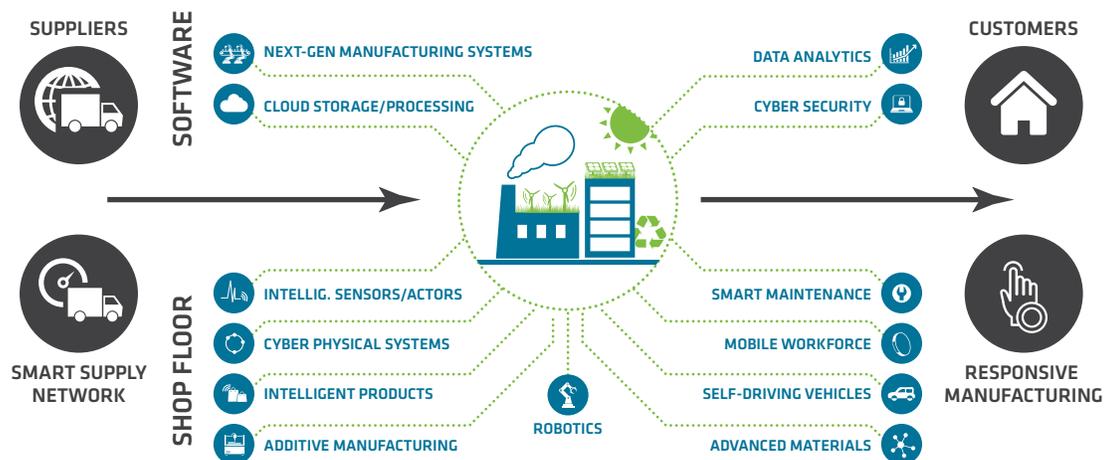


*How will the current technological innovations integrate within factories of the future?*



## 2.5.1 INTELLIGENT FACTORIES

Technological innovations are transforming how factories function. Intelligent factories will use the Industrial Internet of Things (IIoT) to connect IT systems and machine automation infrastructure, resulting in self-organizing systems. Products will use RFID tags and sensors to find their way independently through the production process, and machines and products will be able to communicate with each other cooperatively driving production.<sup>1</sup> The IIoT will also facilitate greater Overall Equipment Effectiveness (OEE) through predictive maintenance and reduced changeover times.<sup>2</sup> The interconnectedness will go beyond the factory walls, with supply chains, production plants, products and logistics all interconnected within the IIoT.



Source: IOT Analytics. 2015. Will the industrial internet disrupt the smart factory of the future?

Design and production processes are also transforming, and will incorporate digitalization, modelling and simulation, which will help optimize raw material use and check the safety of new products, as well as provide adaptive, real time control, revolutionising quality and performance.<sup>3</sup> Combined with new materials development and production technology such as additive manufacturing, these new production processes will create efficiently running factories, with increased adaptability within the production system that provides greater options for customization for customers.

*“The necessary ingredients for creating the factory of the future are already in place (a market full of sensors, new user-friendly web services, faster data communication networks, cloud storage, advanced computing power, and the ability to analyze Big Data intelligently). These elements are guiding the factory of the present – the factory that has been largely unchanged for more than 30 years – toward the Industrial Internet Revolution.”*

*Mike Godsey, Becoming the Factory of the Future: Part 2. Machine & Factory Automation, 2015.*



# FACTORY OF THE FUTURE

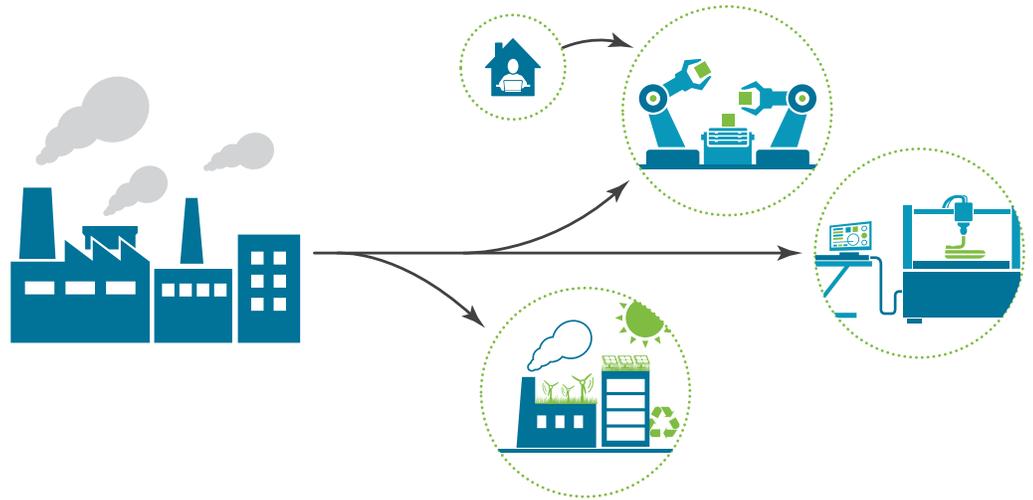


*What evolutions are taking place that will effect the footprint of future factories?*



## 2.5.2 FACTORY FOOTPRINT

The factory of the future will be flexible to allow for a multitude of uses (adaptive reuse to scale) and be designed and built using new materials to maximize energy efficiency and internal volume (open floors and high ceilings). Factories are becoming more purpose-driven (rather than single task focused) as companies embrace the principles of agile production. With increased adaptability and efficiency, and improved timing to market, less space will be needed for single task production lines, or for warehouses to store excess inventory. Additionally, smaller building footprints will be facilitated by the IIoT, coordinated logistics, and an increased reliance on automated production.



Energy efficiency, resource recovery and reuse, and intelligent design principles will also influence most capital investment decisions, as a number of developed countries place priority, and offer significant incentives for sustainably focused enterprises. Economic, environmental and social sustainability will provide the foundation for development of new facilities.

***“The ultimate goal of the factory of the future is to interconnect every step of the manufacturing process. Factories are organizing an unprecedented technical integration of systems across domains, hierarchy, geographic boundaries, value chains and life cycle phases.”***

*International Electrotechnical Commission. Factory of the future: White Paper, 2015.*



# FACTORY OF THE FUTURE

— (?) —  
*What is driving the location of production, and where will factories in the future be located?*

## 2.5.3 FACTORY LOCATION

As we see a transformation in the nature of production, the factory of the future will also shift to be much more variable than the traditional production plant. Factories will be more distributed, and will range from capital intensive super factories producing complex products; to adaptable, reconfigurable facilities, that are integrated with their supply chain partners; to local, mobile and domestic production sites for some products.<sup>3</sup> Some 'factories' may even be located in the home, field or office.

### KEY LOCATION DRIVERS TODAY



### KEY LOCATION DRIVERS IN 2020



**ACCESS TO RELIABLE INFRASTRUCTURE HAS BEEN A MAJOR CONCERN FOR MANUFACTURERS. IN RESPONSE, MANY OF THE EMERGING COUNTRIES HAVE TAKEN STEPS TO IMPROVE THEIR INFRASTRUCTURE QUALITY BY ESTABLISHING WELL SERVICED INDUSTRIAL ZONES AND INVESTING IN ROAD, PORT, RAIL, AND UTILITY ENHANCEMENTS.**

**EMPLOYERS ARE ALSO TAKING A LONG TERM VIEW ON FUTURE PIPELINE OF TALENT. TECHNOLOGICAL ADVANCEMENTS AND THE AGING WORKFORCE IN DEVELOPED ECONOMIES ARE FORCING COMPANIES TO ASSESS WHETHER A COUNTRY'S EDUCATIONAL INFRASTRUCTURE IS ABLE TO SUPPORT EVOLVING WORKFORCE NEEDS.**

Source: Deloitte and MAPI. 2015. Footprint 2020: Expansion and optimization approaches for US manufacturers.

The location and configuration of production facilities will be driven less by access to inexpensive physical labor or raw materials, and driven more by access to a skilled workforce, logistics infrastructure, and end markets.

*“For the top 10 countries identified by survey respondents as targets for future investment, the main focus for companies is to serve new markets, not only because of the size of the consumer base (e.g., Brazil, China, India), but also because countries, such as Brazil, have imposed barriers that make it cost prohibitive for companies to serve those markets from the outside.”*

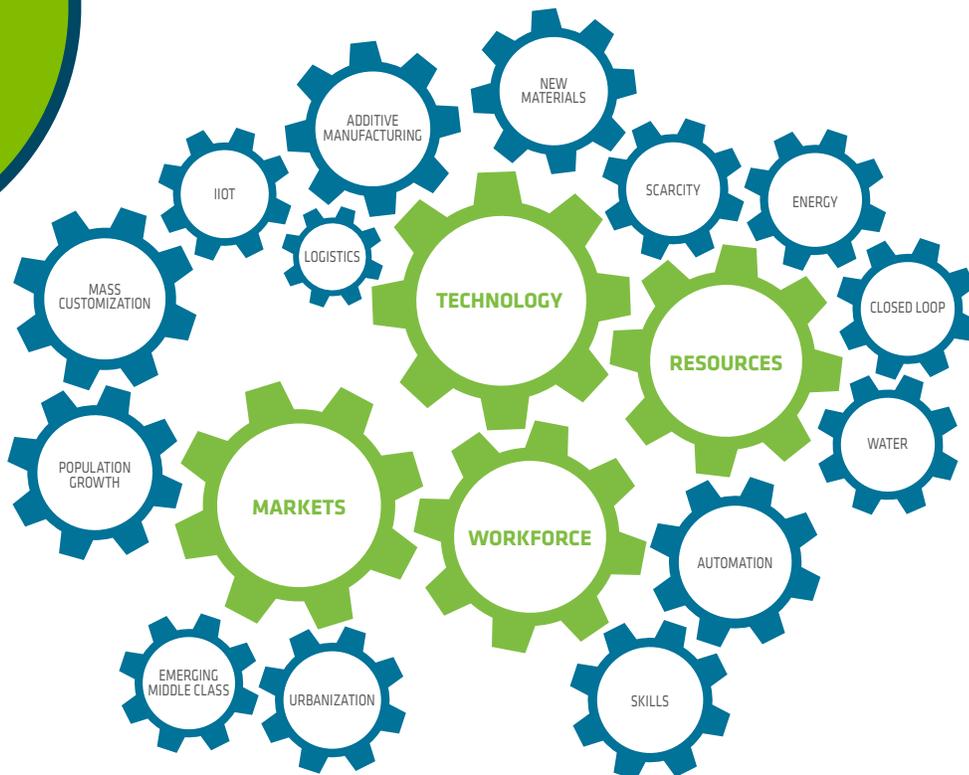
*Deloitte and MAPI. Footprint 2020: Expansion and optimization approaches for US manufacturers, 2015.*

# BUILDING BLOCKS OF THE FUTURE

## 3.0 BUILDING BLOCKS OF THE FUTURE

*The Future of Manufacturing has presented a series of trends and identified the expected changes that will shape manufacturing markets, materials, processes and products. Our foresight methodology suggests that the industry is undergoing a massive transformation as a result of the cumulative influence of these trends.*

*What changes in products, processes, and places will have the most significant impact on the future of manufacturing?*



We are seeing shifts in how things are made, based on technological innovations and a changing workforce; where they are made based on access to resources and markets; what kinds of products are being made with new technologies and changing markets; and what they are made of, due to resource shortages and evolving raw materials. The overall vision suggests that the manufacturing industry is at a tipping point, where these cumulative forces are molding the manufacturers of the future, and the successful ones will be agile and adaptable to meet the fast paced changes in market demands and technological innovations.

***“The future of manufacturing is here. With the U.S. generating 70% of software for industry, we have an opportunity to lead the world in pioneering the digital, connected factory. To do so, we’ll need state-of-the-art factories operated by the world’s most skilled workers.”***

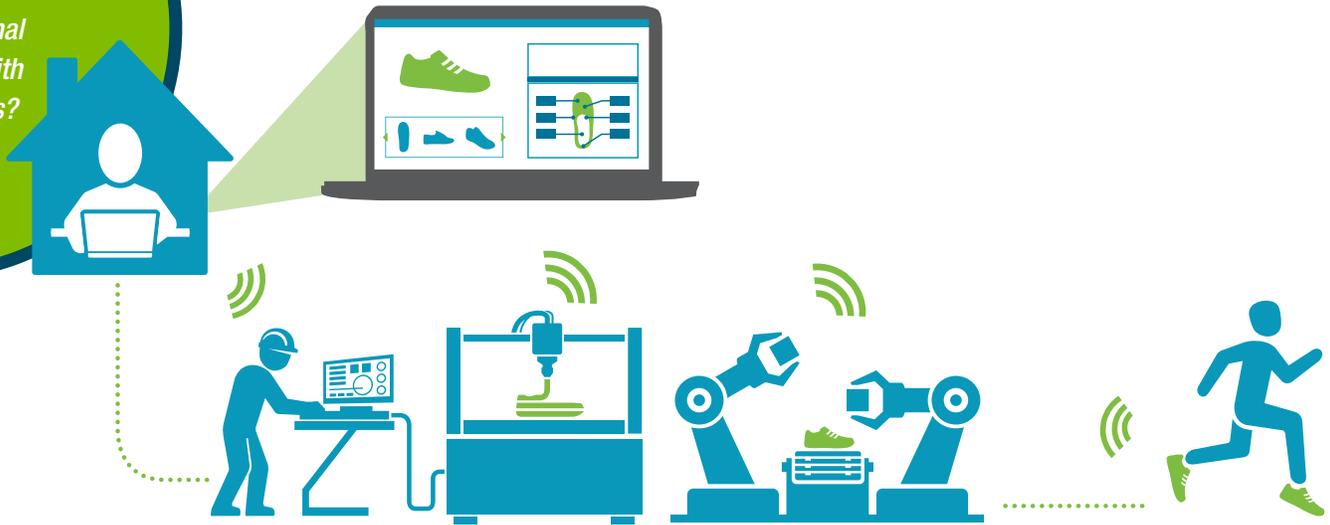
*Eric Spiegel, President and CEO Siemens USA. How the U.S. Can Be a Leader in the Factory of the Future. The Wall Street Journal. June 4, 2015.*

# BUILDING BLOCKS OF THE FUTURE

## 3.1 HOW WILL PRODUCTS BE MADE?

Technological innovations such as the Internet of Things, increasing automation, and new materials and processes are creating ongoing developments in manufacturing systems, as well as an evolution in logistics and product development. We are also seeing changes to the workforce through aging demographics and automation, with labor shortages and a shift from physical labor to highly skilled workers. Together these forces are transforming how things are made.

*How are changes in production blending traditional craftsmanship with new technologies?*



These developments mean that manufacturers are becoming more agile and automated, allowing firms to be flexible in response to changing consumer demands. Advances in additive manufacturing are amplifying the productivity of resource use by giving companies the ability to prototype and make changes on the fly. At the same time, automated solutions are advancing in miniaturization and data science driving industrial robotics to a scale that is appropriate and affordable for most firms. The combination of these factors will result in manufacturers in every sector that are both more nimble and productive. These advances will also drive down the scale of manufacturing, allowing small firms to innovate and produce at lower costs, and more rapidly. Some forms of manufacturing will even occur in the home (e.g. giving consumers the ability to process their own food products or 3D print consumer goods).

*“The emergence of “personalized manufacturing” promises to resolve the contradiction. Using computerized designs, techniques such as three-dimensional printing will enable businesses based in Birmingham or Belize to make complicated parts for products from forklift trucks to space rockets that could be assembled virtually anywhere. Customer choice over how the artifacts look will increase, with only minimal compromise concerning quality or cost.”*

*Peter Marsh, Financial Times, Dec 28, 2011.*

*The future of manufacturing will, perhaps, more closely resemble the local and artisanal trends of the nineteenth century, than the mass production models of the twentieth.*

## BUILDING BLOCKS OF THE FUTURE

### 3.2 WHAT WILL PRODUCTS BE MADE OF?

Increasing demands and shortages of both scarce materials, such as rare earth elements, as well as common, but broadly used resources such as metals, oil, lumber and water, are causing increasing prices and volatility of raw materials for manufacturing. Resource scarcity and technological innovations are driving changes in what products are made from. Materials sciences are searching for alternatives to scarce materials and also synthesizing new compounds. For example, nanomaterials are being developed to work in tandem with new manufacturing processes, such as additive manufacturing. The next great advances in the additive process will come in the use of new metal alloys and the recycling of thermo-formed plastics such as ABS into low-cost consumer-grade resins.

*In an era of increasingly scarce resources, how will manufacturers adapt to be able to meet market demands?*



This will lead to a revolution in material science. Products will be able to be made smaller, lighter, and more efficient. Designers will consider products at the atomic level. These same innovations will extend the longevity of products (e.g. smart lubricants and predictive maintenance). They will also extend their usefulness after through adaptive reuse and recycling.

***“On a worldwide scale, resource consumption is steeply on the rise, and resource consumption is still a reliable companion of economic prosperity. All such empirical facts and figures show that the world’s climate and geological environment are subject to ever increasing pressures, which are pushing the limits of sustainability.”***

*UNEP. Decoupling natural resource use and environmental impacts from economic growth, 2011.*

*New developments in nanomaterials and recycling processes will make use of every available resource from molecule to molecule.*

## BUILDING BLOCKS OF THE FUTURE

### 3.3 WHAT PRODUCTS WILL FUTURE MARKETS DEMAND?

The consumer base is transforming through population growth and urbanization, resulting in a growing middle class and emerging markets in developing countries. As economic growth in these regions continues, these markets will continue to drastically increase the global demand for manufactured goods. As wages continue to grow in emerging nations, these markets have an increasing ability and desire to consume, searching out a range of products from automobiles to household goods to new food experiences.



*Emerging and maturing markets are both shaping the future of manufacturing, how will they diverge and converge?*

We don't expect a change in product mix, per se, because we do not anticipate a shift in the general consumer tastes or industry needs. However, consumers and firms throughout a globalized value chain will demand products that are both more sustainable and smarter. Manufacturers will meet these demands by developing products that take advantage of new innovations in materials and data science to produce products more ethically, as well as those that promote greater connectivity. Consumers will become directly involved in the design and production processes, and drive mass customization, as well as improvements in smarter, modular and scalable manufacturing. These developments will originate in the mature markets, where consumers are able pay a premium for these innovations, and the technologies will quickly diffuse into the global manufacturing industries.

*Mass customization and modular manufacturing will allow consumers to tailor products to their exact personal preferences, improving on quality and longevity of products, and bringing products closer to end markets.*

***Manufacturing is entering a dynamic new phase. As a new global consuming class emerges in developing nations, and innovations spark additional demand, global manufacturers will have substantial new opportunities—but in a much more uncertain environment.”***

McKinsey & Company. *Manufacturing the future: The next era of global growth and innovation*, 2012.

## BUILDING BLOCKS OF THE FUTURE

### 3.4 WHERE WILL PRODUCTS BE MADE?

*How will technological advancements, changing demographics, and evolving markets shift where manufacturing occurs globally?*

The location of production facilities has traditionally been based on access to raw materials and, in recent decades, inexpensive labor. However, the trend is that the location of manufacturing plants is shifting to be based on logistics and multi-modal transportation, access to skilled workers, and proximity to end markets. Emerging markets in developing nations will mean that small firms in most countries may greatly expand their prospective customer base, which will more fully integrate these companies into the global value chain. Larger firms will face increasing pressure to locate production facilities in multiple locations to be close to these end markets. Technological innovations such as the Industrial Internet of Things, additive manufacturing and adaptable robotics, along with a more efficient and responsive logistics network, will make having multiple, smaller production facilities more economically feasible.



In mature markets, we are also seeing a desire, and a premium willing to be paid, for locally produced goods, which is leading to reshoring of some manufacturing processes. This may continue as firms continue to shift away from needing abundant cheap physical labor, to embrace processes that maximize the productivity of fewer highly skilled workers. This will reinforce the traditional strengths of the United States and Western Europe and will reignite their innovation engines.

*“Many companies are finding that their overseas markets are growing faster than domestic markets. Last year, for example, emerging economies grew by five percent inflation-adjusted, while the United States grew by just two percent. Those foreign plants make more sense when they also serve fast-growing countries.”*

B. Conerly, *Reshoring Or Offshoring: U.S. Manufacturing Forecast 2015-2016*. Forbes, 2014.

*Agile, scalable manufacturing processes will allow manufacturers to locate facilities in more locations and to be adaptable to local markets.*





## BRINGING THE BIG PICTURE DOWN TO SCALE

### 4.1 IMPACT ON MANUFACTURING REGIONS

Where will manufacturing occur in the future? The location of production facilities will no longer need to be based on access to cheap labor or raw materials. Technological innovations are improving manufacturing processes and logistics, allowing manufacturers to instead be located closer to end markets. Manufacturing in the United States and Europe will unfold in a different manner than in China, and other large developing countries throughout Asia, Africa, and South America.

Developing economies are rapidly evolving, and there is enormous potential for manufacturing growth and expansion as a result of the emerging middle class demand for consumer goods. In emerging markets we also expect to see pressure for sustainability measures, and improved working conditions and wages. This is already occurring in China, where manufacturing wages are rapidly approaching parity with the United States in a number of sectors.

*Harnessing the skills and knowledge gathered over a century of manufacturing excellence in the western hemisphere and directing it back into the industry can facilitate a new era of manufacturing innovation.*

As production moved to emerging economies for cheaper labor in recent decades, it left behind areas in the U.S. and Northern Europe where manufacturing facilities are now either vacant or have been converted to other uses, and workers have transitioned to other sectors. These former workers are a source of knowledge, and combined with technological innovations, have the potential to bring about a resurgence of manufacturing. This could propel these communities to become world-class knowledge centers and hubs of new research and development activity, as is already occurring in "Rust Belt" locations such as Albany, New York and Akron, Ohio, and Northern Europe.<sup>1</sup> **We expect to see continued redevelopment in other former industrial areas, which will lead to reshoring of some production, focused on their manufacturing strengths, and development of collaboration and research centers, particularly in locations with a long history of manufacturing.**

*Middle class consumer spending is expected to rise from 17.3 trillion USD in 2009 to 55.7 by 2030, with majority growth occurring in Asia, providing opportunities for regional manufacturers, as well as multi-nationals.*





# BRINGING THE BIG PICTURE DOWN TO SCALE

## 4.2 IMPACT ON THE FUTURE WORKFORCE

A transformation is coming in the manufacturing workforce. Automation, combined with shortages of workers due to insufficient skills and aging demographics, will fundamentally change how workers are integrated into production facilities.

As younger workers replace the retiring post-World War II Baby Boom population, particularly in developed nations, there is a growing skills gap. These workers require time and experience to gain the skills of the older colleagues they are replacing. Additionally, they must develop new skills to meet the demands of an increasingly technology driven industry. There is a time lag between the availability of new technology and the training of highly skilled workers to maximize the potential of new processes.

Ownership succession is another significant concern for many manufacturing firms, particularly in the United States, because many small-to-mid-size firms are either privately or family-owned. As the principal owners of these companies approach retirement, companies must cultivate an upcoming generation of entrepreneurs and ensure effective succession strategies are in place.

On the other side of the globe, the legacy of the One Child policy in China has resulted in a rapidly aging and shrinking workforce. The aging workforce is occurring globally, and the effects will be seen at various scales and time frames through out the world.

**Many manufacturers will need to make significant investments to implement efficiency and productivity measures to cope with labor shortages. Forward thinking manufacturers will seek opportunities to work with educational institutions, governments and innovation centers to develop training programs and encourage younger workers to come into the industry.**

*A single manufacturing-based knowledge worker contributes as much as nine times the value added of a single production worker.<sup>2</sup>*

*In developed countries, the average wages for mid-skilled manufacturing workers in STEM fields have increased by 42 % compared to 8 % growth for all manufacturing workers.<sup>2</sup>*



*Manufacturing careers that require some form of post-secondary education are expected to grow by 35 percent over the next decade.<sup>2</sup>*





## BRINGING THE BIG PICTURE DOWN TO SCALE

### 4.3 THE IMPACT OF PROCESS

Technological advances are revolutionizing the future of manufacturing industries.

To date, 3-D printing and nano-materials have mostly been incorporated by large firms such as General Electric and Siemens because many of the most notable advances are still quite expensive to implement. However, we anticipate the costs to continue to decrease as components become more common and materials advances are commercialized. As these innovations diffuse into the industry, manufacturers of all sizes will be able to benefit.

**We expect these new technologies will transform the manufacturing processes used to make products and how they move through the manufacturing ecosystem.**

The cumulative impact of these innovations will result in a manufacturing industry that includes much more variety, from the ability to produce in the home or office to mega-factories. The most significant opportunities will likely be for mid-size firms where the increased productivity will result in the efficiencies of scale that will create significant growth opportunities.

*Additive manufacturing and materials science is transforming how things are being made. In 5 years, the process will be 50% cheaper and 400% faster. It is expected to exceed \$21B in worldwide revenue by 2020.*

*The Industrial Internet of Things is fundamentally changing how things are networked and connected. By 2020, between 25 and 100 billion devices will be 'plugged in'.*

*Process innovations will result in products that are made faster, of better materials, and allow mass customization. All at a lower financial and environmental cost.*





## BRINGING THE BIG PICTURE DOWN TO SCALE

### 4.4 THE IMPACT OF INNOVATION ON INDUSTRY

The impacts of a reinvigorated culture of innovation, including new materials and processes will be seen in all areas of manufacturing, from new sectors in wearable technology and medical devices to traditional industries, such as those that provide intermediate goods to Original Equipment Manufacturers. Product improvements will lead to end goods that have longer useful lives, at lower capital and operating costs.

Many sectors have historically faced a number of constraints due to resource scarcity, in particular higher commodity prices and volatile availability. Traditionally, this has spurred innovation and investment in the discovery of new sources.

**As fewer sources of virgin materials are available, we expect the evolution of raw materials to be in materials science (e.g. nano-materials) and closed loop production cycles.**

We anticipate a series of virtuous cycles forming where the effect of innovations become cumulative. For example, a manufacturer gaining cost savings through adopting automation technologies can turn the productive capacity of their workforce to higher value tasks. Similarly, advances in materials science will lead to new product designs, which may stimulate innovations throughout the value chain.

**Companies that participate in the creation, implementation and diffusion of innovations by developing partnerships with other manufacturers, institutions, and governments, will be more resilient, adaptive and agile.** In the face of predicted raw materials shortages and rapidly changing consumer demands, these firms will be prepared to take the opportunities for growth that are presented by new technology and emerging markets.

*Innovation such as new materials, smart sensors and data science create product enhancements that ensure feedback, preventative maintenance, reduced replacement costs, improved longevity and constant product evolution.*

*Advanced manufacturing strengthens the overall economy by creating higher-income jobs, to create this benefit, nations and firms need to collectively invest in R&D to develop cutting edge manufacturing processes.*



# BRINGING THE BIG PICTURE DOWN TO SCALE

## 4.5 THE IMPLICATIONS

*As the business cases for an array of new innovations and processes are made, proactive firms will anticipate their value and join the ranks of early adopters.*

The question of how the drivers identified in the Future of Manufacturing will impact any particular manufacturing firm depends largely on the nature of the company itself. However, through our research and analysis we have identified that the successful manufacturer of the future must be:

- proactive;
- nimble; and,
- collaborative.

Innovations in a number of sectors are occurring at a rapid pace. Yet, the implementation of many of these, ranging from closed loop manufacturing to automation and additive processes has been relatively slow among small to mid-sized firms due to the high cost. As the advantages of these innovations are demonstrated, and the cost and scale shrink, we expect that forward thinking firms, at all scales, will adopt these technologies.

*The successful manufacturer of the future will effectively balance the speed and quality of production.*

Additionally, consumer markets and tastes are constantly shifting. Manufacturers have recognized that profitability is dependent on rapidly responding to these changing demands. **Firms that adopt an agile production process and use new technologies to rapidly prototype and troubleshoot ideas will develop the competitive advantage of significantly shrinking the time to market for new products.**

The final trait that successful firms will need to thrive in the future of manufacturing is a willingness to collaborate. Robust partnerships building revolutionary innovation networks will bring manufacturers into direct contact with university researchers, venture capital financiers, and procurement markets. Collaboration will allow those firms to leverage their productive capacity to develop and implement new innovations.

**Manufacturers that embody these traits will be poised to take advantage of the rapidly shifting industry and the opportunities for growth that will occur across the globe.**

*Manufacturing networks of excellence are likely to expand and include collaborations in logistics, value chain distribution, and support services. Successful firms will see the benefits that can occur with these types of partnerships.*





## VISION FOR THE FUTURE

### 5.0 VISION FOR THE FUTURE

*Jobs will be eliminated due to automation, however other jobs will be created, and, these will be more highly skilled and higher paying. Very few occupations will be automated in their entirety in the near or medium term, but some activities will be automated, redefining the jobs of many workers.*

The Future of Manufacturing identifies four key drivers of change that are transforming the manufacturing industry and influencing what products are manufactured, how they are made, what they're made from and where they are made. These forces are technological innovations, such as the Industrial Internet of Things, new manufacturing processes (e.g. additive and automated) and materials science (e.g. recycled and nano-materials); access to resources including the scarcity, volatility and sustainability of raw materials, water, and energy; shifting markets due to population growth and the development of a new global middle class; and changes to the manufacturing workforce based on aging demographics, the need for highly skilled workers and automation.

*The Industrial Internet of Things will allow factories to become self-organizing as raw materials, production facilities, and logistics can communicate and cooperate to efficiently move products through the manufacturing process.*

**Our foresight analysis indicates the manufacturing industry of the future will have a range of key characteristics, including: distributed, agile, adaptable, highly automated factories that are close to end markets and run by a smaller, highly-skilled workforce.** They will use new processes to produce

customized, modular products for a range of markets from raw materials that are primarily either newly developed by materials science, or reclaimed and reused from products that are past their useful life. These advances have the potential to create a flexible and highly productive industry that is able to provide manufactured goods to the growing markets, without exhausting and degrading the natural and human resources that support it.

**The Future iQ team is working with manufacturing regions and supply chains throughout North America, Europe and Australia.** Our work uses scenario

planning, stakeholder engagement, network and supply chain mapping, data visualization and other tools to help stakeholders develop detailed strategic insights into the implications and impacts of the changes occurring within the global and regional manufacturing industry.

*“Companies must develop a highly detailed understanding of specific emerging markets, as well as the needs of their existing customers. They will also require agile approaches to the development of strategy—using scenario planning rather than point forecasts, for example.”*

McKinsey Global Institute. *Manufacturing the future: The next era of global growth and innovation*, 2012.

*Increasing demand for manufactured goods in emerging economies has the potential to overwhelm raw material, energy and water resources unless new sources can be accessed, and closed loop systems can be implemented on a broad scale.*

*In the next decade, Additive Manufacturing will dramatically alter manufacturing processes allowing mass customization with only a fractional increase in cost.*

# ABOUT FUTURE IQ

## 6.0 ABOUT FUTURE IQ

### GLOBAL PRESENCE – LOCAL SOLUTIONS

Future iQ is a market leader in the development and application of scenario planning; network analysis, industry and regional analysis, and stakeholder engagement. We specialize in applying innovative tools and approaches to assist organizations, regions and industries shape their futures. With over a decade of business experience, the company has grown to have a global clientele spanning three continents.

To learn more about Future iQ, and our recent projects visit [www.future-iq.com](http://www.future-iq.com) or by email at [info@future-iq.com](mailto:info@future-iq.com)



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

### AUTHORS



#### Lehna Malmkvist

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



#### David Beurle, CEO

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

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