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Executive summary

Fourth Industrial Revolution technologies make environmental sustainability easier.

Lighthouses have established themselves as beacons of the Fourth Industrial Revolution (4IR), adapting to four durable shifts – agility and customer centricity; supply chain resilience; speed and productivity; and eco-efficiency. Among these shifts, eco-efficiency has emerged at the vanguard, its prominence fuelled by increased global concerns about the environmental impact of human activities. United Nations Secretary-General Antonio Guterres called the August 2021 report by the Intergovernmental Panel on Climate Change (IPCC) a “code red for humanity”.

This paper challenges the notion that environmental responsibility is inherently at odds with productivity and, by extension, profitability. Revolutionary sustainability impact lies with green technology and breakthroughs, but 4IR transformations that leverage digital and analytics tools can augment not only green technology but also current production methods by bolstering efficiency. By embracing 4IR-driven transformation, a viable kind of efficiency is possible: i.e., eco-efficiency, wherein sustainability and competitive excellence are not only compatible, but, in fact, interwoven.

Eco-efficiency is the outcome of 4IR technologies which, when directed to solve business problems, simultaneously boost productivity and sustainability. This concept of efficiency has three dimensions. First, it involves digital technology enabling data-informed actions across production and across the end-to-end value chain. Second, it demonstrates measurable improvements across performance indicators such as cost, agility, convenience and quality. Finally, it drives sustainability gains by reducing consumption, resource waste and emissions.

Organizations need first to understand the impact potential that lies with eco-efficiency in order to realize it. If companies are not looking for it – let alone measuring it – they might not fully realize the unclaimed sustainability opportunities hidden in the midst of their 4IR transformations. Opportunities are there. Data collected since the beginning of this project show half of Lighthouses (64%) report sustainability impact as part of their achievements enabled by 4IR transformation.

To address “code red for humanity”, companies must make sustainability part of their business agenda. Lighthouses prove there is room for synergy among technology, productivity and sustainability efforts in different industries; meanwhile, they show others how to accelerate their digitization efforts.

Companies that make a true commitment to environmental stewardship through pledges and corresponding action are setting the bar for sustainability. Those who couple that commitment with the full power of 4IR transformation, thus achieving step-change levels of impact, are leading by example and earning the new designation of Sustainability Lighthouses.
Today’s trends are tomorrow’s standards
The Global Lighthouse Network recognizes industrial leaders

The World Economic Forum, in collaboration with McKinsey & Company, launched the Global Lighthouse Network in 2018. The frontrunner companies that comprise this network continue to demonstrate the true potential of Fourth Industrial Revolution (4IR) technologies to transform the very nature of manufacturing. The 90th Lighthouse has recently been recognized, marking more than a fivefold increase since the launch of the network.

The network’s power has grown through thousands of hours of site visits, both virtual and in person. The site visits unlock the mystery behind each of the 450 advanced use cases in action shared to date. In-depth demonstrations of enablers and commentary from the shopfloor have offered an end-to-end view of these digital transformations. At the site level and across value chains, Lighthouses show what is possible when companies combine bold vision, imaginative leadership and agile working modes to maximize the power of emerging digital technologies.

As the network continues to grow, it becomes increasingly clear that 4IR transformation is possible across geographies and industries. Moreover, the evidence accumulates, bolstering the understanding that four durable shifts in agility and customer centricity, supply chain resilience, speed and productivity, and eco-efficiency are playing out across a diverse set of contexts.1 These are today’s trends – companies from vastly different industries that do very different work are adapting to the same shifts. As they do so, leading companies are showing what lies at the heart of success.
Since publication of the “Reimagining Operations for Growth” white paper, the network has grown with 21 new Lighthouses and 3 designated Sustainability Lighthouses. Determined by an expert panel, the network totals 90 Lighthouses identified across different industry sectors and includes the newest designation of Sustainability Lighthouse.

The Global Lighthouse Network is growing in size and diversity across all industry sectors.

### Consumer packaged goods
- **Alibaba**
  Apparel, China
- **Henkel**
  Consumer goods, Germany
- **Procter & Gamble**
  Consumer goods, China
- **Unilever**
  Consumer goods, China

### Process industries
- **Baoshan Iron & Steel**
  Steel products, China
- **DCP Midstream**
  Oil and gas, USA
- **Renew Power**
  Renewable energy, India
- **Tata Steel**
  Steel products, India

### Advanced industries
- **AGCO**
  Agricultural equipment, Brazil
- **Bosch**
  Automotive, China
- **Ericsson**
  Electronics, USA
- **Foxconn**
  Electronics, China
- **Hitachi**
  Industrial equipment, Japan
- **Micron**
  Semiconductors, Taiwan, China
- **Phoenix Contact**
  Industrial automation, Germany
- **Sany**
  Industrial equipment, China
- **Siemens**
  Industrial automation products, China
- **Wistron**
  Electronics, China

### Pharmaceuticals and medical products
- **Bayer**
  Division pharmaceuticals, Italy
- **GE Healthcare**
  Medical devices, Japan
- **GSK**
  Pharmaceuticals, United Kingdom
- **Johnson & Johnson**
  Consumer Health
  Self-care products, Sweden
- **Novo Nordisk**
  Pharmaceuticals, Denmark
- **Zymergen**
  Biotechnology, USA

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**FIGURE 2** | The Global Lighthouse Network is growing in size and diversity across all industry sectors.
Lighthouses are deploying 124 use cases across manufacturing sites and connecting the value chain end-to-end (1/2)

**Lighthouse use cases: Within manufacturing sites**

### Digital assembly and machines
- Additive manufacturing (3D printing)
- Advanced IIoT applied to process optimization
- AI-guided machine performance optimization
- AI-powered material handling system
- AI-powered process control
- Automated material handling
- Automated tool design
- Collaborative robotics and automation
- Cycle-time optimization through big data analytics on lines PLCs
- Digital engineering
- Digital lean tools (e.g., eKanban, eAndon, eSpaghetti)
- Digital twin for flexible production
- Digitally enabled flexible manufacturing
- Digitally enabled modular production configuration
- Digitally enabled variable takt time
- Light-guided assembly sequence
- Mixed reality to enable digital standard work/trainings
- Real-time locating system (RTLS) for key manufacturing components
- Repair process automation

### Digital maintenance
- Analytics platform for deviation root-cause identification
- Cost optimization of heavy operations through sensor analysis
- Digitally enabled pipeline leak prevention and detection
- Machine alarm aggregation, prioritization and analytics-enabled problem solving
- Predictive maintenance aggregating data based on historical and sensor data
- Remote assistance using augmented reality
- Unmanned vehicles for inspection

### Digital performance management
- Analytics platform for remote production optimization
- Cost optimization of heavy operations through sensor analysis
- Digitally enabled pipeline leak prevention and detection
- Machine alarm aggregation, prioritization and analytics-enabled problem solving
- Predictive maintenance aggregating data based on historical and sensor data
- Remote assistance using augmented reality
- Unmanned vehicles for inspection

### Digital quality management
- Analytics platform for yield management and root-cause analysis
- Artificial intelligence-enabled safety management
- AI-powered optical inspection
- AI-powered automated testing and repair
- Automated in-line optical inspection to replace end-product manual inspections
- Automated inspection enabled by digital thread
- Digital quality audit
- Digital work instructions and quality functions
- Digitally enabled quality failure diagnosis
- Digitized standard procedures for line operations with integrated workflow
- Field quality failures aggregation, prioritization and advanced analytics-enabled problem-solving
- IoT-enabled manufacturing quality management
- Mixed reality glasses to guide operators in the end-of-line inspection
- Quality improvement by predictive analytics
- Scanning to replace and improve performance for high-cost coordinated measuring machines (CMM)

###Digitally enabled sustainability
- Advanced analytics enabled clean water reduction and contaminated water cleaning optimization
- End-to-End CO2 tracking and reporting across entire value chain
- Advanced analytics enabled sustainability optimization
- Digital twin for sustainability
- IoT real-time sensor based data aggregation for energy, emissions, waste, and water management
### Lighthouse use cases: Connecting the value chain end-to-end

<table>
<thead>
<tr>
<th>Supply network connectivity</th>
<th>E2E product development</th>
<th>E2E planning</th>
<th>E2E delivery</th>
<th>Customer connectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agile buying through price prediction</td>
<td>Advanced analytics for performance management across the idea to market</td>
<td>Advanced analytics to optimize manufacturing and distribution footprint</td>
<td>Asset use and yard management for logistics</td>
<td>AI-enabled customer support</td>
</tr>
<tr>
<td>Aggregate demand across end-to-end supplier network</td>
<td>Automated design for manufacturing analysis</td>
<td>Analytics for dynamic warehouse resource planning and scheduling</td>
<td>ATP based on real-time constraints</td>
<td>Connected devices to track and measure consumer behaviours</td>
</tr>
<tr>
<td>Analytics-driven procurement supported by spend intelligence and automated spend cube</td>
<td>Big-data/AI-enabled product design and testing</td>
<td>Closed loop planning</td>
<td>Digital-enabled picking and transport</td>
<td>Connected devices to track and measure product performance</td>
</tr>
<tr>
<td>Analytics-driven supply risk prediction</td>
<td>Crowd-sourcing and competitions to develop digital solutions</td>
<td>Digital integrated business planning</td>
<td>Digital logistics control tower</td>
<td>Customer analytics enabled by RFID</td>
</tr>
<tr>
<td>AI to accelerate scaling of digital applications across sites</td>
<td>Digital thread implementation through product development lifecycles</td>
<td>Dynamic network optimization</td>
<td>Digital track and trace</td>
<td>Customer end-user interface to configure and order a product, and track delivery</td>
</tr>
<tr>
<td>AI-powered contract review for decision making</td>
<td>Product development using robotics</td>
<td>Dynamic production scheduling with digital twin</td>
<td>Dynamic delivery optimization</td>
<td>Delivering to customers wherever they are through new delivery solutions</td>
</tr>
<tr>
<td>Digital supplier performance management</td>
<td>Rapid outsourced prototyping</td>
<td>Dynamic simulation for warehousing design</td>
<td>No-touch order management</td>
<td>Digital Twin of Customer System</td>
</tr>
<tr>
<td>Digitally enabled automatic material call-off system</td>
<td>Testing automation</td>
<td>End-to-end real-time supply chain visibility platform</td>
<td>Predictive maintenance in fleet assets</td>
<td>Digitally enabled customer performance monitoring</td>
</tr>
<tr>
<td>Digitally enabled negotiations</td>
<td>Virtual reality supported prototyping</td>
<td>No-touch master planning (allocation to the plants)</td>
<td>Robotics-enabled logistics execution</td>
<td>Digitally enabled final-mile personalization</td>
</tr>
<tr>
<td>Joint data analytics with equipment OEM for process optimization</td>
<td>3D printing for rapid design prototyping</td>
<td>Predictive demand forecasting</td>
<td>“Uberization” of transport</td>
<td>Digitally enabled real-time connectivity with customer system</td>
</tr>
<tr>
<td>Part traceability from unique digital tag based on surface scanning</td>
<td>3D simulations/digital twin for product design and testing</td>
<td>Predictive inventory replenishment</td>
<td>3D printing</td>
<td>GPS-based map and customer location</td>
</tr>
<tr>
<td>Should-cost modelling to support make-versus-buy decisions</td>
<td></td>
<td>Production planning optimized by advanced analytics</td>
<td></td>
<td>Market insights generated by Advanced Analytics</td>
</tr>
<tr>
<td>Supplier and materials quality tracking</td>
<td></td>
<td>Real-time inventory management (internal/external)</td>
<td></td>
<td>Mass customization and B2C online ordering</td>
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<tr>
<td>Supplier material delivery by e-Kanban</td>
<td></td>
<td>Real-time sales and operations planning (S&amp;OP)</td>
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<td>Online communities for customer insights</td>
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<tr>
<td>Supplier material quality prediction using advanced analytics</td>
<td></td>
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<td>Smart/Intelligent packaging</td>
</tr>
</tbody>
</table>
## Asia

<table>
<thead>
<tr>
<th>Site</th>
<th>Change story</th>
<th>Use case</th>
<th>Impact</th>
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</thead>
<tbody>
<tr>
<td><strong>AUO Taichung</strong></td>
<td>Facing challenges such as labour shortage, highly customized products requirements and extreme climate conditions in the very competitive industry of display panels, AUO Taichung Fab 3 invested in customized automation and developed a digital analytics and AI development platform to improve productivity by 32% and yield of advanced product by 60%, while reducing water consumption by 23% and carbon emissions by 25%</td>
<td>Automated material handling</td>
<td>▲ 12% Productivity</td>
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<td></td>
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<td>AI-powered automated testing and repair</td>
<td>▼ 3% Scrap cost</td>
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<td>Advanced IoT applied to process optimization</td>
<td>▲ 8.5% Sputter OEE</td>
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<td>Predictive maintenance aggregating data based on historical and sensor data</td>
<td>▲ 32% Maintenance cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Advanced analytics enabled sustainability optimization</td>
<td>▼ 20% Carbon emission</td>
</tr>
<tr>
<td><strong>CITIC Dicastal Qinhuangdao</strong></td>
<td>Faced with rising expectations from automotive OEMs for smaller batch size and higher quality, CITIC Dicastal deployed flexible automation, AI and 5G to build a digital manufacturing system to improve flexibility with a batch size of one and reduce manufacturing cost by 33%</td>
<td>AI-powered optical inspection</td>
<td>▼ 81% Manpower for inspection</td>
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<td>Digital-enabled flexible manufacturing</td>
<td>▼ 99.7% Minimal batch size</td>
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<td>AI-enabled CNC quality expert system</td>
<td>▼ 23% OEE CNC</td>
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<td></td>
<td>3D simulations/digital twin for product design and testing</td>
<td>▼ 38% Cycle time</td>
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<tr>
<td></td>
<td></td>
<td>Real-time asset performance monitoring and visualization</td>
<td>▼ 38% Labor productivity</td>
</tr>
<tr>
<td><strong>Contemporary Amperex Technology Co. Ltd. Ningde</strong></td>
<td>Confronted with increasing manufacturing process complexity and demand for high product quality, CATL leveraged AI, advanced analytics and edge/cloud computing to achieve, in 3 years, a defect rate per billion count at the speed of 1.7s per cell, while improving labour productivity by 75% and reducing energy consumption by 10% a year</td>
<td>AI-powered process control</td>
<td>▲ 75% Labor productivity</td>
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<td>AI-powered optical inspection</td>
<td>▼ 80% Defect parts per billion</td>
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<td>Big data/AI-enabled product design and testing</td>
<td>▼ 50% Research &amp; development cycle</td>
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<td>Digital track and trace</td>
<td>▼ 80% Manpower for screening tests</td>
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<tr>
<td></td>
<td></td>
<td>IoT real time sensor-based data aggregation for energy, emissions, and waste management</td>
<td>▼ 10% Energy consumption per year</td>
</tr>
<tr>
<td><strong>Foxconn Wuhan</strong></td>
<td>To meet customer requirements for greater customization and shorter product order lead time, Foxconn Wuhan leveraged advanced analytics and flexible automation at scale to redesign its manufacturing system leading to an 86% increase in direct labour productivity, and reducing quality loss by 38% and order lead time by 29%, down to 48 hours</td>
<td>AI-powered optical inspection</td>
<td>▼ 50% SMT misalignment</td>
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<td>Digitally enabled man-machine matching</td>
<td>▼ 23% Labor productivity</td>
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<td>Lights-out injection moulding workshop</td>
<td>▼ 38% Manufacturing lead time</td>
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<td>Intelligent kitting and replenishment</td>
<td>▼ 40% Kitting efficiency</td>
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<td></td>
<td></td>
<td>Advanced analytics enabled sustainability optimization</td>
<td>▼ 37% Energy consumption per unit</td>
</tr>
<tr>
<td><strong>Foxconn Zhengzhou</strong></td>
<td>Confronted with the lack of skilful workers, unstable quality performance and demand uncertainty, Foxconn Zhengzhou adopted flexible automation to improve labour productivity by 102%, and utilized digital and AI technologies to reduce quality defects by 38% and improve OEE by 27%</td>
<td>Repair process automation</td>
<td>▲ 60% Testing labour efficiency</td>
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<td>Automated material handling</td>
<td>▲ 75% Labour for material delivery and feeding</td>
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<td>Quality improvement by predictive analytics</td>
<td>▲ 15% Quality defect rate</td>
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<td></td>
<td></td>
<td>IoT real time sensor-based data aggregation for energy, emissions, and waste management</td>
<td>▲ 30% Energy efficiency for Factory Management Control System</td>
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<td></td>
<td>IoT-enabled manufacturing quality management</td>
<td>▼ 27% OEE</td>
</tr>
<tr>
<td><strong>Haier Tianjin</strong></td>
<td>To meet increased customers’ expectations for diversified products, faster delivery and higher quality of service, Haier’s greenfield washing machine factory in Tianjin integrated 5G, IoT, automation and advanced analytics to accelerate product design by 50%, reduce defects by 26% and save energy consumption per unit by 18%</td>
<td>3D simulations/digital twin for product design and testing</td>
<td>▼ 50% Research &amp; development lead time</td>
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<tr>
<td></td>
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<td>Flexible manufacturing: Hybrid assembly line to meet customer orders</td>
<td>▼ 50% Order fulfillment lead time</td>
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<td>Automated material handling</td>
<td>▼ 67% Line inventory</td>
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<td>Advanced analytics enabled sustainability optimization</td>
<td>▲ 18% Energy consumption per unit</td>
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<tr>
<td></td>
<td></td>
<td>Big data/AI-enabled product design and testing</td>
<td>▲ 27% OEE</td>
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<tr>
<td><strong>Innolux Kaohsiung</strong></td>
<td>In the context of fierce competition in the panel industry, and faced with increasing quality requirement from customers and severe decline in gross profit, Innolux fab 8 invested in advanced automation, IoT technology and advanced analytics to improve process capability by 40%, reduce yield loss by 33% and in return unlock niche products production</td>
<td>AI-powered process control</td>
<td>▲ 40% Process capability</td>
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<td></td>
<td></td>
<td>AI-powered automated testing and repair</td>
<td>▼ 95% Yield loss rate</td>
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<td>Supplier material quality prediction using advanced analytics</td>
<td>▲ 40% Quality events</td>
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<td>Digitally-enabled quality failure diagnosis</td>
<td>▼ 91% Quality alert time</td>
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<td></td>
<td></td>
<td>Predictive maintenance aggregating data based on historical and sensor data</td>
<td>▲ 2.3% OEE of bottleneck machine</td>
</tr>
</tbody>
</table>

**FIGURE 5** New Lighthouses show a variety of use cases
### Site | Change story | Use case | Impact
--- | --- | --- | ---
**Asia** continued

<table>
<thead>
<tr>
<th>Company</th>
<th>Site</th>
<th>Change story</th>
<th>Use case</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS ELECTRIC</td>
<td>Cheongju</td>
<td>To respond to an increase in demand and the need to reduce costs, LS ELECTRIC has transformed one of its plants in Cheongju, South Korea, with an IoT-based automation, machine learning-powered inspection and advanced process control, enabling mass customization and lowering production cost by 20%</td>
<td>Digital-enabled flexible manufacturing</td>
<td>▼ 87% Equipment set-up time</td>
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<td>Automated material handling</td>
<td>▼ 39% Logistics labour</td>
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<td></td>
<td>AI-powered optical inspection</td>
<td>▼ 33% Defect rate</td>
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<td></td>
<td>Quality improvement by predictive analytics</td>
<td>▲ 80% Inspection accuracy</td>
</tr>
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<td></td>
<td>AI-powered process control</td>
<td>▼ 30% Warranty claims</td>
</tr>
<tr>
<td>Sany</td>
<td>Beijing</td>
<td>Confronted with growing demand and rising complexity in the multi-category and small-batch heavy machinery market, SANY Beijing deployed advanced human-machine collaboration automation, AI and IoT Technologies to boost labour productivity by 85% and reduce production lead time by 77% from 30 to 7 days</td>
<td>Adaptive welding with intelligent robot</td>
<td>▲ 130% Welding production efficiency</td>
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<td></td>
<td>AI-guided machine performance optimization</td>
<td>▲ 100% Production capacity</td>
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<td>Collaborative robotics and automation</td>
<td>▲ 83% Model change time</td>
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<td>5G-based dual AGV heavy-duty logistics</td>
<td>▲ 50% Average transferring time</td>
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<td></td>
<td></td>
<td></td>
<td>AI-guided machine performance optimization</td>
<td>▲ 31% Machine efficiency</td>
</tr>
<tr>
<td>Schneider Electric</td>
<td>Wuxi</td>
<td>Schneider Electric's 20-year-old electronics parts factory in Wuxi, China, confronted increased demand for product adaptation and order configuration with a flexible production line by deploying 4R technologies such as modular cobot-stations and AI vision inspection to reduce time-to-market by 25%, and advanced analytics to auto-generate root cause analysis and detect anomalies across the supply chain, which have increased on-time delivery by 30%</td>
<td>End-to-end real-time supply chain visibility platform</td>
<td>▲ 30% On-time delivery</td>
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<td></td>
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<td></td>
<td>Field quality failure aggregation, prioritization and advanced analytics enabled problem-solving</td>
<td>▼ 72% Warranty cost</td>
</tr>
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<td>Digital-enabled flexible manufacturing</td>
<td>▲ 25% Time to market</td>
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<td>Robotics-enabled logistics execution</td>
<td>▲ 43% Warehouse labour</td>
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<td></td>
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<td></td>
<td>Digital twin for sustainability</td>
<td>▲ 32% HVAC energy consumption</td>
</tr>
<tr>
<td>Unilever</td>
<td>Taicang</td>
<td>To seize the booming business in e-commerce and big-box channel, Unilever Taicang ice cream factory deployed one-scan, one-view platform to provide E2E supply chain visibility in manufacturing and food handling for customers, and combined the digital voice of consumers with agile R&amp;D digital platform to improve innovation lead time by 75%, from 12 to 3 months</td>
<td>One-click AI sales forecasting</td>
<td>▲ 92% Forecast efficiency</td>
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<td>Digital-enabled flexible manufacturing</td>
<td>▲ 98% Change-over time</td>
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<td>AI-powered process control</td>
<td>▲ 95% Quality defect rate</td>
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<td>Market insights generated by advanced analytics</td>
<td>▲ 75% Innovation lead time</td>
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<td>Digital track and trace</td>
<td>▲ 28% Sales growth</td>
</tr>
<tr>
<td>Western Digital</td>
<td>Penang</td>
<td>With an increase in flash memory demand of more than 2X, stringent quality requirements and the need to optimize costs, Western Digital Penang embarked on lights-out manufacturing journey based on Fourth Industrial Revolution technologies. By automating production and logistics, they were able to deliver 32% factory cost improvement, and transitioned to build-to-order with intelligent planning system, thereby reducing product inventory and order lead time by 50%</td>
<td>Lights-Out Automation with Digitized Warehouse</td>
<td>▲ 360% Labour productivity in manufacturing and warehouse</td>
</tr>
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<td>APV Fleet Optimization with Digital Twin and AI/ML</td>
<td>▲ 15% OEE</td>
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<td>Production planning optimized by advanced analytics</td>
<td>▲ 55% Manufacturing lead time</td>
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<td>Quality improvement by predictive analytics</td>
<td>▲ 50% Annualized failure rate</td>
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<td></td>
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<td></td>
<td>Predictive maintenance aggregating data based on historical and sensor data</td>
<td>▲ 60% Quality excursion reduction in assembly process</td>
</tr>
<tr>
<td>Western Digital</td>
<td>Prachinburi</td>
<td>With rapidly growing demand, rigorous quality requirements and cost pressure for hard disk drive (HDD), Western Digital Thailand leveraged connectivity and advanced analytics technologies to transform a capacity-saturated manufacturing site into a digital operation system with real-time visibility in suppliers, production, logistics and customers and data-based insights and predictions, ultimately increasing factory output by 123%, avoiding 30% in procurement and production costs, and reducing product return rate by 43%</td>
<td>Analytics driven supply risk prediction</td>
<td>▲ 32% Procurement material cost avoidance</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Supplier material quality prediction using advanced analytics</td>
<td>▲ 41% Scrap cost avoidance</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Analytics platform for remote production optimization</td>
<td>▲ 7% OEE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Field quality failures aggregation, prioritization and advanced analytics enabled problem-solving</td>
<td>▲ 43% Annual rate-of-return improvement over two years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dynamic delivery optimization</td>
<td>▲ 46% Logistic cost</td>
</tr>
</tbody>
</table>
### Europe

<table>
<thead>
<tr>
<th>Site</th>
<th>Change story</th>
<th>Use case</th>
<th>Impact</th>
</tr>
</thead>
</table>
| **De’ Longhi**  
Treviso | In order to step up competitiveness, De’Longhi’s Treviso plant invested in digital and analytics to become more agile (reducing minimum order quantity by 92% and lead time by 82%), more productive (improving labour productivity by 33%), and achieve high standard quality (improving field quality by 33% and obtaining Food and Beverage industry certification) | Digital-enabled flexible manufacturing  
Digital track and trace  
Quality improvement by predictive analytics  
Digital dashboards to monitor OEE performance  
Digitally enabled man-machine matching | ▼ 92% Minimum order quantity  
▼ 7% Warranty repair cost  
▲ 30% Machine lifespan  
▼ 7% Asset utilization  
▼ 15% Scrap |
| **Flex**  
Althofen | Confronted with strong competition from lower-cost regions, Flex’s site in Althofen deployed 4IR technologies to improve operational efficiency and agility. By meeting higher regulatory and quality standards, Flex attracted higher margin and longer lifecycle medical business, increasing revenue by 50% within the same physical footprint | End-to-end real-time supply chain visibility platform  
Digital tools to enhance a connected workforce  
Cycle time optimization through big-data analytics on lines PLCs  
IoT real-time sensor based data aggregation for energy, emissions, waste, and water management  
Automated material handling | ▲ 25% Customer satisfaction  
▼ 85% Line clearance time  
▼ 24% SMT placement performance  
▼ 16% Energy reduction per employee  
▼ 72% Work-in-progress |
| **Johnson & Johnson Vision Care**  
London | J&J Vision Care transformed customer experience, through personalized 4IR technologies using Adaptive Process Control, AI and robotics to offset increasing complexity (+ 50% SKUs) which enabled 100% personalized packaging configurations, 8 percentage point increase in customer service level, and reduced the carbon footprint for inbound freight by 50% | Customer end-user interface to configure and order a product and track delivery  
Digital logistics control tower  
AI enabled customer support  
Digitally enabled final mile personalization  
Robotics-enabled logistics execution | ▲ 10% Order automation growth to 93%  
▼ 100% Warehouse stock management  
▲ 10% Research & development cycle  
▲ 86% Manpower for label application  
▲ 26% Lenses shipped |

### Middle East

<table>
<thead>
<tr>
<th>Site</th>
<th>Change story</th>
<th>Use case</th>
<th>Impact</th>
</tr>
</thead>
</table>
| **Arçelik**  
Eskişehir | Confronted with rising customer demand and increasing product diversity, Arçelik leveraged their agile studio to deploy in 2 years over 30 advanced use cases across automation, robotics-enabled logistics and data-driven AI systems to enable flexible manufacturing with a return of investment of 1.2 years | Analytics platform for remote production optimization  
Digital-enabled flexible manufacturing  
Quality improvement by predictive analytics  
AI-powered process control  
Automated material handling | ▲ 18% Test capacity  
▼ 81% Set-up time of pre-assembly line  
▼ 40% Scrap  
▲ 4x Process capability  
▼ 89% Assembly line stoppages |
| **Saudi Aramco**  
Abqaiq | Motivated by the need to access new levels of quality and sustainability, the 70-year-old world’s largest oil processing and crude stabilization plant has harnessed the power of data, advanced analytics and automation to transform its manufacturing processes, achieving a 21% increase in product quality and 14.5% reduction in energy use | Unmanned vehicles for inspection  
AI-powered process control  
AI-powered process control  
AI-powered maintenance aggregating data based on historical and sensor data  
Digital twin for sustainability | ▼ 80% Operator risk exposure  
▲ 35% Customer satisfaction  
▲ 11% Energy intensity  
▼ 20% Unplanned maintenance  
▲ 5% Power generation |
This 1970's factory characterized by low-mix, high-volume production, set out on a 4IR transformation journey centred on people, data transparency and availability to reduce processing costs by 15%, energy consumption by 14% and enhance plant OEE up to 90%.

Faced with high complexity, cost pressure and operating room inefficiencies, DePuy Synthes deployed “Advanced Case Management”, a 4IR programme leveraging open API architecture, machine-learning algorithms and a suite of digital tools across its joint restoration implant portfolio (hips and knees) value chain in North America to reduce the number of instrument trays in the operating room by 63%, implant inventory by 40% and ultimately lowering the time to set up the operating room by approximately 15% per location.

Protolabs is a digital native manufacturer that embarked on a transformation journey taking it from a prototyping-only provider to a production supplier by leveraging its digital thread to connect customers to its injection molding production services. As a result, it outperforms traditional manufacturing competitors by reducing production lead-times down to as low as 1 day and generating a gross margin 20 points of percentage above industry average.

Ericsson’s greenfield 5G factory is powered 100% by renewable electricity from on-site solar and green-e® certified renewable electricity from the utility grid. The smart factory integrates sustainable technologies such as thermal ice storage tanks with the IIoT stack to proactively monitor energy usage and is designed to utilize 24% less energy and 75% less indoor water usage, avoiding 97% operational carbon emission** than comparable buildings. This year it became Ericsson’s first factory globally to achieve LEED Gold® certification.

In an effort to improve visibility into factory consumption to drive better decision-making, Henkel deployed utility meters on machines integrated in a digital twin that connects and benchmarks 30 factories and prescribes real-time sustainability actions that has led to 38% less energy (kWh/tonne) used, and has reduced water consumption 28% (m³/tonne), and waste 20% (kg/tonne) across factory baselines set in 2010.

In order to capture greater energy consumption granularity, when and where it happens in the plant, the Lexington smart factory leveraged IoT connectivity with power meters and predictive analytics to optimize energy cost, and as a result led to 26% energy reduction (GWh), 30% net CO₂ reduction, and 20% water use reduction and Superior Energy Performance 50001™ certification by the US Department of Energy.

*Sustainability Lighthouses show 4IR-enabled sustainability impact

Ericsson
Lewisville, US

Henkel
Düsseldorf, Germany

Schneider Electric
Lexington, US

100% Electricity from renewable sources

97% Reduction in carbon emissions

14% Factory designed to reduce indoor water consumption

24% Factory designed to reduce electricity usage

38% Less energy utilized

28% Reduced water consumption

20% Reduced waste across factory

26% Reduced energy consumption

30% Reduction in net CO₂ emission

20% Reduced water consumption

* Emission calculations uses EPA Greenhouse Gas Equivalencies Calculator

** Impact measured in tonnes of CO₂ compared to brownfield factory
A detailed look at Lighthouse success cases reveals that organizations investing in 4IR technology are realizing improvements in productivity, sustainability, operating costs, customization and speed to market. Companies that drive competitive efficiency through digital transformation can make every kilowatt hour count and every natural resource matter, using every machine and square foot of production space to its fullest, optimized potential.

### FIGURE 7

Lighthouses show 4IR-enabled sustainability impact

<table>
<thead>
<tr>
<th>KPIs improvements</th>
<th>Impact range observed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sustainability</strong></td>
<td></td>
</tr>
<tr>
<td>Greenhouse gas emissions reduction</td>
<td>100%</td>
</tr>
<tr>
<td>Waste reduction</td>
<td>4-80%</td>
</tr>
<tr>
<td>Water consumption reduction</td>
<td>5-65%</td>
</tr>
<tr>
<td>Energy efficiency</td>
<td>1-58%</td>
</tr>
<tr>
<td><strong>Productivity</strong></td>
<td></td>
</tr>
<tr>
<td>Factory output increase</td>
<td>2-140%</td>
</tr>
<tr>
<td>Productivity increase</td>
<td>4-250%</td>
</tr>
<tr>
<td>OEE increase</td>
<td>2-84%</td>
</tr>
<tr>
<td>Product cost reduction</td>
<td>4-70%</td>
</tr>
<tr>
<td>Operating cost reduction</td>
<td>3-92%</td>
</tr>
<tr>
<td>Quality cost reduction</td>
<td>2-99%</td>
</tr>
<tr>
<td><strong>Agility</strong></td>
<td></td>
</tr>
<tr>
<td>Inventory reduction</td>
<td>5-100%</td>
</tr>
<tr>
<td>Lead-time reduction</td>
<td>10-99%</td>
</tr>
<tr>
<td>Change-over shortening</td>
<td>11-100%</td>
</tr>
<tr>
<td>On-time delivery increase</td>
<td>16-30%</td>
</tr>
<tr>
<td><strong>Speed to market</strong></td>
<td></td>
</tr>
<tr>
<td>Speed-to-market reduction</td>
<td>10-89%</td>
</tr>
<tr>
<td>Design iteration time reduction</td>
<td>2-98%</td>
</tr>
<tr>
<td><strong>Customization</strong></td>
<td></td>
</tr>
<tr>
<td>Lot size reduction</td>
<td>40-100%</td>
</tr>
</tbody>
</table>

Source: World Economic Forum Global Lighthouse Network
4IR enhances sustainability and productivity
2.1 Eco-efficiency: A vital response to the global call for climate action

The Paris Agreement seeks to stave off global temperature rise this century, limiting it to less than 2°C above pre-industrial levels. Moreover, it compels efforts to limit the increase even more ambitiously to less than 1.5°C. By 2020, 83 countries and the European Union (EU) had reported a total of 700 policies related to sustainable consumption and production to achieve these goals.

In contrast, however, only 40 countries had by 2020 reported on sustainable public-procurement policies or plans that would encourage environmentally-efficient products, promote more socially-responsible purchasing practices, and increase the sustainability of supply chains. United Nations Secretary-General Antonio Guterres, called the August 2021 report by the Intergovernmental Panel on Climate Change (IPCC) a “code red for humanity”.

It is this call-to-action that puts eco-efficiency at the vanguard of the durable shifts. Eco-efficiency is the outcome of 4IR technologies which, when directed to solve business problems, simultaneously boost productivity and sustainability. As companies achieve eco-efficiency, they challenge the notion that environmental responsibility is inherently at odds with increasing operational performance.

2.2 4IR accelerates sustainability

This bolstered global environmental consciousness has made sustainability a must-have to maintain business viability; moreover, it is necessary to comply with increasingly complex regulations. As they respond to this urgent call to action, industrials can take heart in learning that alongside more immediately recognizable green initiatives such as renewable energy sourcing, the same digital transformation efforts that yield positive return on investment (ROI) also introduce a range of sustainability benefits.

As pressure from climate change increases year by year, an encouraging lesson has emerged: while the greatest environmental benefits come from core green sustainability initiatives (e.g., commitments to renewable energy), 4IR technologies make being sustainable easier. Those companies that are able to solve business problems while simultaneously reducing environmental detractors such as waste, consumption and emissions are at the leading edge of sustainability in the Fourth Industrial Revolution. The following sections provide data illustrating the kind of impact Lighthouses are achieving and take a closer look at five case studies involving 4IR technologies and sustainability improvement.
Lighthouses show the way: Measurable sustainability impact
Most lighthouses report that their 4IR transformation improves sustainability

Well over half of Lighthouses (64%) report sustainability impact as part of their 4IR transformation, deriving from both direct and indirect impact use cases. For example, among the 14 Lighthouses in Process Industries, 29% report sustainability gains on KPIs deriving from direct impact sustainability use cases, but 50% of them report indirect impact from other use cases.

Similarly, but even more telling, while 25% of the 12 Consumer Packaged Goods Lighthouses cite direct sustainability use case impact, a full 50% report impact stemming from indirect use cases – 4IR efforts aimed at solving different business problems. Among Advanced Industries and Pharma & Medical Products, the breakdown is more evenly distributed.

The 4IR efforts – both those directly aimed at impacting sustainability and use cases aimed at entirely different purposes – are having positive effects for the environment.

Of course, achieving either sustainability impact alone, or efficiency alone, does not equate to achieving eco-efficiency. To truly address our “code red for humanity”, the combination is a must.

To achieve it, companies must make sustainability a driving force of their business agendas. Lighthouses again show this is happening among leaders.

Source: World Economic Forum Global Lighthouse Network
**FIGURE 10** Lighthouses reporting sustainability improvement also show productivity increase

<table>
<thead>
<tr>
<th>KPI improvements</th>
<th>Impact range observed*</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG emissions reductions</td>
<td></td>
</tr>
<tr>
<td>Waste reduction</td>
<td></td>
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<tr>
<td>Water consumption reduction</td>
<td></td>
</tr>
<tr>
<td>Energy efficiency</td>
<td></td>
</tr>
<tr>
<td>Factory output increase</td>
<td></td>
</tr>
<tr>
<td>Productivity increase</td>
<td></td>
</tr>
<tr>
<td>OEE increase</td>
<td></td>
</tr>
<tr>
<td>Product cost reduction</td>
<td></td>
</tr>
<tr>
<td>Operating cost reduction</td>
<td></td>
</tr>
<tr>
<td>Quality cost reduction</td>
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</table>

* Each dot represents a single Lighthouse that recorded this impact
Unlocking sustainability: A closer look
The three most common direct impact sustainability use cases among Lighthouse sites demonstrate advanced technology being applied intentionally to meet sustainability goals:

– The most direct utilizes IIoT (industrial internet of things) sensors and data visualization to monitor equipment performance and provide early warnings for resource consumption.

– Another advanced use case involves the use of digital twins to create a dynamic energy model that recommends how to optimize high-energy consumption processes.

– The most dynamic use case employs advanced analytics to power real-time energy management systems capable of auto-adjusting settings.

Additionally, a wide range of use cases provide indirect sustainability impact. Two impactful advanced use cases serve as good examples:

– Digital delivery optimization uses advanced analytics to consolidate shipments, which in turn provides emissions benefits.

– Artificial intelligence-enabled process improvement utilizes automation software to improve workflow and traceability alongside flexible real-time resourcing to eliminate human error in the product lifecycle. This reduces rejected material waste while improving energy efficiency along the production line.

Now we’ll take a closer look at five eco-efficiency case studies to see how these top advanced use cases achieve sustainability improvements. It is worth noting that these case studies provide insights from across broadly divergent industries in the manufacturing sector, ranging from refineries to advanced electronics. While three of these case study sites employ the most common direct impact use cases described above, two show how indirect impact use cases mentioned above can also have a prominent effect.

FIGURE 11

4IR technologies enable sustainability

<table>
<thead>
<tr>
<th>Use cases</th>
<th>Case studies</th>
<th>4IR technology driving impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct impact sustainability use case:</strong> Purpose-built to optimize resource efficiency</td>
<td><strong>IoT/sensor and visualization for production sustainability</strong></td>
<td>IIoT platform connected to sensors installed on machinery tracks energy consumption and feed management tools to support shop-floor decisions</td>
</tr>
<tr>
<td><strong>Digital twin for production sustainability</strong></td>
<td>**Digital twin of energy network created to simulate complex, dynamic processes, which allows for simulation of optimum energy utilization scenarios based on data from operations (steam), weather (wind turbines) and electricity grid (cost)</td>
<td></td>
</tr>
<tr>
<td><strong>Advanced analytics for production sustainability</strong></td>
<td><strong>AI-optimized process</strong></td>
<td><strong>AI-powered process optimization software and track-trace technology to improve production planning and product quality, reducing material waste and water consumption</strong></td>
</tr>
</tbody>
</table>

**Indirect sustainability impact use case:** Focuses on operational KPI with sustainability a second order impact

**Data-driven and digitally connected logistics**

**Western Digital**

**AI-optimized process**

**Unilever**

Global Lighthouse Network: Unlocking Sustainability through Fourth Industrial Revolution Technologies 21
Ericsson's green efforts at its smart factory in Lewisville, Texas, USA begin with intentional building design that integrates sustainability measures from the ground up, including the heating, ventilation and air-conditioning systems. The factory features a 40,000-gallon tank that collects, treats and reuses rainwater. Additionally, a chiller coupled with ice storage tanks enables efficient site cooling using gathered water. Meanwhile, on-site solar panels generate sufficient electricity to fully power the factory, using surplus energy to freeze the rainwater for future usage.

On top of this green building design, Ericsson has integrated 4IR smart factory tools that augment the sustainability impact even further. A 4G/5G sensor network informs a smart management platform that monitors and visualizes consumption, leaks and temperature throughout the facility. It also automates powering equipment on or off by analysing energy consumption data. Finally, when it detects underperforming equipment, it alerts site staff and provides recommended proactive maintenance solutions.

This advanced site, which has earned LEED Gold® certification, sources 100% of its electricity from renewables, including on-site solar panels. The facility was designed to cut indoor water consumption by 75%, reduce energy consumption by an estimated 24% from that of comparable buildings, and nearly eliminate carbon emissions compared to a brownfield factory. By coupling a green factory design with 4IR sustainability tools, Ericsson has built a site designed to achieve notable direct sustainable impact through the application of a sophisticated advanced digital use case making it a model for companies aspiring to eco-efficiency. This use case is an example of how 4IR technologies can build on green technologies to push their impact further.
Ericsson’s green smart factory equipped with sensors that monitor technology sustainability in real time, enabling digital management tools to flag abnormal energy and water consumption.

**Green building technology integration**

Integrating sustainability into building design and operations such as heating, ventilation and air-conditioning systems enabled Ericsson to boost its efficiency and sustainability:

- Installed a 40,000-gallon tank to collect, treat and reuse rainwater
- Utilized a high-efficiency magnetic levitation chiller and thermal ice storage tanks to move cooling demand to off-peak hours
- Installed on-site solar panels to produce up to 17% of on-site power requirement

**4IR smart factory sustainability tools**

Ericsson built 4G/5G connected sensors into a smart management platform to:

- Monitor and visualize consumption, leaks, temperature in the facility
- Automate powering equipment on or off by analysing its energy consumption data
- Generate alerts of underperforming equipment and recommended maintenance solutions

**Impact**

- 100% electricity from renewable sources
- 97% reduction in carbon emissions**
- 75% factory designed to reduce indoor water consumption***
- 24% factory designed to reduce electricity usage***

* Emission calculations uses EPA Greenhouse Gas Equivalencies Calculator
** Impact measured in tonnes of CO₂ compared to brownfield factory
*** Based on design specifications

*Third party certified Ericsson’s first global factory to achieve LEED Gold® certification*
SOCAR uses digital twins to enable further sustainability impact

Among the most advanced use cases employed by the world’s leading manufacturers is the use of digital twins. SOCAR engineered a virtual replica of its energy network based on real-time operational data to create data-driven insights and recommendations to optimize operations. Leveraging these virtual replicas, the energy optimization model across business units created a connected data model between the Petkim petrochemical plant and STAR refinery facility in Izmir, Turkey. Using 4IR technology, process information and external data sources, the system designs optimal energy solutions to meet production plans and has enabled SOCAR to enhance energy utilization efficiency.

Across both the brownfield Petkim petrochemical plant and STAR refinery, SOCAR has deployed over 3,000 4IR sensors to augment available data on equipment. Meanwhile, at the greenfield STAR refinery, these sensors are also feeding statistical machine-learning tools used to optimize the business unit’s electricity needs, balancing steam utilization and available wind power. Lab measurements train the data and validate results. Additionally, machine learning optimizes energy consumption solutions for refinery units.

By connecting the STAR and Petkim energy and steam networks, SOCAR is able to power the digital twin energy optimization model that integrates the system as a whole. The connected steam grids and energy data models are able to leverage analytics to provide self-generated steam-balancing recommendations to operators, which increase the overall efficiency of steam and electricity usage.

The model’s dynamic design minimizes energy costs on the business unit level, guiding operators with optimal energy solutions that take into account electricity market prices, natural gas prices, boiler efficiencies, turbine loads, and let-downs. With a constant stream of data, the digital twin model is able to maintain real-time awareness of conditions affecting efficiency, thereby providing up-to-date optimizing solutions at any moment.

This has yielded a 14% reduction in greenhouse gas (GHG) emissions, a 13% cut in water consumption and a 6% reduction in natural gas consumption.

Global Lighthouse Network: Unlocking Sustainability through Fourth Industrial Revolution Technologies
SOCAR has built and deployed a digital twin of its energy network to optimize energy efficiency across its business units. This connected data between its Petkim and STAR facilities is powered by sensors, process information and external data sources.

Recommendations are designed to guide operators to improve business unit level wide electricity usage based on electricity market prices, natural gas prices and boiler efficiencies, turbines and let-downs loads and available wind energy.

- **Impact**
  - **14%** greenhouse gas emissions reduction
  - **13%** water consumption reduction
  - **6%** natural gas consumption reduction

Built on available energy sources data at the disposal of SOCAR, a complex energy network model between STAR and Petkim has been recreated as a digital twin. This model generates recommendations for most cost-efficient energy production/usage strategies across both sites.

3,000 sensors monitor live energy consumption across Petkim and STAR. This data is collected to simulate consumption patterns.

Connected steam grids and energy data models, allowing analytics self-generated steam balancing recommendations to operators to increase steam/electricity utilization efficiency.

Integrates with other AA operations models (e.g., oxygen levels optimizer in furnaces) to further reduce GHG emissions, fuel consumption and utilities consumption.
AUO engages advanced analytics for sustainability impact

Smart technology can optimize systems for ideal performance while also affording sustainability gains. AUO, a producer of advanced display and solar panels with global reach, has developed an in-house, auto-feedback energy system at its Taichung site. The system utilizes IoT sensors and virtual models to drive automatic, real-time adjustments to equipment-operating parameters, boosting eco-efficiency.

The auto-feedback energy system enables smart modification of the product recipe between production runs by balancing equipment parameters such as power consumption and load, while accounting for environmental conditions in the factory such as temperature, humidity, atmospheric pressure and enthalpy (the measure of heat content in a given system). This enables the process to be optimized for each run of glass panel production, while likewise enhancing resource management and making better use of water and raw materials.

The smart system improved the chiller cycle, which comprises 15%-18% of the site’s energy consumption. By shifting from manual control to advanced analytics, temperature can be ideally regulated for clean-room operations. The simulation and prediction model determines the best control point based on a statistical model that correlates various parameters, such as outlet temperature, chiller load and clean dry-air flow. This results in the clean room receiving temperature-optimized chilled water based on historical data and the control point algorithm. The system also equips the cooling tower, which exchanges waste heat, with an early warning system to indicate problems.

The impacts of this auto-feedback energy system include a 23% reduction in water consumption, a 20% cut in carbon emissions and a 6% reduction in overall site energy consumption. This case study highlights how Lighthouses have deliberately impacted environmental sustainability by leveraging 4IR technologies.
In an effort to optimize utility consumption for run-to-run production, AUO developed in-house an auto-feedback energy system using IoT sensors and virtual models to automatically adjust in real time equipment-operating parameters.

**Auto-feedback energy system**

Run-to-run control common in semiconductor manufacturing accounts for the multiple stages process, allows modification of a product recipe between “runs”, enabling consistent reproducibility.

Feedback system balances:

— Equipment parameters such as power consumption and load

— Factory environmental conditions such as temperature, humidity, atmospheric pressure, enthalpy

— Conditions unique to in-production glass panels being produced run-to-run

Resources managed and optimized: water, raw material management, and chilled water temperature.

**Impact**

- **23%** water consumption reduction
- **20%** carbon emissions reduction
- **6%** energy consumption reduction

**Water efficiency certification**

The first global display industry to receive ISO 46001 certification for water efficiency management.
Western Digital applies 4IR to optimize delivery logistics

The transport of materials, especially air freight, can be a resource-heavy undertaking. Western Digital in Prachinburi, Thailand, used 4IR technology to reduce GHG emissions while simultaneously cutting logistics costs. With its automated logistics system, the company utilized operational data with IoT and machine-learning tools to develop a shipment consolidation and logistics optimizer. This has optimized air freight shipment usage, thereby reducing costs and eliminating GHG emissions from unnecessary shipments.

The impact hinges on a machine-learning data model that improves transportation reliability. The system processes data from IoT-connected sensors along with operational (transportation management system) data to form a continuously updated dataset. IoT sensors attached to each shipment monitor and report real-time logistics data, including GPS location and conditions such as tilt, temperature shock, humidity and light. Meanwhile, the digital transportation management system streamlines operational data like carrier details, service performance, shipment requirements, pick-up information and customer data.

This combined wealth of data and the analytics power to make sense of it enables the building of an optimization model that generates best-in-class logistics recommendations. By correlating shipment delivery performance data points such as transit times, routing, shock, temperature and customer satisfaction, the reliability model creates carrier performance “score cards” to inform carrier selection. As result of the model, the system delivers scenario recommendations that improve routing, shipping consolidation and transit times while decreasing latency for real-time decision making.

By deploying this 4IR automated system, Western Digital has cut GHG emissions by 12% while enjoying a 46% reduction in logistics costs.
Western Digital in Prachinburi, Thailand, utilized operational data with IoT and machine learning tools to develop a shipment consolidation and logistics optimizer. The outcome optimized air freight shipment usage, reduced costs and eliminated emissions from unneeded shipments.

**Transportation reliability model optimizes logistics, eliminating excess air freight miles**

Machine learning data model optimizes shipments consolidation and freight utilization to improve transportation reliability and, as a result, reduces emissions attributed to the transportation network.

- Processes IoT (sensors) and operational transportation management system data into continuous stream of model optimization dataset to provide best-in-class logistic solutions recommendation

- Correlates shipment delivery performance data points (transit times, routing, shock, temperature, costumer satisfaction) to create carrier performance score cards used for carrier selection

- Delivers scenario recommendations to improve routing, shipping consolidation, transit times and decreases latency for real-time decision/action

**IoT enabled real-time shipment tracking**

IoT sensors attached to each shipment to monitor and report real-time logistics data (e.g., GPS coordinates, temperature shock, tilt, humidity, light)

**Digital transportation management system**

Deployed a transportation management system to streamline operational data (e.g., pick up information, shipment requirements, customer data, carrier details and service performance)

**Impact**

- 46% logistic costs reduction
- 12% greenhouse gas emissions reduction
Unilever deploys optimizing algorithms to improve quality and throughput

By integrating varied 4IR solutions at its Dubai Personal Care plant, Unilever improved its production line performance while making sustainability gains. The company coupled embedded IoT devices and production line optimization systems to drive improvements in both quality and throughput while cutting waste and water consumption.

At the heart of these achievements lies a sophisticated cloud computing platform, which unlocked 4IR opportunities. The platform enabled consolidation of existing IT architecture, including production plans, bills of material, material management, automation system programmable logic controllers (PLCs) and enterprise resource planning (ERP) systems. Additionally, the computing platform utilizes data from 4IR technologies, such as registry data from Radio Frequency Identification (RFID) sensors or QR codes and that gained from wireless devices embedded in equipment.

This platform uses a sequence-optimizing software to reduce changeovers. Designed in-house, the software generates efficient production plan sequences for multi-product scenarios. By reducing changeovers, production line OEE is boosted while water consumption for line cleaning is reduced. Meanwhile, track-trace technology utilizing IoT-enabled equipment and RFID/QR codes enables smart validation and production control. Validation process checkpoints and automation of critical work steps combine to reduce human error, thus reducing the potential for quality deviations while cutting waste. Finally, an inflight correction system utilizes dosing software to optimize dosing accuracy. Continuous self-optimization logic, informed by historical errors and real-time sensor data, further reduces quality deviation and waste.

These 4IR technologies applied to the production line have afforded Unilever's Dubai site a 42% reduction in material waste, a 15% reduction in water consumption, and cost savings of 26% per tonne.

Unilever, Dubai Personal Care plant embedded **IoT devices** and developed **AI-powered optimization systems for production lines** to drive improvements in quality and throughput while reducing waste production and water consumption.

**Cloud-computing platform unlocked 4IR digital opportunities**

**Consolidated existing IT architecture**
(e.g., production plans, bills of material, material management, automation system PLCs and ERP systems)

**Data from 4IR technologies**
(e.g., registry data from RFID/QR codes, wireless devices embedded in equipment such as weighing scales)

**Impact**
- **42%** material waste reduction
- **26%** cost per tonne reduction
- **15%** water consumption reduction

**Sequence optimizer software to reduce changeovers**
In-house designed computational sequencing software powered by AI assists production planners to compute efficient production plan sequences for multi-product production plans.

**Track-trace technology to improve quality control**
QR codes, RFID technology and IoT-enabled (smart) equipment validate and control production steps.

**Inflight correction system to optimize dosing accuracy**
Dosing AI software allows the control system to self-improve its dosing accuracy in a continuous self-optimization logic.

Historical errors and real-time production line sensor data analysed by the dosing software prevents under/overfill which can also lead to quality deviations and waste.

**Global Lighthouse Network: Unlocking Sustainability through Fourth Industrial Revolution Technologies**
The eco-efficiency pacesetters: Sustainability Lighthouses
The Global Lighthouse Network was established to light the way for 4IR transformation across the manufacturing sector, and its 90 frontrunner sites have already set new benchmarks when it comes to successful 4IR transformation at scale. These leading companies are also positioned to lead a next-level drive when it comes to sustainability.

### 5.1 A global community sets a global goal

At the World Economic Forum Annual Meeting 2020 in Davos, foremost leaders from industrial companies charged the Global Lighthouse Network with the task of uncovering how sites and end-to-end value chains could make themselves more sustainable through technology. Additionally, the network was encouraged to identify member organizations that especially exemplified sustainability impact – and could serve as aspirational models for other companies.

### 5.2 A meaningful designation among recognized industrial leaders

The new designation of “Sustainability Lighthouse” has been created to recognize these leaders. Sustainability Lighthouses, in addition to achieving the impressive level of 4IR maturity characteristic of other Advanced Lighthouses, have demonstrated exemplary commitment to environmental sustainability through intent, impact and scale of deployed advanced use cases.

Identifying Sustainability Lighthouses was based on pre-existing information shared as part of the Lighthouses’ initial applications. This close examination of available data from the 90 member sites helped determine which among them might best inspire future Lighthouses in this regard. With 64% reporting sustainability impact, further discernment was needed to identify the true frontrunners. Some 16 Lighthouses highlighted dedicated advanced use cases aimed at enabling sustainability impact. Eventually, three emerged from an independent panel of experts for their use of 4IR technology and step-change impact in environmental categories: Ericsson (Lewisville, USA), Henkel (Düsseldorf, Germany)\(^3\) and Schneider Electric (Lexington, USA)\(^4\).

A Sustainability Lighthouse designation created to highlight pacesetters

Sustainability Lighthouse designation reflects the same level of 4IR maturity of other Advanced Lighthouses and highlights a commitment to environmental sustainability through intent, impact and scale of deployed advanced use cases.

The first cohort of designated Sustainability Lighthouses came from members of the Global Lighthouse Network.

**FIGURE 17**

The first Sustainability Lighthouses were identified from across the Global Lighthouse Network.

**3 Lighthouses**

Identified as the first cohort of Sustainability Lighthouses against peers

- Ericsson: Lewisville, USA
- Henkel: Düsseldorf, Germany
- Schneider Electric: Lexington, USA

**90 Lighthouses**

Within the Global Lighthouse Network, 64% impacting sustainability through their top 5 use cases

**Call-to-action**

Global Lighthouse Network invites future Sustainability Lighthouses to join the network. Together, the network learns and shares insights to advance 4IR adoption and generate greater environmental impact.
Sustainability Lighthouses are pursuing ambitious impacts on environmental sustainability and realizing highly notable achievements in return. They have been explicit about incorporating sustainability goals with specific timelines as part of their 4IR journey. The results they have achieved fall into multiple environmental categories and reach the level of step-change improvement.

Frontrunner in deploying 4IR technology at scale to set new levels of operational performance
- Transforming the entire manufacturing context, break down internal divisions, share data with external stakeholders and build new capabilities
- Transforming the ways in which people work together, keeping people at the centre to realize their full potential alongside digital technology

Highest ambitions for environmental sustainability along with step-change achievement
- Sustainability goals and timeline included as part of 4IR journey
- Multiple environmental categories with step-change improvements
- Sustainability impact across multiple 4IR use cases deployed

5.3 | Call for applications

The Global Lighthouse Network continues to grow and encourages leading organizations to consider applying to join as site or as an end-to-end value chain. All members of the network – whether newly recognized or existing – are eligible to be considered for designation as Sustainability Lighthouses. Excited forward-thinking companies are invited to learn more by emailing LighthouseNetwork@weforum.org.
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Endnotes


The World Economic Forum, committed to improving the state of the world, is the International Organization for Public-Private Cooperation.

The Forum engages the foremost political, business and other leaders of society to shape global, regional and industry agendas.