Future of Smart Manufacturing in a Global Economy

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Broadcom Foundation
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Outline

• Context and trends
• Industry 4.0
• Manufacturing in the 21\textsuperscript{st} Century
• Ideas for the Future
• Conclusions
World Population over the last 12,000 years and UN projection until 2100

OurWorldInData.org/world-population-growth/ • CC BY-SA
World GDP over the last two millennia
Total output of the world economy; adjusted for inflation and expressed in 2011 international dollars.

GDP per capita
Real GDP per capita is measured using US$, inflation adjusted at prices of 2011. A single benchmark in 2011 makes these series suitable for studying the growth of incomes over time (but not for comparing income levels between countries over time).

Source: Maddison Project Database (2018)
Energy consumption growth
Global demographic shifts will drive the coming decades

![Figure 2. Population of the world: estimates, 1950-2015, and medium-variant projection with 95 per cent prediction intervals, 2015-2100](image)


**Table 1. Population of the world and regions, 2017, 2030, 2050 and 2100, according to the medium-variant projection**

<table>
<thead>
<tr>
<th>Region</th>
<th>2017</th>
<th>2030</th>
<th>2050</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>7,550</td>
<td>8,551</td>
<td>9,772</td>
<td>11,184</td>
</tr>
<tr>
<td>Africa</td>
<td>1,256</td>
<td>1,704</td>
<td>2,528</td>
<td>4,468</td>
</tr>
<tr>
<td>Asia</td>
<td>4,504</td>
<td>4,947</td>
<td>5,257</td>
<td>4,780</td>
</tr>
<tr>
<td>Europe</td>
<td>742</td>
<td>739</td>
<td>716</td>
<td>653</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>646</td>
<td>718</td>
<td>780</td>
<td>712</td>
</tr>
<tr>
<td>Northern America</td>
<td>361</td>
<td>395</td>
<td>435</td>
<td>499</td>
</tr>
<tr>
<td>Oceania</td>
<td>41</td>
<td>48</td>
<td>57</td>
<td>72</td>
</tr>
</tbody>
</table>


![Figure 3. Population by region: estimates, 1950-2015, and medium-variant projection, 2015-2100](image)

Gross Domestic Product, 2016

Source: World Bank – WDI

OurWorldInData.org/economic-growth • CC BY-SA
Manufacturing, value added (constant 2010 US$)

World Bank national accounts data, and OECD National Accounts data files.

License: CC BY-4.0
Manufacturing Supply Chains are Global

Boeing 787

A major case study in complex innovative product development and manufacturing

# Apple iPhone

![Apple iPhone Diagram](image)

## Apple iPhone 7 32GB (A1174)

<table>
<thead>
<tr>
<th>Component Category</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Material Costs</td>
<td>$215.80</td>
<td></td>
</tr>
<tr>
<td>Component Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conversion Costs</td>
<td>$5.00</td>
<td></td>
</tr>
<tr>
<td>Assembly / Insertion / Test Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Cost</td>
<td><strong>$220.00</strong></td>
<td></td>
</tr>
</tbody>
</table>

## Important Components

<table>
<thead>
<tr>
<th>Component Category</th>
<th>Manufacturer Name</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple A11, Quad-Core 64-Bit ARM Based CPU, Hexa-Core GPU, 10nm FinFET</td>
<td>TSMC (Apple)</td>
<td>Apple A11, Quad-Core 64-Bit ARM Based CPU, Hexa-Core GPU, 10nm FinFET</td>
<td><strong>$26.90</strong></td>
</tr>
<tr>
<td>Baseband Processor, Multi-Mode</td>
<td>Intel Corp</td>
<td>Baseband Processor, Multi-Mode</td>
<td>$33.90</td>
</tr>
<tr>
<td>RF Transceiver, Multi-Mode (6y 3)</td>
<td>Intel Corp</td>
<td>RF Transceiver, Multi-Mode (6y 3)</td>
<td></td>
</tr>
<tr>
<td>Antenna Switch Module</td>
<td>TDK Corp</td>
<td>Antenna Switch Module w/ Filters</td>
<td></td>
</tr>
<tr>
<td>Antenna Switch Module</td>
<td>TDK Corp</td>
<td>Antenna Switch Module w/ Filters</td>
<td></td>
</tr>
<tr>
<td>Qorvo Inc</td>
<td>Qorvo Inc</td>
<td>Qorvo Inc</td>
<td></td>
</tr>
<tr>
<td>Broadcom Ltd (Avago)</td>
<td>Broadcom Ltd (Avago)</td>
<td>Broadcom Ltd (Avago)</td>
<td></td>
</tr>
<tr>
<td>Skyworks</td>
<td>Skyworks</td>
<td>Skyworks</td>
<td></td>
</tr>
<tr>
<td>Qorvo Inc</td>
<td>Qorvo Inc</td>
<td>Qorvo Inc</td>
<td></td>
</tr>
<tr>
<td>Broadcom Ltd (Avago)</td>
<td>Broadcom Ltd (Avago)</td>
<td>Broadcom Ltd (Avago)</td>
<td></td>
</tr>
<tr>
<td>Skyworks</td>
<td>Skyworks</td>
<td>Skyworks</td>
<td></td>
</tr>
<tr>
<td>Li-Polymer, 3.8V, 1960mAh</td>
<td>Hisense Display</td>
<td>Li-Polymer, 3.8V, 1960mAh</td>
<td>$2.50</td>
</tr>
<tr>
<td>BT / GNSS / WLAN</td>
<td>Universal Scientific Industrial</td>
<td>BT / WLAN Module</td>
<td>$0.00</td>
</tr>
<tr>
<td>GNSS Receiver</td>
<td>Broadcom Ltd</td>
<td>GNSS Receiver</td>
<td></td>
</tr>
<tr>
<td>Front End</td>
<td>Broadcom Ltd</td>
<td>Front End</td>
<td>$39.90</td>
</tr>
<tr>
<td>BT / WLAN &amp; GNSS Front End</td>
<td>Broadcom Ltd</td>
<td>BT / WLAN &amp; GNSS Front End</td>
<td></td>
</tr>
<tr>
<td>7MP, 26mm w/ Fixed Lens</td>
<td>12MP, 138mm f/1.8, w/ AutoFocus, &amp; Optical Image Stabilization</td>
<td>Display</td>
<td>$39.90</td>
</tr>
<tr>
<td>4.7” 1334x750 IPS LCD, w/ In-Cell Touch</td>
<td>4.7” 1334x750 IPS LCD, w/ In-Cell Touch</td>
<td>Display</td>
<td>$39.90</td>
</tr>
<tr>
<td>Taptic Engine</td>
<td>Taptic Engine</td>
<td>Mechanicals</td>
<td>$18.20</td>
</tr>
<tr>
<td>Antennas, Connectors, Microphones, PCBs, Speakers, etc.</td>
<td>Lattice Semiconductor</td>
<td>Memory</td>
<td>$16.40</td>
</tr>
<tr>
<td>Processors, Transistors, Diodes, etc.</td>
<td>SK Hynix</td>
<td>Power Management</td>
<td>$7.20</td>
</tr>
<tr>
<td>PMIC, Main</td>
<td>Dialog Semiconductor</td>
<td>PMIC, Main</td>
<td></td>
</tr>
<tr>
<td>PMIC, RF</td>
<td>Intel</td>
<td>PMIC, RF</td>
<td></td>
</tr>
<tr>
<td>Audio Codec</td>
<td>Cirrus Logic</td>
<td>Audio Codec</td>
<td></td>
</tr>
<tr>
<td>Audio Amplifier</td>
<td>Cirrus Logic</td>
<td>Audio Amplifier (2y 3)</td>
<td></td>
</tr>
<tr>
<td>NFC Controller</td>
<td>Nordic</td>
<td>NFC Controller</td>
<td></td>
</tr>
<tr>
<td>Internal vs. external, passive, etc.</td>
<td>Miscellaneous</td>
<td>Sensors</td>
<td></td>
</tr>
<tr>
<td>Barometric Pressure Sensor</td>
<td>Bosch Sensortec GmbH</td>
<td>Other Sensors</td>
<td></td>
</tr>
<tr>
<td>Electronic Compass</td>
<td>AltiPace</td>
<td>Box Contents</td>
<td>$11.80</td>
</tr>
<tr>
<td>Accelerometer, Gyroscope, Touch ID Fingerprint sensor, A7/A8/Proximity sensor, etc.</td>
<td></td>
<td>Lightning Cable</td>
<td>USB to Lightning</td>
</tr>
<tr>
<td>Audio Adapter, Lighting to 3.5mm Jack</td>
<td>Lightning to 3.5mm Audio Adapter</td>
<td>Audio Adapter</td>
<td></td>
</tr>
<tr>
<td>Lightning Connector, w/ Lightning Connector</td>
<td>Headset w/ Lightning Connector</td>
<td>Headset, Stereo, w/ Lightning Connector</td>
<td></td>
</tr>
<tr>
<td>Wall to USB Type A Jack, 6V, 1A</td>
<td>Charger</td>
<td>Chargers</td>
<td></td>
</tr>
<tr>
<td>Box Contents</td>
<td></td>
<td>Bases and Supports</td>
<td></td>
</tr>
</tbody>
</table>

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Summary of Key Drivers

• Population growth and demographic changes
• Global economy, supply chains, trade, and talent flows
• Intense and growing competition
• Economic prosperity under sustainability constraints
What is Advanced Manufacturing?

“What is Advanced Manufacturing? The President’s Council of Advisors on Science and Technology defined Advanced Manufacturing as follows:

“Advanced manufacturing is a family of activities that

• depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or

• make use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry, and biology.

It involves both new ways to manufacture existing products, and the manufacture of new products emerging from new advanced technologies.”

President’s Council of Advisors on Science and Technology Report to the President on Ensuring American Leadership in Advanced Manufacturing
How will (smart) manufacturing landscape change in the coming years?
Key Related Terms

• Industry 4.0
  • European vision
  • Fourth Industrial revolution

• Smart Manufacturing
  • US based Smart Manufacturing Leadership Coalition (SMLC)

• Cyber-Physical Systems (CPS)

• Internet-of-Things (IOT)
Fig. 1. Four industrial revolutions.
Figure 5: Stages in the Industrie 4.0 development path (source: FIR e. V. at RWTH Aachen University)
Collaborative interaction

CPS Vision of Industrie 4.0.

Source: Final report of the working group Industrie 4.0 [1]
The McKinsey Digital Compass maps Industry 4.0 levers to the 8 main value drivers.

- **Productivity increase of 3 to 5%**
- **30 to 50% reduction of total machine downtime**
- **20 to 50% reduction in time to market**
- **10 to 40% reduction of maintenance costs**

**Value Drivers**

- **Time to market**
  - Forecasting accuracy increased to 85%+
  - Co-creation/custom innovation
  - Concurrent engineering
  - Rapid experimentation and simulation

- **Supply/demand matching**
  - Data-driven demand prediction
  - Data-driven design to value

- **Quality**
  - Statistical process control
  - Advanced process control
  - Digital quality management

- **Inventories**
  - In-situ 3-D printing
  - Real-time supply-chain optimization
  - Batch size 1

- **Labor**
  - Human-robot collaboration
  - Robotic monitoring and control
  - Digital performance management
  - Automation of knowledge work

- **Asset utilization**
  - Routing flexibility
  - Machine flexibility
  - Remote monitoring and control
  - Predictive maintenance
  - Augmented reality for MRO

- **Resource/processes**
  - Smart energy consumption
  - Intelligent lots
  - Real-time yield optimization

- **Service/after-sales**
  - Predictive maintenance
  - Remote maintenance
  - Virtually guided self-service

**Industry 4.0 Levers**

- **Customer co-creation/open innovation**
- **Concurrent engineering**
- **Rapid experimentation and simulation**

**Notes**

1. Maintenance, repair, and operations.


McKinsey & Company
Implementers have already captured impressive benefits from Industry 4.0. (See the sidebar “Industry 4.0 Drives Tangible Advantages.”) New ways to generate value from Industry 4.0 are still being discovered, and the value will increase as solutions become more mature and widely adopted. Indeed, some of the technologies, such as the following ones, are still at an early stage in terms of maturity or adoption.

- **Simulation.** Simulation technologies, such as digital twin (which enables creating virtual representations of physical objects, processes, and systems), have the potential to reduce commissioning time, facilitate the coding of machines, and improve quality. Companies can use simulation technologies to troubleshoot potential issues on a production line even before putting it in place.

- **Advanced Robots.** Today, the use of advanced robots is mainly limited to collaborative robots, which work in close proximity to humans and are easily programmable. As the technology progresses, robots will be able to apply the output of algorithms and make decisions appropriate for the context. For example, a US technology startup has designed robots that use vision systems and artificial intelligence to analyze the shape and dimensions of a product and apply this information to determine how to pick it up. This is the initial application of a potentially disruptive change.

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### Nine Technologies Are Reshaping Production

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced robots</td>
<td>Autonomous, cooperating industrial robots, with integrated sensors and standardized interfaces</td>
</tr>
<tr>
<td>Additive manufacturing</td>
<td>3D printers, used predominantly to make spare parts and prototypes</td>
</tr>
<tr>
<td></td>
<td>Decentralized 3D printing facilities, which reduce transport distances and inventory</td>
</tr>
<tr>
<td>Augmented reality</td>
<td>Digital enhancement, which facilitates maintenance, logistics, and SOPs</td>
</tr>
<tr>
<td></td>
<td>Display devices, such as glasses</td>
</tr>
<tr>
<td>Simulation</td>
<td>Network simulation and optimization, which use real-time data from intelligent systems</td>
</tr>
<tr>
<td>Horizontal and vertical system integration</td>
<td>Data integration within and across companies using a standard data transfer protocol</td>
</tr>
<tr>
<td></td>
<td>A fully integrated value chain (from supplier to customer) and organization structure (from management to shop floor)</td>
</tr>
<tr>
<td>The Industrial Internet of Things</td>
<td>A network of machines and products</td>
</tr>
<tr>
<td></td>
<td>Multidirectional communication among networked objects</td>
</tr>
<tr>
<td>Cloud computing</td>
<td>The management of huge volumes of data in open systems</td>
</tr>
<tr>
<td></td>
<td>Real-time communication for production systems</td>
</tr>
<tr>
<td>Cybersecurity</td>
<td>The management of heightened security risks due to a high level of networking among intelligent machines, products, and systems</td>
</tr>
<tr>
<td>Big data and analytics</td>
<td>The comprehensive evaluation of available data (from CRM, ERP, and SCM systems, for example, as well as from an MES and machines)</td>
</tr>
<tr>
<td></td>
<td>Support for optimized real-time decision making</td>
</tr>
</tbody>
</table>

Source: BCG analysis.

**Note:** SOP = standard operating procedure. CRM = customer relationship management. ERP = enterprise resource planning. SCM = supply chain management. MES = manufacturing execution system.
Figure 1 - Defining characteristics of Smart Products

**Aware**

*Smart Products* are equipped with sensor technology giving access to condition information regarding the product and its environment.

**Connected**

*Smart Products* are equipped with a M2M communication device that enables interaction and data exchange with other cyber-physical systems.

**Intelligent**

*Smart Products* are equipped with computing power that enables autonomous decision-making and self-learning processes based on defined algorithms.

**Responsive**

*Smart Products* are equipped with control technology that enables autonomous product adaption based on internal or external commands.

Source: Capgemini Consulting
Figure 2 - Value creation through Smart Services and remote service delivery

Smart services enable service-driven business models in product-based industries

E.g. Predictive Maintenance

Collection, storage and analysis of data through digital service infrastructure

Real-time data captured and communicated by CPS

E.g. Installed Base as data source

Smart Products and a digitally enabled service staff are required for offering Smart Services

Service Profitability

Increased service revenues and reduced delivery costs

E.g. Field Service Efficiency

Remote service staff information provision leads to improved field service efficiency

Source: Capgemini Consulting
Figure 8 - Basic structure of a Connected Supply Chain

The supply chain control tower creates transparency along the supply chain by linking data and material flows.

Source: Capgemini Consulting
Figure 10 - The market mechanism enabling Decentralized Production Control

1. Customer order
   - What is your price for this operation?

2. Cutting station 2
   - 150 - No capacity

3. Cutting station 1
   - 50 - Based on my required setup and current schedule

4. Cutting station 3
   - 30 - I'm already set up for this material class
   - Further processing

5. Cyber-physical shop floor
   - M2M communication, information flow
   - Material flow

Source: Capgemini Consulting
### Figure 12 - Business impact: Smart Factory

#### Smart Features

<table>
<thead>
<tr>
<th>Decentralized production control</th>
<th>Automated machine configuration</th>
</tr>
</thead>
</table>

#### Functionality

<table>
<thead>
<tr>
<th></th>
<th>Process cost</th>
<th>Batch size</th>
<th>Lead time</th>
<th>Product quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible production planning &amp; control</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Automated machine configuration</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Detection of inefficiencies</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>●</td>
</tr>
<tr>
<td>Prediction of quality issues</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

#### Influence on Key Success Factors

- Minimization of operating cost by adapting process parameters (e.g. energy / fuel consumption)
- The detection of process inefficiencies through big data analytics is crucially important for reducing process costs
- Predictive detection of machine wear & tear, avoiding unscheduled downtimes (e.g. predictive maintenance)
- Reduction of quality cost through sophisticated simulations (e.g. first-time-right production ramp-up)
Figure 13 - Assessment of Technology Enablers' importance for realizing the value drivers of Industry 4.0

<table>
<thead>
<tr>
<th>Technology Enabler</th>
<th>Mobile</th>
<th>Cloud</th>
<th>M2M</th>
<th>Advanced Analytics</th>
<th>Community Platforms</th>
<th>3D printing</th>
<th>Advanced Robotics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Products</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Smart Services</td>
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<td>Extended Innovation</td>
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<td>Connected Lifecycle Innovation</td>
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<td>Agile Collaboration Networks</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Connected Supply Chain</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Decentralized Production Control</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Data-driven Operational Excellence</td>
<td></td>
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</tr>
</tbody>
</table>

Technology Enabler relevancy: Technology Enabler is of little importance for realizing this value driver ○ ○ ○ Technology Enabler is crucial for realizing this value driver

Source: Capgemini Consulting
Internet of Things in Manufacturing

MANUFACTURING PLANT
- Monitor production flow in near-real time to eliminate waste and unnecessary work in process inventory.
- Implement condition-based maintenance alerts to eliminate machine downtime and increase throughput.

GLOBAL FACILITY INSIGHT
- Manage equipment remotely, using temperature limits and other settings to conserve energy and reduce costs.
- Aggregate product data, customer sentiment, and other third-party syndicated data to identify and correct quality issues.

CUSTOMER SITE
- Transmits operational information to the partner (e.g. OEM) and to field service engineers for remote process automation and optimization.
- Provide cross-channel visibility into inventories to optimize supply and reduce shared costs in the value chain.

GLOBAL OPERATIONS
- I can see my production line status and recommend adjustments to better manage operational cost.
- I gain insight into usage patterns from multiple customers and track equipment deterioration, enabling me to reengineer products for better performance.
- I know when to deploy the right resources for predictive maintenance to minimize equipment failures and reduce service cost.

THIRD-PARTY LOGISTICS
- Implement condition-based maintenance alerts to eliminate machine downtime and increase throughput.

Source: Microsoft
IoT Applications

• The application of IoT is projected to generate $1.2 to $3.7 trillion of value globally by 2025, in four primary forms:
  ▪ operational efficiency;
  ▪ predictive and preventative maintenance;
  ▪ supply chain management;
  ▪ inventories and logistics.

• Factory floor efficiency will have the largest impact
  • Increasing productivity by as much as 25 percent.

• IoT + data analytics + machine learning

Source: McKinsey
Predictive Maintenance

• Using sensors to monitor machinery in real-time, thus “transforming the maintenance model from one of repair and replace to predict and prevent.”

• Example: Ford placed IoT sensors on production equipment:
  • Downstream machines can detect if work pieces from an upstream machine deviate from specifications
  • Possible problems in upstream machines that can be identified and fixed.

• Example: Toyota reduces the burden of recalls by
  • Knowing exactly which machine produced each component of each vehicle
  • Enabling it to track and isolate the problems much more rapidly.

Source: ITIF
Supply Chain Integration

• Firms are likely to see significant improvements in operational efficiencies as intelligent devices connect machines on all the factory floors across a supply chain.

• Example: BMW concept of “connected supply chain”.
  • Upstream Tier 1 and 2 suppliers IoT-enabled their production equipment
  • Track and communicate production machines’ operational status

https://automotivelogistics.media/intelligence/bmw-shaping-self-steering-supply-chain
Inventory Optimization

• IoT can facilitate inventory optimization.

• Example: “iBins” system from Wurth USA
  • intelligent camera technology to monitor the supply boxes
  • wirelessly transmit the data to an inventory-management system
  • automatically reorders supplies as needed.

• IoT-enabled autonomous transport vehicles and robots
  • Factory floor operations
  • Materials transport
  • Logistics systems.

Source: Wurth, McKinsey
Thousands of sensors in each Rolls-Royce engine track everything from fuel flow, pressure and temperature to the aircraft’s altitude, speed and the air temperature.

Data instantly fed back to Rolls-Royce operational centers.

Civil aircraft availability center continuously monitoring data from 4,500 in-service engines.

Providing customers with valuable aftermarket services, e.g., showing airlines how to optimize their routes.
Andrew Ng on AI in Manufacturing

“AI technology is well suited to addressing the challenges facing manufacturing, such as variable quality and yield, inflexible production line design, inability to manage capacity, and rising production costs. AI can help address these issues, and improve quality control ... shorten design cycles, remove supply-chain bottlenecks, reduce materials and energy waste, and improve production yields.”

https://medium.com/@andrewng/revitalizing-manufacturing-through-ai-a9ad32e07814
Issue of Standards

The Alliance for Internet of Things Innovation
Towards the future
Circular Economy

OUTLINE OF A CIRCULAR ECONOMY

PRINCIPLE 1
Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows. ReSOLVE levers: regenerate, virtualise, exchange.

PRINCIPLE 2
Optimise resource yields by circulating products, components, and materials in use at the highest utility at all times in both technical and biological cycles. ReSOLVE levers: regenerate, share, optimise, loop.

PRINCIPLE 3
Foster system effectiveness by revealing and designing out negative externalities. All ReSOLVE levers.
Smart manufacturing technologies can impact some of these areas and enable circular economy.

Much larger role for materials, natural resources, and energy.

It will take more than technology.
Key role for policy and regulations.
Future of Manufacturing

What should/will manufacturing look like in 20 years?

• Sustainable manufacturing for a low carbon future, e.g., circular economy
• Affordable and economic goods and services
• Secure and reliable products, production, logistics, and distribution
• People and jobs: human-centered
UC Irvine is a Leader for the Future of Manufacturing

• Member of two Manufacturing Innovation Institutes:
  
  • Clean Energy Smart Manufacturing Innovation Institute (CSEMII)
  
  • Reducing EMbodied-Energy And Decreasing Emissions (REMADE) Institute
  
• Institute for Design and Manufacturing Innovation (IDMI)
Conclusions

• Industry 4.0 and smart manufacturing will remain at the center of manufacturing revolution for the coming decade or longer
• Enormous challenges and opportunities in manufacturing ahead
• Technological progress will be critical
• But it must be human centered and aimed at societal prosperity and long term sustainability
Thank you!

Comments/ideas/questions?

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