World Economic Forum

# Global Lighthouse Network:
## Adopting AI at Speed and Scale

WHITE PAPER

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**Images:** Getty Images, Unsplash

# Contents



The Global Lighthouse Network is a World Economic Forum initiative co-founded with McKinsey & Company and counselled by an Advisory Board of industry leaders that includes Contemporary Amperex Technology Limited (CATL); Foxconn Industrial Internet; Henkel; Johnson & Johnson; Koç Holdings; McKinsey & Company; Schneider Electric; and Siemens. Factories and value chains that join the network are designated by an independent panel of experts.

# Executive summary

## The World Economic Forum's Global Lighthouse Network has grown nearly tenfold since its founding, with each cohort defining manufacturing's leading edge.

Each of the first three industrial revolutions had a defining breakthrough: steam-powered mechanization, electricity-powered mass production and computer-powered automation. It is now clear that machine intelligence, powered by unprecedented access to terabytes of data, defines the Fourth. With newfound capabilities to automate and optimize critical trade-off decisions, AI is rising into the role of conductor, orchestrating an ensemble of Fourth Industrial Revolution technologies to a symphony of unprecedented results.

Five years into the Global Lighthouse Network, more than 700 proven Fourth Industrial Revolution use cases – 200 of which involve advanced AI techniques – prove Lighthouses are past pilots. The new focus is tackling the "**Scaling Slump**", the natural adoption slowdown beyond the learning curve's "false peak", when some companies balk at the potential costs of replicating single-site approaches across entire networks.

Lighthouses, though, are pushing through. Some 82% are focused on designing for scale from day one, with immediate aspirations for dozens, even hundreds, of implementations. They are treating entire factories, not individual use cases, as the new "pilot", seeking tenfold the transformation impact and nearly double the return on investment of single-site approaches.

The capabilities Lighthouses have built to speed past pilots are the same ones they are extending as they drive towards scale. First, they set the GPS: designing an effective strategy and roadmap for value capture across factories and now networks. Then they power the engine with delivery capabilities – talent, agile,[1] technology and data – and keep it well-oiled with ecosystem collaborations that support learning and innovation. Steering requires effective change management; for this, Lighthouses often deploy a strong transformation office.

Early AI pilots were often developed at the process step level, where scope was smallest, risks were lowest and iterations were fastest. Today, Lighthouses' capabilities have accelerated AI well past pilots: the 200-plus mature AI use cases implemented by Lighthouses span **every process step**.

Lighthouses are also democratizing AI with "**assetization**", the art and science of packaging use cases for speed and scale of deployment. Some have used toolkits to fully deploy AI use cases in just days and weeks, not months and years. These include modular code packages to ensure interoperability with existing technology, productivity tools such as no-code platforms to accelerate deployment and digital upskilling materials to ensure adoption.

AI "command centre" approaches – which connect, control and respond to disruption across collections of individual processes – are increasingly common in Lighthouses. They are powered by "cognitive automation": the ability to automate complex trade-off decisions, bringing them a step closer to human *on* the loop instead of *in* it. The job of tomorrow's operator will be to do the tasks of today's technician.

Importantly, they are also “training for trust”, prioritizing “closed-loop” feedback to increase confidence intervals well before handing over control.

Generative AI – the latest breakthrough in machine intelligence – is also a priority for Lighthouses. Every new Lighthouse has a GenAI pilot underway, and understandably so: it has the potential to contribute $2.6–4.4 trillion in annual value to the global economy, nearly a quarter of which could be captured by manufacturing and supply chain-related productivity improvements.

Lighthouses show that GenAI’s impact lies where data is least structured. On the shop floor, pilots are often “shortcuts” for people productivity-oriented use cases, such as technician advisers and operator co-pilots. Many of these pilots have been implemented in just weeks, accelerated by the capabilities Lighthouses have already built; for GenAI, the starting line is far more advanced than it was for applied AI five years ago.

As the Fourth Industrial Revolution inflects from “learning” to “doing” – and as Lighthouses begin to surmount the “Scaling Slump” – the network-level impacts that result will only increase the distance between leaders and laggards. This calls for a strategic response – first by learning from Lighthouses to speed past pilots, and then by charting the course: be it as **innovators**, proving the impact of first-of-their-kind technologies and use cases; as **accelerators**, solving challenges of network-level speed and scale; or as **fast followers**, rapidly incorporating off-the-shelf solutions once proven to be scalable and cost effective. In the face of these newfound choices, only one response is fatal: the doldrums of inaction.

This paper reflects on the progress of the Fourth Industrial Revolution through the lens of AI’s rapid adoption. Section 1 (The Fourth Industrial Revolution inflection point) reflects on the current situation – and why the shift from learning to doing calls for a strategic response from all manufacturers. Section 2 (Capabilities power Lighthouses up the adoption curve) examines how the frontrunners have built the capabilities to speed past pilots – and how extending them can make scaling possible. Section 3 (Accelerating adoption in the age of AI) presents the implications of these capabilities: the ability of Lighthouses to rapidly implement machine intelligence across the value chain for unparalleled performance gains. Lastly, Section 4 (Shaping the next five years of the Global Lighthouse Network) looks at the future of the Global Lighthouse Network.

# Introducing the 2023 Lighthouse cohort: today's leading edge

When the World Economic Forum teamed up with McKinsey & Company in 2018 to identify the most innovative leaders in manufacturing, a small group emerged to form the Global Lighthouse Network (GLN).

Today, the GLN is a globally recognized community transforming factory and value chain operations with Fourth Industrial Revolution technologies. Each member is indisputably a leader in its respective industry. To reflect this, the GLN has assembled an advisory board to help steer the network's future direction.

The latest cohort represents the leading edge of the Fourth Industrial Revolution; this paper introduces these vanguard Lighthouses and explores how they have progressed beyond pilot purgatory and embarked on the steep journey of scaling.

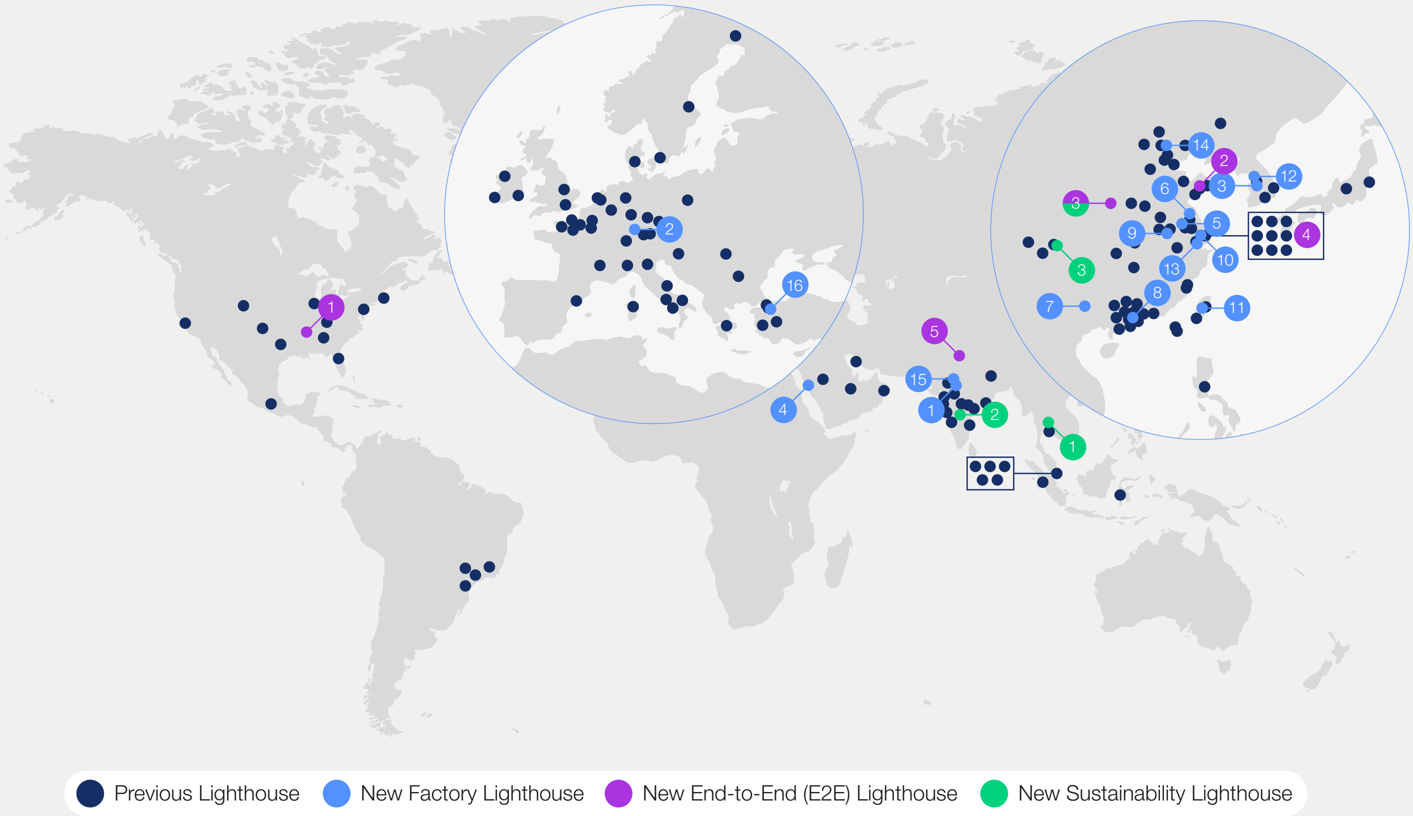
## The Global Lighthouse Network today: 153 lighthouses

The GLN has grown almost tenfold since its inception, from 16 to 153 Lighthouses. Each is recognized for its leadership in using advanced technologies and approaches to drive growth, improve resilience and deliver environmental sustainability. Ninety-nine are Factory Lighthouses, driving transformations within the four walls of a particular production site, while 54 are End-to-End (E2E) Lighthouses, deploying technologies for impact across their value chains; 17 are also Sustainability Lighthouses, demonstrating exemplary use of technology for emissions, waste and water reductions.

## Factories at the Fourth Industrial Revolution's leading edge

The GLN is proud to welcome its 2023 cohort of 21 Lighthouses, 16 of which are Factory Lighthouses, and five of which are E2E Value Chain Lighthouses (see Appendix). In addition, four Sustainability Lighthouses have been recognized for their outstanding use of technology to reduce their environmental footprint on top of their prior Lighthouse designations (see Appendix). These latest additions offer a glimpse into the future of advanced manufacturing and value chains; together, they comprise the leading edge of the Fourth Industrial Revolution. The main trends among them include an unprecedented level of digital maturity, the rapid proliferation of machine intelligence and transformation programmes that execute at-scale deployments from the outset.

FIGURE 1 | **New Lighthouse sites in Wave 11**




## New Lighthouses in 2023

1
**ACG Capsules**
Pithampur, India
Pharmaceuticals

2
**Agilent Technologies**
Waldbronn, Germany
Medical equipment

3
**AMOREPACIFIC**
Osan, South Korea
Cosmetics

4
**Aramco**
Yanbu, Saudi Arabia
Oil and gas

5
**CATL**
Liyang, China
Electronics

6
**CITIC Pacific Special Steel** Jiangyin, China
Steel products

7
**CR Building Materials Tech** Tianyang, China
Cement

8
**GAC AION New Energy**
Guangzhou, China
Automotive

9
**Haier**
Hefei, China
Home appliances

10
**Hengtong Alpha**
Suzhou, China
Optoelectronics

11
**Ingrasys**
Taoyuan, Taiwan, China
Electronics

12
**K-water**
Hwaseong, South Korea
Water

13
**LONGi**
Jiaxing, China
Renewable energy

14
**Mondelēz**
Beijing, China
Food products

15
**ReNew**
Ratlam, India
Renewable energy

16
**VitrA Karo**
Bozüyük, Turkey
Building materials

1
**DHL Supply Chain**
Memphis, United States
Logistics

2
**Haier**
Qingdao, China
Home appliances

3
**Johnson & Johnson**
Xi'an, China
Pharmaceuticals

4
**Kenvue**
Shanghai, China
Self-care products

5
**Unilever**
Sonepat, India
Food products

1
**Kenvue**
Bangkok, Thailand
Self-care products

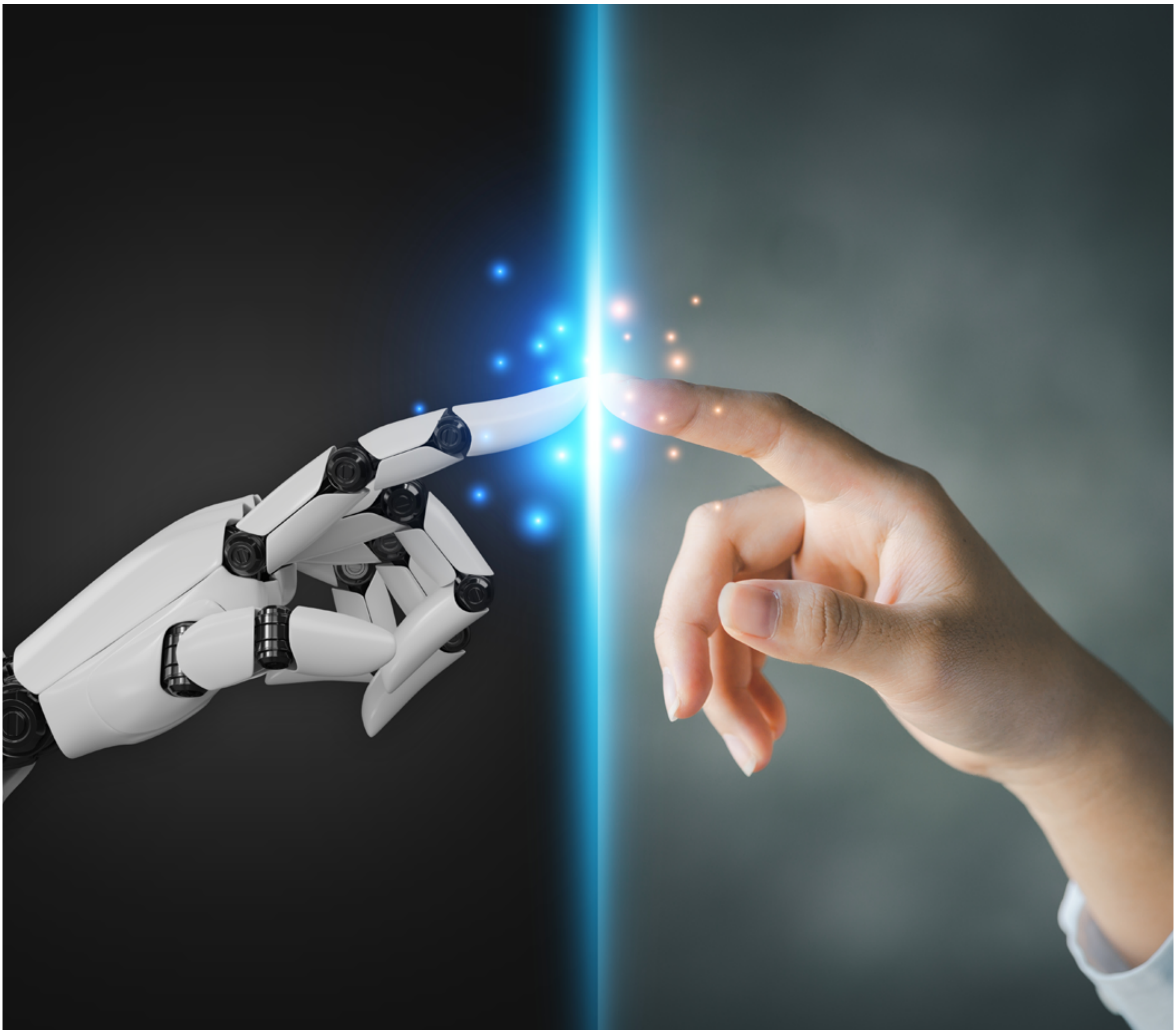
2
**Schneider Electric**
Hyderabad, India
Electrical components

3
**Siemens**
Chengdu, China
Industrial automation

**Source:** Global Lighthouse Network

# 1 The Fourth Industrial Revolution inflection point

Manufacturers face a new narrative as rapid technology breakthroughs, changing people dynamics, escalating geopolitical tensions and accelerating climate change have uncovered global supply-chain vulnerabilities.



Such vulnerabilities have driven a new focus on resilience, pushing executives to transform operations. Additionally – and perhaps somewhat counterintuitively – these disruptions have rebooted manufacturing in otherwise stagnating markets and driven leaders to consider their operations afresh. Many have found that where operations face new challenges, technology provides new solutions.

The accelerating pace of the Fourth Industrial Revolution enables next-level performance, workforce inclusivity and sustainability. Each Lighthouse cohort provides a three-to-five-year look ahead at the future of value chain operations, and today's cohort affirms a Fourth Industrial Revolution inflection point. Two factors mark this inflection point: first, machine intelligence technologies are reaching unprecedented levels of maturity; second, leading companies are redefining the concept of a pilot as they scale impact by using entire factories – not individual use cases – as pilots.

## 1.1 Disruption and uncertainty have driven innovation

To be ready for future disruptions and withstand shocks, manufacturers are boosting investment in artificial intelligence (AI) technology, sustainable energy and other technological innovations. Some 90% of senior executives report that increasing supply-chain resilience is a priority, and annual AI investments have reached around $150 billion – all while supply-chain leaders have invested in advanced analytics to connect data more effectively.[2] Preparation for uncertainty has become an industry norm, with executives expecting the impact of disruption to increase by between 15 and 25% over the next five years.[3]

Geopolitical changes have enabled advanced manufacturing to flourish in markets where, only 30 years ago, stagnation was the norm. Growth in the United States' manufacturing sector, for example, had been languishing in a 1.4% growth rate over the past two decades.[4] Now, AI, digital technologies, sustainable features and higher skill sets among advanced manufacturing and supply chains have reinvigorated the market: in the past five years, industrials in the USA have generated total shareholder returns about 400 basis points higher than in the previous 15 years.[5]

## 1.2 Machine intelligence is defining the Fourth Industrial Revolution

The core purpose of this paper is to explore this Fourth Industrial Revolution inflection point by examining the innovations and approaches of the newest Lighthouses, but it is helpful to reflect first on human society's four distinct industrial revolutions. They provide essential context to explain why machine intelligence is the natural culmination of that development – with the potential for exponential impact in conjunction with other Fourth Industrial Revolution technologies such as wearables, co-bots and autonomous vehicles when deployed in the manufacturing context.

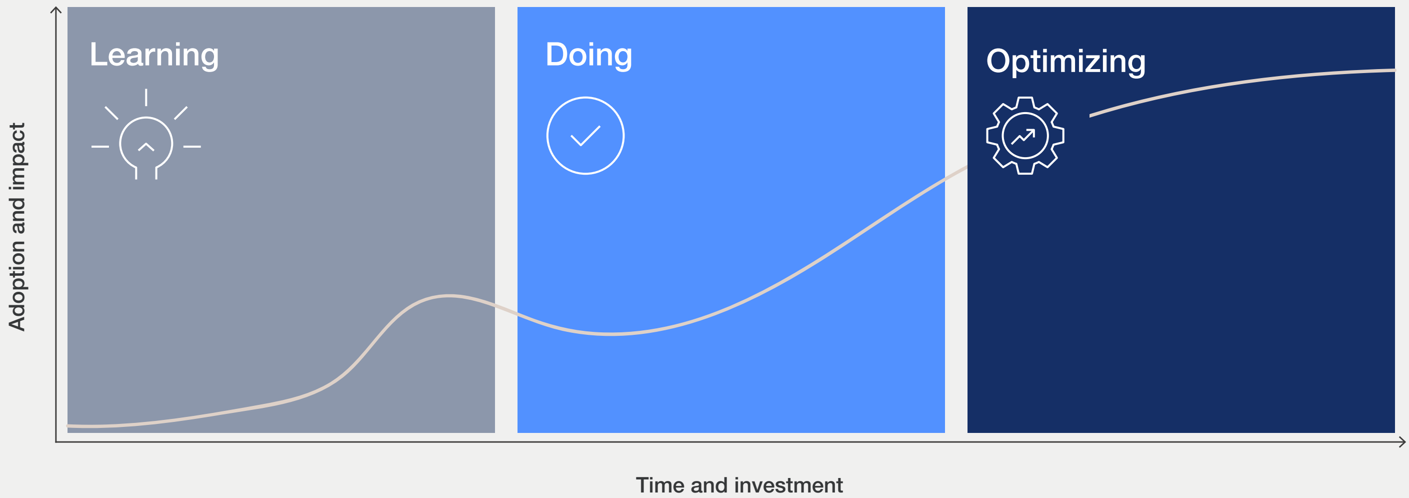
### Four revolutions; four foundational technologies

The First Industrial Revolution of the mid-1700s was enabled by steam, while 1870 saw the Second Industrial Revolution, when the widespread creation and transmission of electricity enabled mechanization at scale and unlocked mass production. The Third, in around 1969, marked the acceleration of the computer age, powered by semiconductors and transistors, and this unlocked programmable logic that automated basic control systems.[6] Today, the advent of (big) data has enabled "intelligence" – the ability to make informed trade-off decisions that augment and optimize critical processes and control systems.

### Delayed adoptions; breakthrough innovations

Global industry transformation has never happened immediately. Each revolutionary shift experienced a lag period between the introduction of the enabling foundation and widespread adoption – and this has always taken the shape of an S-curve. The first phase is adoption, the learning curve, which is characterized by trial-and-error refinements and can be long. The second phase, a doing curve, involves a race for widespread adoption as companies find ways to spread new innovations throughout their production networks. The last, an optimizing phase, sees companies coalescing around best-in-class solutions, standards and protocols – and costs start to stabilize.

FIGURE 2 | The industry transformation S-curve




**Source:** McGrath, Rita, "The Pace of Technology Adoption Is Speeding Up, *Harvard Business Review*, adapted by the Global Lighthouse Network; World Economic Forum, *Unlocking Business Model Innovation through Advanced Manufacturing*, January 2022

### Machine intelligence is the next breakthrough

Machine intelligence is to the Fourth Industrial Revolution what the steam engine was to the first: the defining breakthrough that enables – and is enabled by –numerous other technological advances. Much as steam enabled the impact of new piston and condenser designs, intelligence is empowering flexible robotics and autonomous vehicles. A rapid changeover, for example, requires a symphony of solutions: flexible robotics to handle different products; automated guided vehicles (AGVs) to reload material; 3D printing to customize line fixtures; and wearables to give critical alerts to managers and technicians. In this symphony analogy, machine intelligence is the conductor, turning what would be a cacophony of sounds into an orchestra.

But to serve this function, AI requires petabytes (PB) of data generated and collected from enterprise systems, machine sensors, connectivity infrastructure and the workers themselves. AI's meteoric rise in manufacturing has in part been enabled by manufacturers' newfound capabilities to generate and connect data at an unprecedented scale. For some Lighthouses, terabytes – or even petabytes – of new data can be generated weekly, and sometimes more. Section 3 of this paper will explore the reach and impact of mature AI across today's Lighthouses.

**This landscape of digitalization, automation, robotics and AI, all merged together, is critical for Industry 4.0 transformation.**

Brand Cheng, Chief Executive Officer, Foxconn Industrial Internet

## 1.3 The adoption S-curve: from learning to doing in the second chapter

As Lighthouses prove impact with an increasing number of advanced use cases, they have a decreasing need for pilots and proofs of concept (POCs) of advanced technologies. Take AI, for instance. It has enabled over half of all "top" use cases from the past three Lighthouse cohorts, up from just 10% across the first three. Correspondingly, 82% of Lighthouses design new use cases, including AI use cases, with scale in mind from day one.[7] They are past the "learning curve", and are no longer experimenting with individual use cases. Instead, they are using factories as pilots – showing greater ambitions, scaling the Fourth Industrial Revolution across entire production networks and, in some cases, entire organizations.

## The reality of the "Scaling Slump"

Scaling is not easy – some companies falter, balking at the prospect of replicating single-factory approaches across their entire network. It is an expensive proposition: often, a resource requirement of more than $100 million is required to successfully transform large companies.[8] This is because there are new problems to solve: the data, technology, talent and organizational solutions at the factory level are not the same at the network level.

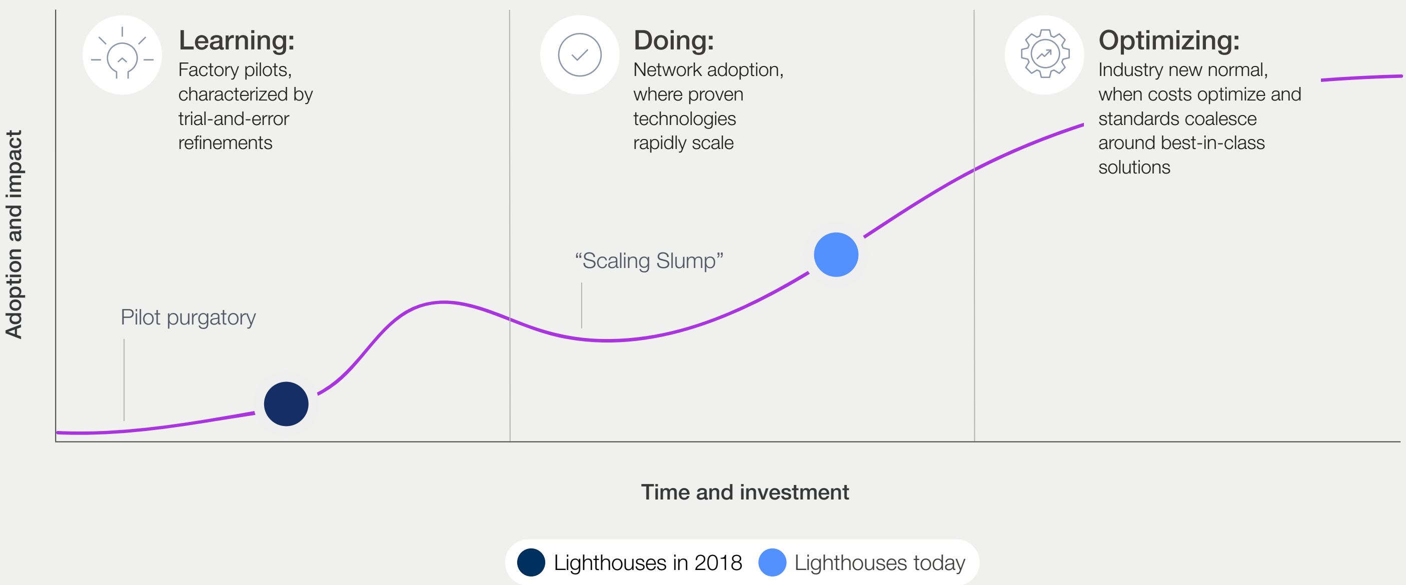
This Scaling Slump is not new. In previous industrial revolutions, adopting the transformative technology was not represented by a "clean" S. There exists a false peak that mirrors the adoption curves of consumer technologies such as the telephone, electricity and the automobile.[9]

## From learning to doing

Not everyone reaches the Scaling Slump, and even fewer choose to push through, but those that do define entire industries. Once Toyota managed to scale the Toyota Production System across its entire manufacturing footprint, it was not long before lean manufacturing and Six Sigma approaches became the standard for millions of factories globally. New guidebooks were written, new certifications and regulations were developed and new tools were built to institutionalize these innovations. This is the third phase of the curve: optimization, a "new normal" where approaches standardize and costs stabilize. It's why the AI conversation in sectors such as technology and banking, which are in this third phase, is so focused on protocols, standards, certifications and compliance – these sectors have the capability to realize mass AI adoption. One example of this is Microsoft fully integrating ChatGPT into Bing months after its launch.

For manufacturers, however, the Fourth Industrial Revolution is just entering the second stage, as Lighthouses move from learning to doing. Though emerging technologies such as generative AI (GenAI) may not see rapid industry-wide adoption, they are already seeing factory-scale adoption by Lighthouses. All new Lighthouses already have a GenAI pilot in the works, and many have implemented, tested and iterated GenAI use cases for impact in as little as days and weeks, not months or years. They have been able to do so because they've already built Fourth Industrial Revolution key enablers, including well-developed data and technology infrastructure, a robust talent base and a well-oiled approach to agile implementation.

FIGURE 3 **Lighthouses move from learning to doing**




**Source:** Global Lighthouse Network

# 1.4 Lighthouses lead the way for fast followers

**75%** of Lighthouses can now deploy a new advanced use case in less than six months

The adoption of transformative technologies is accelerating, with Lighthouses focusing not just on one factory but on 10 to 50 at a time. And the business impacts of scaled transformation will shape manufacturing's competitive landscape, with companies experiencing improvements in cost, quality, service, agility and sustainability that are orders of magnitude beyond what can be expected from single-site transformations, driving a maturity chasm between those doing and those still learning.

This maturity chasm is evident in the wake of recent disruption and volatility. Consider that 85% of Lighthouses saw revenue reductions of less than 10% during the height of the COVID-19 pandemic; this was true for only 14% of other manufacturers. Lighthouses could react quicker: though they faced the same supply-chain risks, 65% of Lighthouses were already dual-sourcing and increasing inventory by 2022, while only 24% of other companies were.[10]

## The foundations for speed and scale: strategy, capabilities and adoption

Lighthouses have crossed the maturity chasm with clear business strategy, a capability-centric approach to people and technology and effective change management. They rarely invest in technology for its own sake, ensuring clear business value from every use case. They are also patient in the formative years of transformation – typically anticipating between 10 and 20 months for use case implementation, with a payback period of around two and a half years. It is a long time horizon, but the returns are worth it – **Lighthouses' Fourth Industrial Revolution use cases have averaged between two and three times return on investment within three years and between four and five times return on investment within five years**.

Implementation is getting faster, too. The last three Lighthouse cohorts implemented use cases 26% faster than the first three, and **75% of Lighthouses report they can now deploy a new advanced use case in less than six months. Even more impressively, 30% said they can do so in less than three months**. When compared with the 10–20 months it took Lighthouses to implement their first few use cases, it becomes clear that technology adoption is self-perpetuating – the more that companies do it, the faster they get. With this comes an increased agility to respond to disruption, which is one reason for the increasing performance gap between leaders and laggards.[11]

## Choose a way forward: innovate, accelerate or follow fast – but don't lag

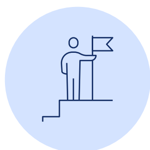
There is one fatal response to industry acceleration: doing nothing. As Lighthouses and an increasing number of their peers achieve network-level impacts to make better products more efficiently, a strategic response becomes increasingly important. Laggards don't often survive.

An effective response can take many forms. When it comes to choosing a network-level digital strategy, a company can choose to be an **innovator** – an industry groundbreaker that bets on and proves at the factory level the next big technology, catapulting past today's leaders. Lighthouses have historically taken this role. Alternatively, a company might take the path of an industry **accelerator** – concentrating on network-level impact, raising the bar for the whole industry. Many Lighthouses are increasingly focused on becoming accelerators. Finally, there are **fast followers**, which use the playbook written by innovators and accelerators, capturing sufficient value with few of the learning curve's costs. All 10 million-plus of the world's factories, large and small, can learn from Lighthouses to become Beacons for the Fourth industrial Revolution.

FIGURE 4 **Three strategic responses to industry acceleration**

### Innovator

Industry innovators, securing competitive advantage by piloting new technologies and proving their impact



### Accelerator

Industry accelerators, achieving competitive advantage through the speed and scale of technology adoption, with production network-level impact

### Fast follower

Fast followers, which incorporate off-the-shelf solutions once proven to be scalable and cost-effective

**Source:** Global Lighthouse Network

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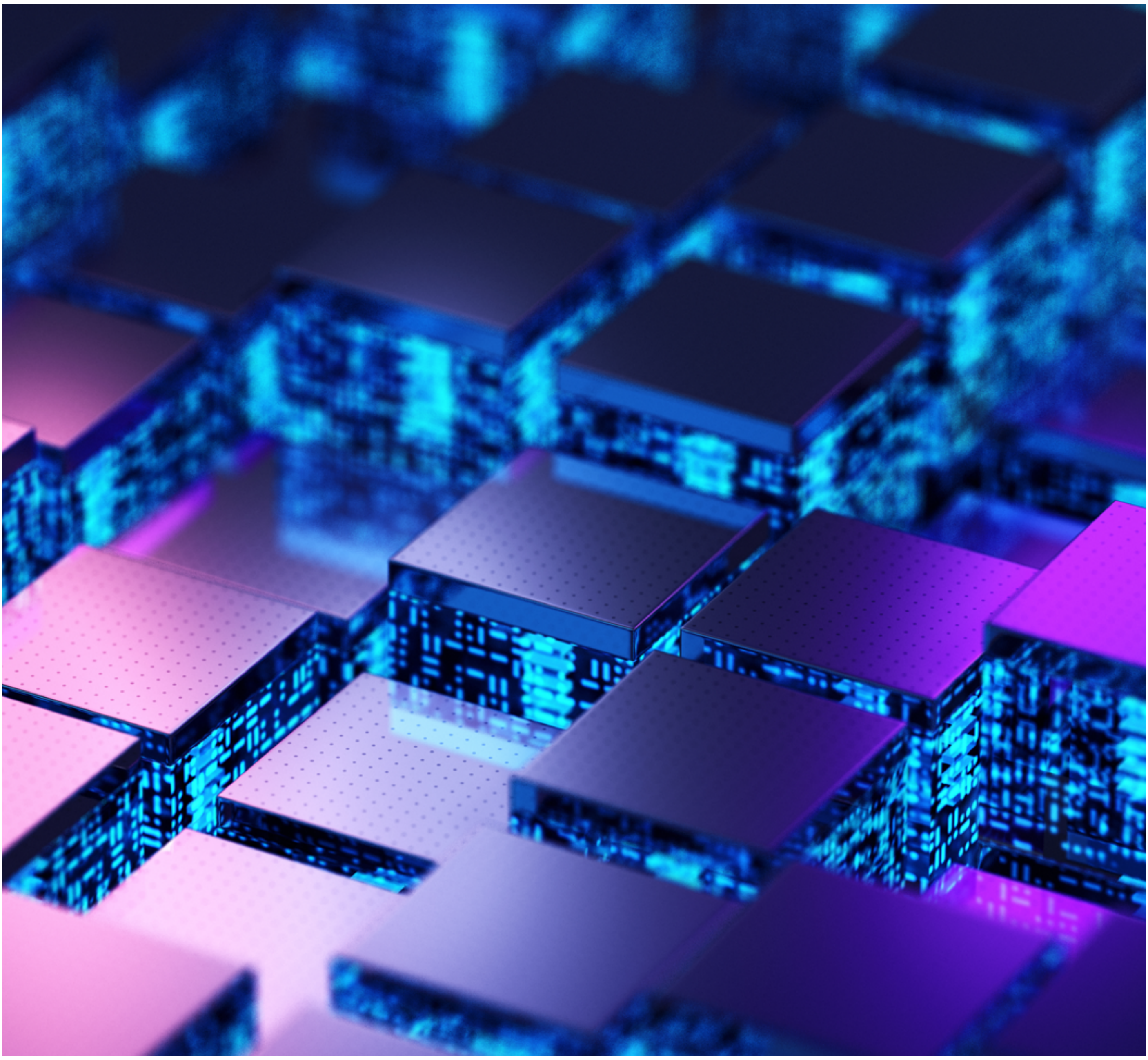
# Capabilities power Lighthouses up the adoption curve

When technologies reach a certain maturity, the next challenge becomes speed and scale – when factories and entire supply networks, not use cases, become the pilots.



## 2.1 From dozens of use cases to dozens of factories

With scale, the concept of a use case no longer involves one implementation but rather dozens – or even hundreds. The transformation impacts increase tenfold, and return on investment grows to nearly two times that of single-site transformations, driven by cost and scale synergies and the comparative reduction – or even elimination – of the need to pilot new technologies.

## 2.2 **Lessons from leaders:** a six-part guide to building a Fourth Industrial Revolution engine

Lighthouses, like digital leaders in other industries,[12] have driven themselves up the adoption curve with a six-part approach to site transformation: first they (1) set the strategy. Then they build delivery capabilities across (2) talent, (3) agile, (4) technology and (5) data. Finally, they (6) implement change management.

They are now adapting this approach for network and organizational scale (see Figure 5). It can be likened to driving a car.

They first set the (1) **strategic roadmap**: the GPS guides the transformation towards an organization reimagined with technology, and the route set prioritizes and sequences the value at stake – including across use cases (at the site level) and factories (at the network level).

They then build the delivery capability, which is the engine that powers transformation. The engine parts – its pistons, crankshafts, drivetrain and timing belt – are: (2) programmes to hire, train and retain digital **talent**; (3) an **agile operating model** that fosters speed, quality and collaboration, often including digital studios; (4) a **technology** backbone with a clear, scalable and distributed architecture for easy provision of digital services and solutions; and (5) a **data** architecture and governance to enable critical decisions and ensure quality, easy consumption and reuse. And no less critical to its function is the motor oil: ecosystem collaborations keep the engine purring as universities, technology providers, innovation incubators, public entities and many others shape best-in-class capabilities. Each Lighthouse in this recent cohort has listed an ecosystem collaboration as a key enabler of its Fourth Industrial Revolution journey.

But capabilities alone are not enough. Whether at the site or network level, adoption and scaling is ensured through (6) effective **change management**: the steering wheel. This often includes a transformation office, which nearly 70% of Lighthouses cite as the most critical of the six (see Figure 5).

These six enablers are tried and true for digital and analytics transformations across industries.[13] And Lighthouses' early approaches to scale demonstrate that they are true for manufacturers, too.

FIGURE 5 | **Six enablers leveraged by Lighthouses to scale transformation**

Pilot to factory | Factory to network[1,2]

## Strategy

**1 Strategic roadmap:** to align the senior leadership team on the transformation vision, value and roadmap and reimagining business domains to deliver outstanding customer experiences and create competitive distance

- Identify desired value to be captured from transformation
- Prioritize and plan which use cases will deliver said value

\+ Create strategy to scale value, identifying whether to sequence deployment as technology-led, capability-led or one-at-a-time

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## Capabilities

**2 Talent:** to ensure you have the right skills and capabilities to execute and innovate

- Perform gap analysis to identify additional skills required
- Train colleagues in digital roles to perform capability-building activities

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- Create enterprise-wide talent strategy, including plan to systematically hire/train new profiles
- Provide performance incentives to ensure morale and motivation

LONGi

**3 Agile operating model:** to increase the metabolic rate of the organization by bringing business and technology together

- Create agile squads aligned to use cases
- Source talent from the right sources (e.g. corporate, vendor, site) to staff cross-functional teams and roles (e.g. business, IT, engineering)

\+

- Implement matrix organization structure
- Align internal (e.g. P&L performance) and external (e.g. supplier delivery) organizational incentives

ReNew

**Ecosystem collaboration**

- Contribute to curriculums and hire from **universities** and other talent sources
- Establish win-win collaborations with **tech vendors and start-ups** for speed, scale and new business models
- Collaborate with **incubators, universities, start-ups and others** to design, test and iterate new use cases
- Partner with **universities and research institutions** on next-gen analytics, data management and security practices

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**4 Technology:** to allow your organization to more easily use technology to innovate with pace

- Design to integrate within existing systems
- Strategize to minimize migration downtime and major redeployments

\+

- Develop vendor ecosystem strategy
- Standardize reference architecture for interoperability
- DevSecOps for critical software projects

**5 Data:** to enrich and make data easy to consume across the organization to improve customer experiences and business performance

- Drive strategy for master data identification and integration across corporate IT, OT and vendor systems
- Embed[3] data/analytics using integration platforms

\+

- Build reusable data products and IT/OT service models for scale
- Host master data in cloud to accelerate analytics and deployment

## Change mgmt.

**6 Adoption and scaling:** to maximize value capture by ensuring the adoption and scaling of digital and analytics solutions, by building new skills and leadership characteristics and by tightly managing the transformation progress and risks

- Enact site-level transformation office with corporate sponsorship
- Administer role modelling, following top-down strategy, beginning with site leadership
- Validate impact by tracking key metrics in standardized format

\+

- Implement enterprise transformation office led by chief experience officer (CxO)
- Create strategy to disseminate change story throughout organization

SIEMENS

**Notes:** 1. "Factory to network" enablers are typically built on top of "pilot to factory" enablers; 2. Featured company case examples are from the 11th Lighthouse cohort; 3. Embed within the platforms in which data/analytics are used.

**Source:** Framework developed in *Rewired: A McKinsey Guide to Outcompeting in the Age of Digital and AI*; manufacturing-specific insights curated by Global Lighthouse Network

### Set the strategy

Companies must first understand why, what and how to transform before taking action to accelerate. This comes in the business strategy and road-mapping phase: identifying, prioritizing and capturing pockets of value that support overall business priorities. Leaders must understand how the product will produce meaningful value; what key performance indicators (KPIs) are explicitly to be improved; if the plan sufficiently accounts for network-wide capabilities; what the time frame is; and how change management will be incorporated.

This requires careful consideration of the industry, the size and diversity of the production network and the available IT infrastructure. While these tailored approaches have taken many forms across hundreds of examples, three have stood out as particularly effective: technology-led approaches focus on deploying one technology or use case at a time across numerous factories simultaneously; capability-led approaches are often driven by a capability-focused centre of excellence (CoE) that proactively identifies and pushes digital innovations from one site to another; and "build and replicate" approaches involve the deployment of people and capabilities to one site at a time. In this most recent wave, new CATL and Johnson & Johnson Lighthouses were propelled by their organization's broader digitalization strategies. Tata Steel, with Lighthouses from past cohorts, is the network's prime case study for the "build and replicate" scaling strategy. All powered their respective strategies with talent, agile, technology and data capabilities.

FIGURE 6 **Examples of three tailored approaches to a strategic roadmap**

## Technology-led

Use cases deployed at many sites at once; resourcing primarily from IT / corporate

CATL

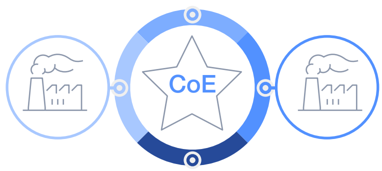
Deploys single use cases **across hundreds of production lines simultaneously** (e.g. AI for energy optimization)

Roll-out from **central technical organization** (e.g. "Intelligent Manufacturing Department")

Standardized approach **enabled by strong central IT network** and **similarity of production lines** across factories

## Capability-led

CoE proactively matches use cases and factories; resourcing primarily from corporate




J&J Innovative Medicine

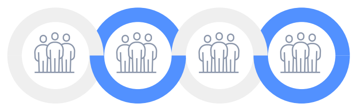
**CoE proactively identifies, packages and scales use cases across sites** (e.g. energy optimization use case at 32 sites)

**CoE holds key digital capabilities and resources** – a first call for sites to share best practices and receive implementation support

**Sites "pull" from CoE** for specific use case customizations and missing site capabilities

## Build and replicate

Transforming one site at a time; resourcing primarily from the "active" site



TATA STEEL

**Champions site** transforms first then **replicated one at a time** (Netherlands site led two India sites – all are now Lighthouses)

**Chosen because all plants are large and operate similarly** – today ~80% of total production comes from a Lighthouse site

**Source:** Global Lighthouse Network

### Build deployment capabilities: talent, agile, technology and data

If the strategy is the GPS and change management is the steering wheel, then deployment capabilities are the engine that powers the transformation: a high-quality talent bench; an agile operating model that fosters speed and customer-centricity; technology platforms that enable distributed innovation; and data that is high quality and consumable. Like a good car engine, the best-performing capabilities are not built alone; it takes an ecosystem of strategic partnerships – with universities, innovation centres and technology partners – to lubricate and maintain the engine for sustainable performance.

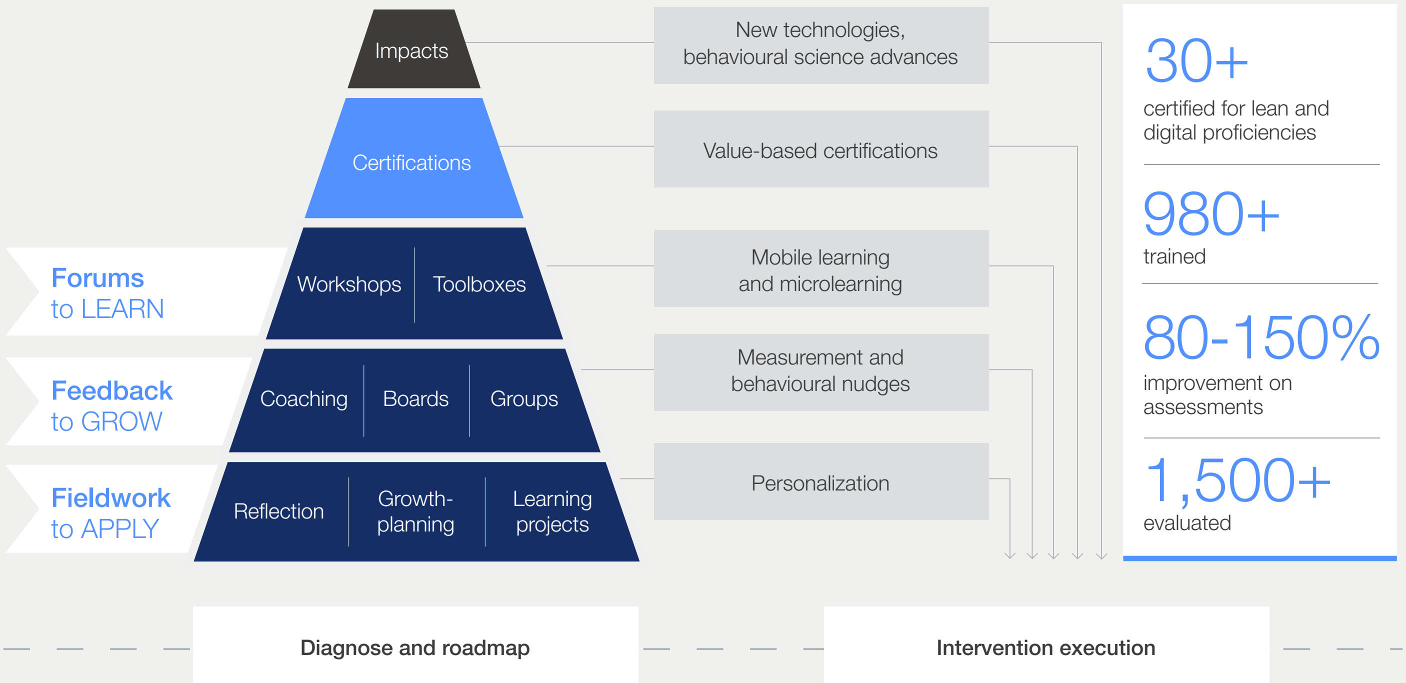
Though no manufacturers have yet achieved full network or organizational scale with Fourth Industrial Revolution technologies, multiple Lighthouses have made early but important advances, with best practices in line with those in other sectors. The remainder of this section explores these early glimmers – a starting point, but not yet a playbook, for manufacturers aspiring to scale impact to network level in the coming years.

## **Talent:** LONGi takes a holistic approach to talent evaluation, training and certification

Organizations need a talent roadmap as robust as their technological roadmap. While technology is often replicated and standardized after maturity, talent is unique to any given organization. It is the core challenge for effective transformation; nonetheless, it is often the key to success. Lighthouses often deploy learning journeys, reskilling incentives and performance recognitions to attract, train and retain the top talent.

LONGi, a Chinese solar-technology manufacturer, exemplifies a talent strategy focused on reskilling the existing workforce. The site implemented an evaluation training certification (ETC) method to tailor the development of almost 1,000 employees through skills-gap identification, personalized learning and value-based certification. A diagnostic informed a comprehensive talent roadmap. The 3F model of forums (learning), field (practice) and feedback (evaluation) grounded all learning, especially for new digital roles such as agile coaches and data scientists. A closed-loop, impact-driven certification process mapped the impact of employees' work while recognizing and supplementing their capabilities.

FIGURE 7 **LONGi's 3F approach to reskilling its workforce**



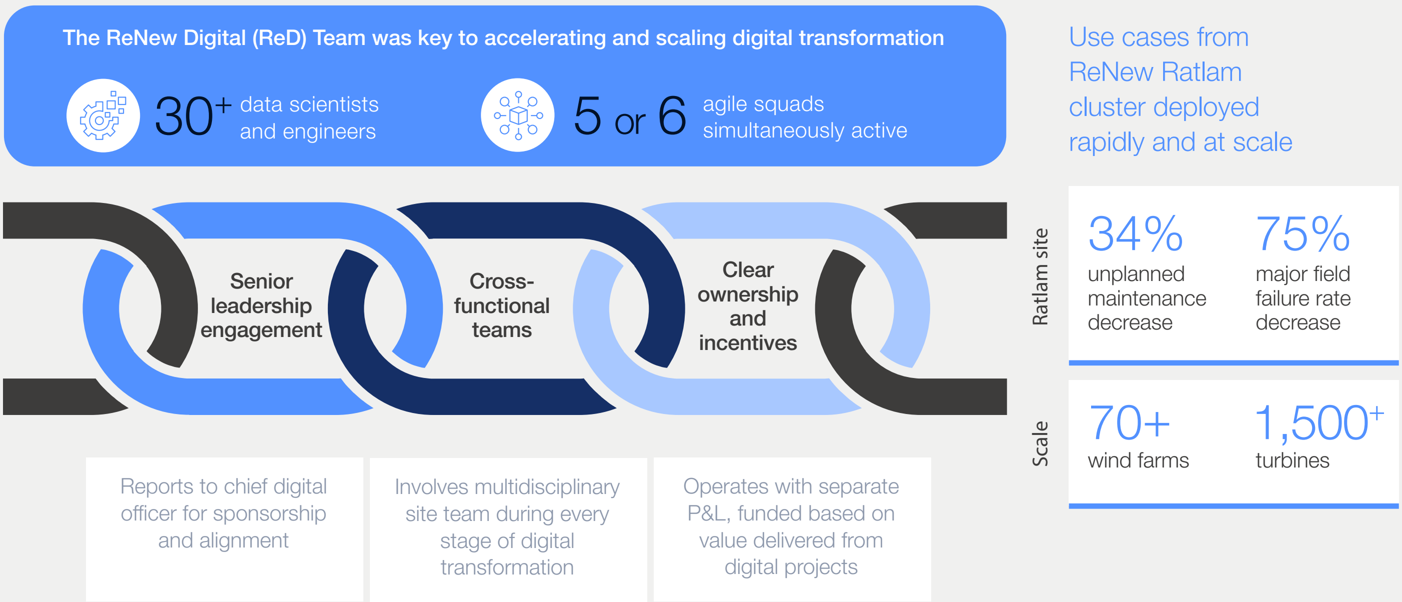

**Source:** LONGi, Global Lighthouse Network

## **Agile:** ReNew's ReD team reimagines ways of working

Organizational transformations focus on step changes in the operating model, company culture and capabilities, leading to a revolution in the way people work. Success depends on full leadership alignment, which is necessary to ensure resource allocation, clear incentives and the thoughtful construction of working teams.

ReNew is a prime example. Its ReNew Digital (ReD) team of nearly 30 engineers and data scientists runs five or six agile pods, each focused on a different use case. The team maintains leadership buy-in, with active chief digital officer (CDO) sponsorship, aligns incentives with an independent profit and loss, funded in part by new use case impacts, and uses a multistakeholder staffing model that includes end users, business owners, data scientists, engineers and process owners from all relevant departments.

FIGURE 8 **ReNew's agile pods**



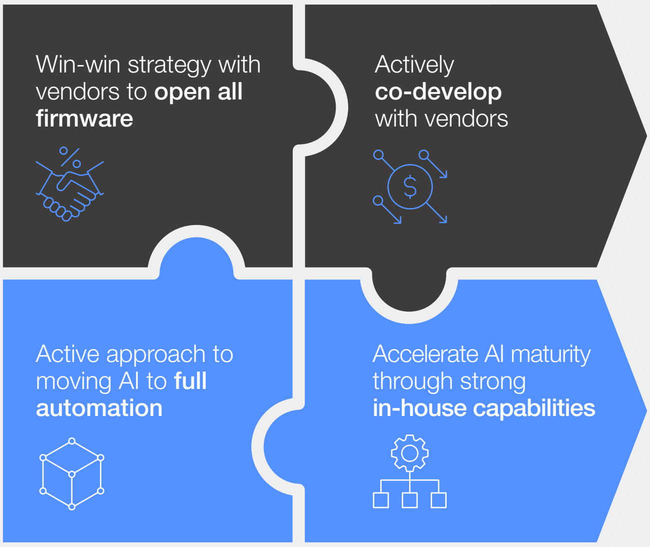

**Source:** ReNew, Global Lighthouse Network

## **Technology:** Ingrasys sets the stage for vendor collaboration

A technology backbone equips organizations with the infrastructure to deploy new use cases and capture business value. Often leaders believe a single tech change is the best start to Fourth Industrial Revolution transformation. However, starting small works only with an integrated plan for growth from day one, because fragmentation often stunts growth. That's why, even as AI and other technologies continue to evolve, Lighthouses emphasize accessible and adaptable data environments with decoupled architecture solutions (e.g. microservices) for flexibility and scalability alongside high-productivity development environments and tools.

Ingrasys demonstrates the benefits of starting small but with a clear plan for growth. Manufacturing servers require a significant number of black-box vendor technologies, and Ingrasys addresses this with clear design principles and requirements for vendors that enable security and scale. This requires most, if not all, of their vendors to open up firmware for data and controls accessibility, to design data outputs to mesh with Ingrasys technology infrastructure and to collaborate for customized developments and win-win solutions. In one case, an automated optical inspection (AOI) vendor collaborated on a new, physical IT / OT plug-in or "media link" on the machine, enabling Ingrasys to deploy an in-house-developed AI inspection model, augmenting the pre-existing vendor solution. That vendor is now offering this "bring-your-own AI" as a service solution to customers.

FIGURE 9 | **Ingrasys combined vendor collaboration with in-house AI capability**




Ingrasys deployed custom AI models across 95 AOI[1] devices:

**Integrating vendors into tech stack** through co-development of new media link. This enabled:

**In-house, custom AI models** developed by on-site analytics teams, ensuring data security and rapid training iterations

This enabled:

**99%**
SMT[2] defective rate decrease

**94%**
root cause analysis time reduction

**48%**
labour productivity in quality testing

**Notes:** 1. Automated optical inspection; 2. Surface mount technology.

**Source:** Ingrasys, Global Lighthouse Network

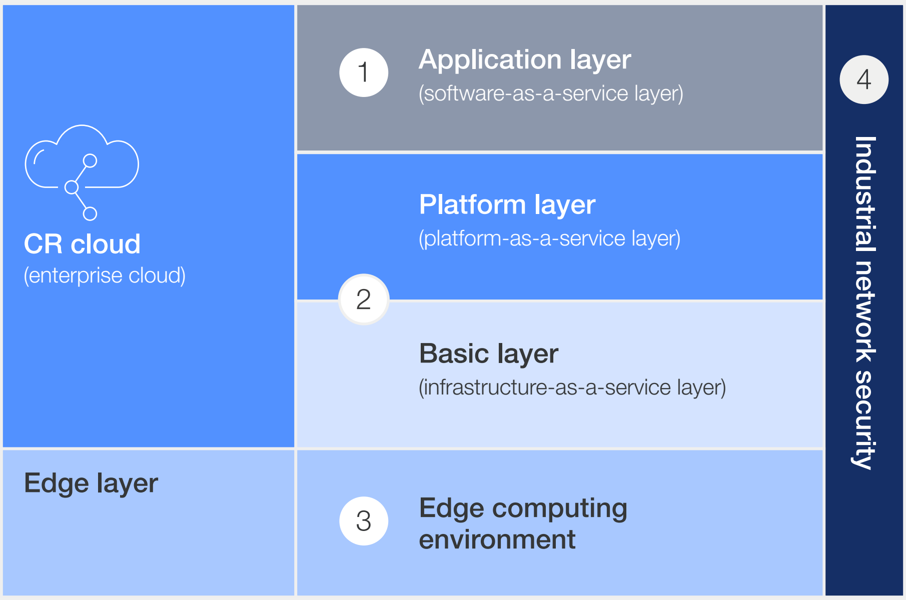
## Technology and data: China Resources Building Materials Technology employs a scalable architecture across dozens of sites

Underpinning effective technology use is the capability to employ large amounts of data for powerful analytics. Lighthouses aiming to scale tend to focus on building the data products they know will underpin each of their solutions and use cases. Clear reference architectures and data pipelines enable both business intelligence and AI solutions, and automated tools support active data quality and maintenance.

CR Building Materials Tech's data and analytics across 35 sites are powered by the Runfeng intelligent industrial internet platform, which enabled a 50% improvement in digital use-case deployment speed. It features four service layers, each enabling data accessibility, accuracy and efficiency. Within the application layer, innovative microservices architecture improves tenant management, bolsters system flexibility and ensures maintainability. The platform layer merges flexible configuration, enhanced deployment and AI-driven analytics with a unified data ecosystem, ensuring scalable storage and cloud management. The edge computing environment excels at managing industrial operations in real time, running applications deployable across all 35 Runfeng sites.

FIGURE 10 **The four service layers underpinning CR Building Material Tech's data platform**

### Runfeng intelligent industrial internet platform




### IIoT infrastructure highlights

1. **Innovative microservices architecture** to enable tenant management, system flexibility and robust maintainability across applications
2. **Unified and flexible data ecosystem**, ensuring scalable storage and cloud management (including middleware services and industrial data platform)
3. **Extensive real-time data coverage** to enable edge processing and data management
4. **Quadruple-layered security system** ensures comprehensive data flow protection across cloud infrastructure and computing, storage, etc.

### Impact

**24/7**
**continuous highly reliable operating environment** for critical functions (e.g. energy management, PM planning)

**35**
**sites and multiple business units** with standardized, accessible, secure data

**50%**
improvement in digital use-case deployment speed

**Source:** CR Building Materials Tech, Global Lighthouse Network

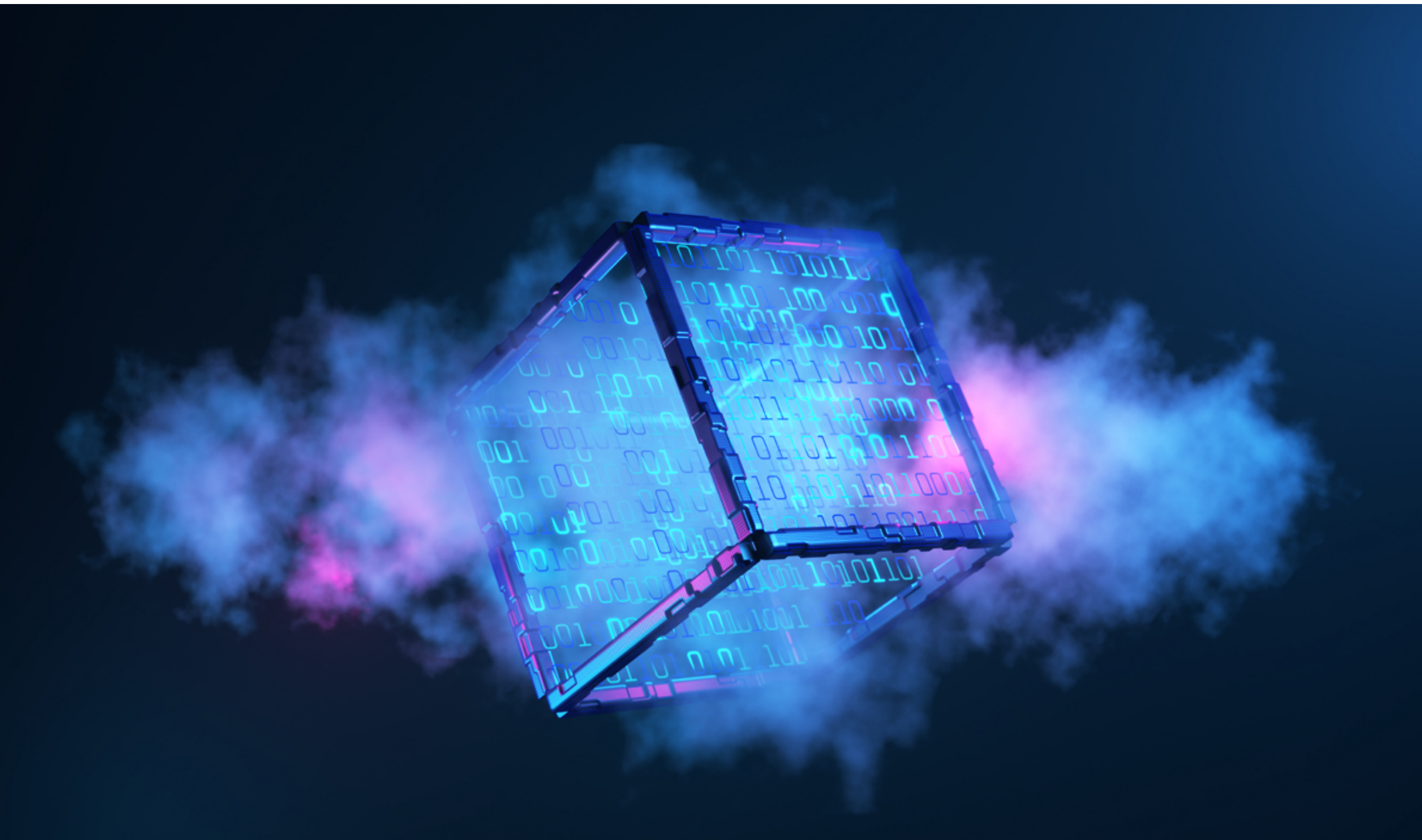
**Implement change management**
Capabilities alone can't drive transformation. Steering around potholes and roadblocks requires effective change management. Often Lighthouses use transformation offices (TOs) for this; in fact, 70% cite TOs as the most critical enabler to transformation. Their role is to clear impact tracking, appropriate financial incentives, proactive risk management and the building of critical digital skills and culture across the organization. Many also support active "assetization" (see Section 3.2) of solutions for easy replication.

### Siemens builds long-term capability with short-term project management office

Siemens has embedded change so thoroughly that its Transformation Office (TO) was designed to make itself obsolete; it is a catalyst to embed new capabilities and digital ways of working into every part of the organization. Its Chengdu site, a new Sustainability Lighthouse, illustrates this. It pioneered a new order-scheduling module within Siemens' modular manufacturing execution system (MES) platform. It was able to lean on an MES capability group – one of nearly 10 other technology groups – with experts from across the network. Based on the potential impact, the Chengdu factory was eligible for additional budget, above and beyond the site plan, to implement the use case. When developed, the MES capability group could seek recognition for scaling the development to receive a "copy with pride" award. Hence, the capability groups were key to leaning the PMO, ensuring the scalability of the pioneered pioneered MES module, and implementing it across the Siemens production network.

## 2.3 Looking ahead to next-level scaling

Having explored how Lighthouses have achieved all that they have, it's time to focus on what lies ahead. The next section of this paper will examine how AI – the defining element of the Fourth Industrial Revolution – has been infused into Lighthouses' operations and how it will supercharge existing technologies to unlock previously unattainable advancements for the entire manufacturing sector.



3

# Accelerating adoption in the age of AI

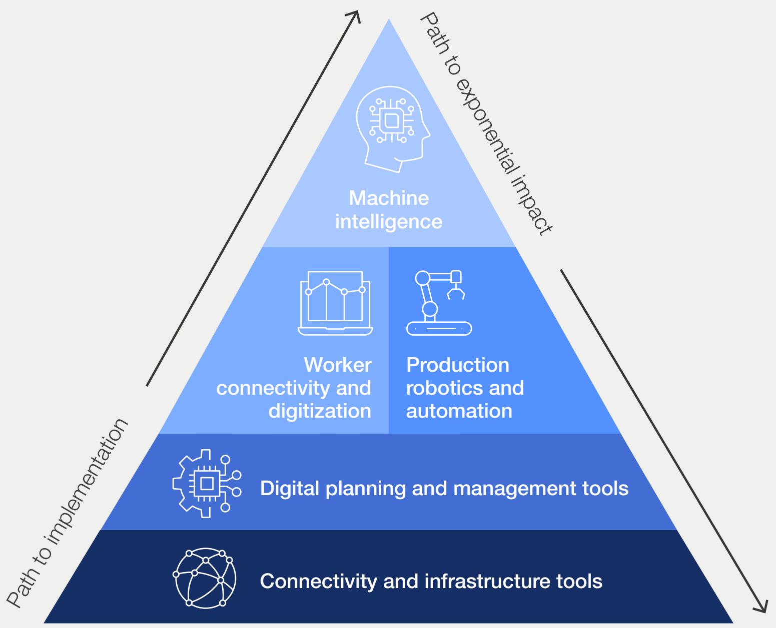
Lighthouses are extending their talent, agile, technology and data capabilities in the pursuit of network – and even organizational – scale. This enables these frontrunners to capture the full value of Fourth Industrial Revolution technologies.

This value comes from myriad technology solutions, including: (1) connectivity and infrastructure tools such as 5G and edge that can connect data and make local computations; (2) digital planning and management tools including manufacturing execution (MES), customer relationship management (CRM) and product life-cycle management (PLM) systems that plan, prioritize and control operations technologies; (3) worker connectivity tools such as dashboards, wearables and augmented-reality technologies that empower improved human–machine interactions and insights; (4) production robotics and automation tools such as 3D printing and AGVs that can help to reimagine how goods are manufactured; and, finally, (5) machine intelligence technologies that can make trade-off decisions including forecasting, optimization and augmentation capabilities.

Machine intelligence is the pinnacle of the technology pyramid – the proverbial conductor of the Fourth Industrial Revolution technology orchestra, creating a symphony of impact wherever deployed – at sites, across production networks and even throughout entire organizations. A rapid changeover, for example, requires flexible robotics to handle different products, AGVs to reload material, 3D printing to customize line fixtures and wearables to give critical alerts to managers and technicians. And for it all to work, it requires AI as the conductor.

The maturity of AI, then, is indicative of the maturity of the Fourth Industrial Revolution. The latest cohort of Lighthouses shows that advanced AI techniques are past pilot purgatory; they are mature, scaled and quickly deployed, even for emerging and high-impact variants such as GenAI. The remainder of this section of the paper explores the state of manufacturing AI through the lens of the newest Lighthouses.

FIGURE 11 **The technology pyramid**




5 **Machine intelligence to optimize, augment or automate decision-making**, such as heuristic models, analytic AI and generative AI

4 **Production robotics and automation that disrupts processes**, such as co-bots and flexible robots, AGVs and drones, and 3D printing

3 **Digital worker productivity tools at the operator or process level**, e.g. augmented / virtual reality, wearables and exoskeletons

2 **System-level digitalization of planning and management processes**, such as MES, PLM, CRM and other enterprise tools

1 **Underlying data, connectivity and computing tools**, e.g. cloud and edge hosts, 5G communication and data lakes

**Source:** McKinsey & Company, adapted by the Global Lighthouse Network

## The defining element: what AI looks like in Lighthouses

Lighthouses are the standard-bearers for AI in manufacturing. Between 50% and 60% of the 200-plus most recent use cases have relied on applied AI in some form; this number was less than 10% just three years ago. Each of the 21 newest Lighthouses has at least one implementation of applied AI, and collectively these 50-plus use cases span all supply-chain domains, from planning to manufacturing to delivery and beyond.

CITIC Pacific Special Steel, a special steel manufacturer in China, has deployed dozens of AI use cases across its production process, including by predicting the inner workings of its blast furnaces to enable intelligent process parameter optimization and energy management. K-water, a public water utility in South Korea, implemented an autonomous AI operating system to control full plant operations. Agilent, a life science equipment manufacturer in Germany, "assetized" its computer vision technology into a toolkit so effective that it enabled deployment of five distinct computer vision use cases in just four months.

These technologies are maturing rapidly as companies improve the "confidence intervals" on AI's predictions and recommendations. In some cases, confidence in these models exceeds the confidence in planners or operators, demonstrating that true decision automation is imminent. Mondelēz's baking facility and K-water's sanitation process provide two glimpses of what this can look like, where front-line workers are more technicians than machine operators, engaged *on* the loop instead of *in* it.

If the rapid adoption of GenAI in banking and technology is anything to learn from, it's likely that – for Lighthouses, at least – impact at a factory scale will be just around the corner. The knowledge, skills and data foundations Lighthouses have built as they've moved past pilots for other Fourth Industrial Revolution technologies will likewise prove relevant for GenAI. This is true for ACG Capsules, a pharmaceuticals contract manufacturer in Pithampur, India, which fully developed and deployed a standard operating procedure (SOP)-interfacing co-pilot in less than five weeks.

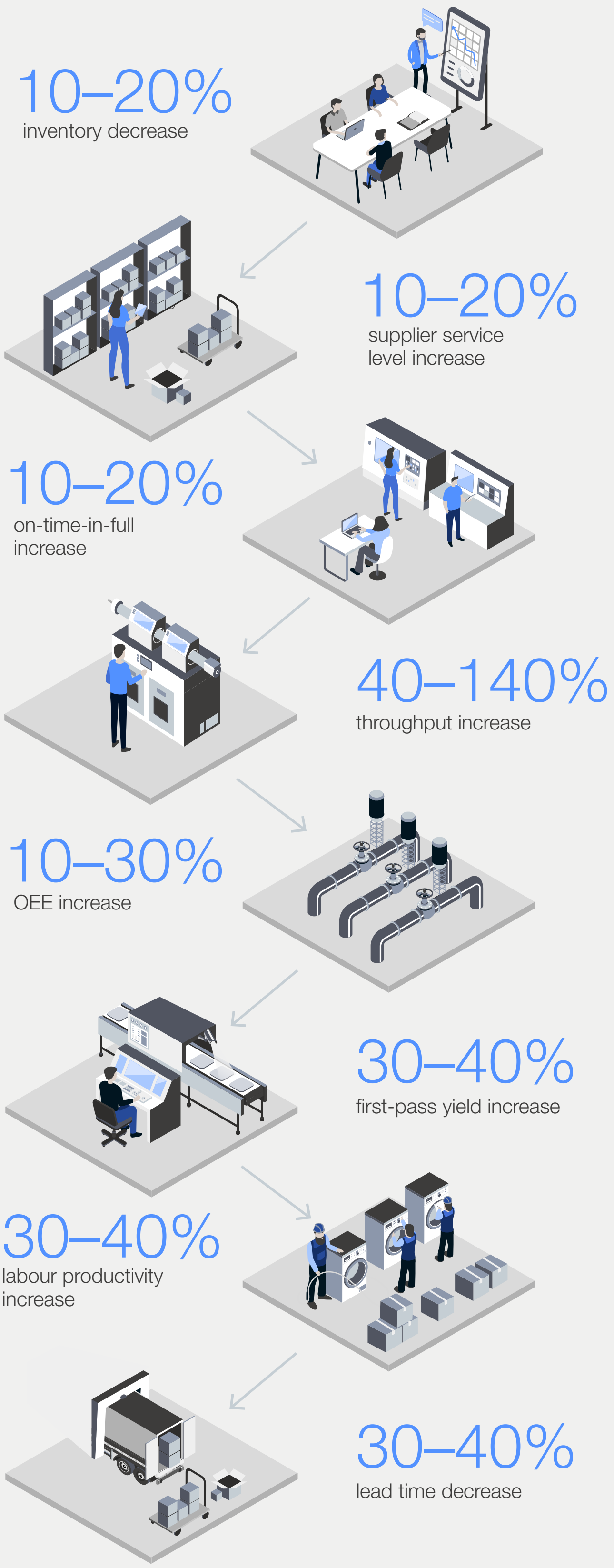
AI is advancing to impact quickly, and is only speeding up. Manufacturers no longer need to ponder whether it's possible or impactful. Lighthouses have already proved that. Instead, they need to focus on the risks, regulations and complexities of responsible AI implementation – a critical topic worthy of its own publication. Lighthouses are not immune to these risks, and they have not been cavalierly bullish. They have taken measured approaches, ensuring they have the expertise, systems and leadership to reap the benefits of AI responsibly.

## 3.1 **Impact is everywhere:** applied AI in every process

Early applied AI pilots were developed at the process-step level, where the scope was smallest, risks were lowest and iterations were fastest. As such, it is only natural now that over 80% of Lighthouse use cases involving AI are likewise executed at the process step level. What's notable, though, is that AI is having significant impact at every supply-chain process step – including planning, asset management, quality and delivery.

The most recent cohort of Lighthouses demonstrates this breadth and diversity. Consider planning: Ingrasys deployed an AI-demand forecasting model that uses past data to train the model; this has delivered 27% more accuracy in just three years. Or process optimization, where Hengtong Alpha Optic-Electric automatically optimizes preform and drawing parameters with a model trained on past strategies. Or quality, where VitrA Karo deployed computer vision in its kiln, which decreased the scrap rate by 68%. Or delivery, where CR Building Materials Tech has adaptively optimized heavy transport equipment routes to decrease pickup lead times by 39%.

FIGURE 12 | **The latest Lighthouses have implemented AI with high impact across every step of the supply chain**



**10–20%** inventory decrease

**10–20%** supplier service level increase

**10–20%** on-time-in-full increase

**40–140%** throughput increase

**10–30%** OEE increase

**30–40%** first-pass yield increase

**30–40%** labour productivity increase

**30–40%** lead time decrease

### Supply-chain planning

**Agilent** uses supplier information to predict material availability, enabling proactive response to SC risks

**Ingrasys** uses order history and market data to predict orders more accurately than provided forecasts

### Supply-chain management

**Unilever** automated inventory replenishments based on the previous day's sales, stock targets, capacity constraints, etc

**Johnson & Johnson** identifies and mitigates SLOB[1] risks by using AI to automate data analysis and recommend actions

### Production scheduling

**ACG Capsules** optimizes its production schedule with a novel colour-matching AI and validates it with a digital twin

**GAC AION** achieves automatic scheduling across 100K+ configurations, enabling plan-driven resource distribution

### Process optimization

**CITIC Pacific Special Steel** deploys AI across furnace, rolling and cooling steps for special high-mix, small-batch products

**Hengtong Alpha** uses past strategies to inform parameter optimization of preform and drawing processes

### Asset management

**Aramco** predicts the remaining useful life of reactors to minimize corrosion and optimize maintenance

**CATL** implemented factory-wide predictive maintenance to optimize maintenance plans based on real-time data

### Quality and testing

**LONGi** performs RCA[2] with multi-modal image analysis, feature-based tracing and a closed-loop "quality adviser"

**VitrA Karo** automatically detects and rejects undesirable tiles from entering the kiln with computer vision

### Assembly

**Haier** optimizes the allocation of production capacity and resources with AI to match personnel skills with processes, equipment and materials

### Delivery

**CR Building Materials Tech** employs adaptive algorithms on top of 3D digital modelling for "no-touch pickup" of new customer orders, including flexible cement bag load planning and execution

**Notes:** 1. Slow-moving and obsolete; 2. Root cause analysis; impacts are averages across all Lighthouses in the 11th cohort.

**Source:** Global Lighthouse Network

# 3.2 **Impact far, wide and fast:** democratizing AI with 'assetization'

Achieving the impacts the new Lighthouses did – with 20%, 40% or even 60% improvements across critical KPIs such as throughput, quality and delivery performance – has required them to scale past pilots and POCs to full implementation of use cases across every machine and production line. Some undertook their own four- or five-year journeys to pilot, learn and scale new technologies and use cases. Others – such as CATL in Liyang, China, Unilever in Sonepat, India, and Johnson & Johnson in Xi'an, China – were able to draw on the experiences of their company's other Lighthouse sites to design for scale from day one. They applied advanced AI and other technologies across numerous processes, skipping the steep learning curve that the earliest Lighthouses had no choice but to overcome.

One of the ways in which today's Lighthouses have sped past pilots is with a strategic focus on "assetization": that is, the art and science of packaging use cases for speed and scale of deployment. Other industries are also taking this approach: high AI performers are now 1.6 times more likely than other organizations to create AI applications using emerging low-code or no-code programs, allowing them to speed up the process of development even further.[14]

Agilent, a life science equipment manufacturer in Waldbronn, Germany, not only developed a computer vision use case that achieved a 40–50% defect rate reduction but also assetized it. It built an in-house, ready-to-deploy AI solution library for detecting anomalies and responding to process deviations, bundling computer vision tools with plug-in connectors to MES and test software and packaging with SOPs, user documentation and training guides for operators. This democratization of computer vision technology empowers technicians – not just engineers – to identify, deploy and test new camera and vision applications end to end. This enabled Agilent to deploy five new applications across 57 work centres and 16 product lines in less than four months.

FIGURE 13 **Agilent's computer vision toolkit**


**Agilent's computer vision toolkit enables speed and scale through democratized access to advanced vision capabilities**

**Source:** Agilent Technologies, Global Lighthouse Network

# 3.3 Towards system-level decision automation

As AI reaches maturity, Lighthouses are pursuing higher levels of decision-making, or "cognitive automation" – the ability to operate with humans *on* the loop instead of *in* the loop. Like any advance, maturity comes in stages. First, this means applying intelligence to maintain steady-state operational processes, such as using AI to set process parameters in real time. Second, the (correct) identification of restorative actions – for instance, suggesting a corrective action for a machine's underperformance, or recommending a recipe adjustment to compensate for an input material impurity, with humans *in* the loop. Finally, it evolves to full "self-healing" manufacturing and supply-chain operations, with humans *on* the loop.

Most Lighthouses have already achieved the first two. They are also accelerating towards the third – the technological achievement that underpins the concept of "lights-out" operations, where factories will achieve next-level improvements in productivity, quality and service levels and where the new front line will look more akin to augmented technicians than they do to the operators of today. Evolving to this point is risky; that's why some companies such as Schneider Electric are "training for trust", designing clear methods to improve confidence intervals in each AI recommendation well before handing over control. Two additional Lighthouses – Mondelēz and K-water – are examples of this evolution.

## Command centres for cognitive automation: two cases

Mondelēz, a biscuit manufacturer in Beijing, China, constructed a dough production workshop with an AI control centre spanning five automated production lines, four AGVs and nine ingredients in the supply chain. It optimizes the dough fermentation process, analyses its consistency for accuracy and improves capacity and speed across the entire production line and relevant supply chains.

In the face of climate change-induced volatility in the water supply, South Korea's K-water deployed an AI operations system to control processes such as mixing and coagulation. This helped increase the production volume by 31% in just two years, and work is under way on scaling to 42 other plants.

Both examples use centralized intelligence. They are beyond applying AI to individual process steps, instead adopting AI command centres that operate across the full production system. These solutions make the more difficult and responsive operational decisions, such as when new information emerges about a material shortage, or when a special priority order comes in, or when an energy source is affected, requiring rapid line rebalancing.
AI, unhindered by the limitations of insufficient memory, can sift simultaneously through millions of data points, understand them and optimize the mechanisms that connect them all – the next step towards a fully autonomous factory.[15]

FIGURE 14 **Centralized intelligence in use across the whole production system**

**K water** – **Autonomous operations command centre**

+104% Labour efficiency increase

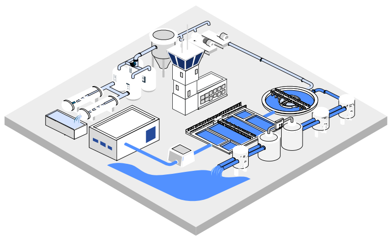
+10% Power consumption reduction

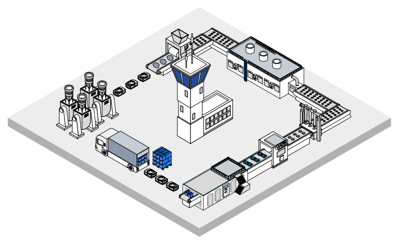
**Mondelēz International** – **"Lights-out" baking workshop**

+108% Process capability increase

+91% Productivity improvement

Three tiers to decision autonomy





| Three tiers to decision autonomy | K-water | Mondelēz |
|---|---|---|
| **Process step optimization** | Local AI models for optimal pump and peak power control across 14 process steps (e.g. chemical, mixing) | Local AI models across all 9 dough-making process steps to ensure consistent texture (e.g. mixing, fermentation) |
| **E2E operations command centre** | AI autonomous operation across all water treatment steps | Digital lean manufacturing management system oversees all dough-making steps |
| **Intelligent troubleshooting** | Autonomous analysis of sensor data to schedule optimal PM (e.g. filtration, disinfection) | Self-adjustment of 50+ critical parameters related to 20 defect types (e.g. biscuit inspection) |

**Source:** K-water, Mondelēz, Global Lighthouse Network

## 3.4 GenAI innovations across the value chain

Generative AI is expected to add between $2.6 and $4.4 trillion in annual value to the global economy[16] – nearly a quarter of which could be productivity improvements of up to two times and task automations of nearly 70% across manufacturing and supply chain-related activities, primarily driven by new capabilities in content generation, insights extraction and user interaction.[17]

What could these groundbreaking capabilities mean for manufacturing operations? Consider the hypothetical wind turbine engineer case (see below). This is the vision that Ni Jun, Chief Manufacturing Officer of CATL, laid out in this year's Lighthouses Live.

Lighthouses have realized this potential and are bringing GenAI to areas where data is most unstructured. This includes product development and procurement-related activities (such as the turbine example), along with two additional domains. First, enabling people productivity in manufacturing and supply chains – these pilots include GenAI-powered technician advisers and SOP-instructing chatbots. Second, accelerating digital capability-building – including through innovations in data management and software development co-pilots, personalized trainers and assessors for operators, and team assistants for agile squads. These kinds of use cases could enable robust digital transformations to happen faster than the two-or three-year sweet spot maintained by conventional wisdom.

The greater the quantity and quality of data across the value chain, the more effectively an organization can tune its GenAI models to be useful. And for companies willing to be creative, this data can take many forms – such as potential transcripts of conversations between technicians and operators, which contain valuable insights.

> **We are trying to use generative AI to help fresh engineers quickly learn those basic rules. Can we help engineers and college graduates, after half a year learning the GenAI tool, to become an independent designer?**
>
> Ni Jun, Chief Manufacturing Officer, CATL

**GenAI and engineering design: a hypothetical**

A first-year engineer asks GenAI to mock up a 3D model showing some changes to his company's newest wind turbine blades. He then uses the platform to coordinate dozens of analytic simulations employing applied AI models. The platform generates a report of potential product performance, documenting two areas for design improvement and one compliance issue. The engineer engages a "design adviser", which references past company designs and even web-scraped customer reviews, to generate iterations. After a few hours of back and forth, the engineer has a high-quality, cost-optimized and fully simulated design that is as good as, if not better than, those produced by his more seasoned peers.

FIGURE 15 | **Using GenAI across the value chain**

x % of Lighthouses with a pilot · Product improvement · Process optimization · People productivity

### Design (26)

- "Discover" new products (e.g. new chemicals, circuit designs)
- Accelerate/simulate testing phases
- Predict product market fit with consumer insights
- Optimize traditional part designs (e.g. component weight)

+4 additional

### Source (16)

- Pre-screen, summarize and extract clauses of interest
- Generate category strategies with external sources
- Role-play negotiations and prepare scenarios
- Automate document generation (RFPs, contracts)
- Create supplier performance reports

+4 additional

### Plan (16)

- Provide insights into inventory health and drivers of ageing
- Automate supplier risk analyses
- Chatbot for real-time supply-risk action planning

+3 additional

### Make (58)

- "Technician adviser" to troubleshoot
- Automate process failure analysis
- Co-pilot for SOPs, performance reports, training aids

+2 additional

### Deliver (21)

- Analyse and screen carrier shipment terms to enhance negotiation
- Generate and verify required documents for transportation
- Interactive virtual assistant to augment driver services (e.g. voice navigation)

+1 additional

### Serve (16)

- Personalized and interactive e-commerce pages
- Synthesize info for pricing decisions (e.g. competitors' prices)
- Review transcripts and coach call-centre agents
- Provide step-by-step instructions to customer to self-diagnose issues

+4 additional

### Technology (58)

**Data and technology**

- Accelerate software generation (co-pilot)
- Dynamic security scans to stabilize and accelerate code maintenance

+2 additional

### People (68)

**Talent and organization**

- Self-serve HR (e.g. automated onboarding)
- Recruiting co-pilot (e.g. develop job descriptions)
- Generate one-off/ customized learning scenarios

+1 additional

**Source:** McKinsey & Company, adapted to reflect Global Lighthouse Network examples

# 3.5 Speeding past pilots for GenAI, too

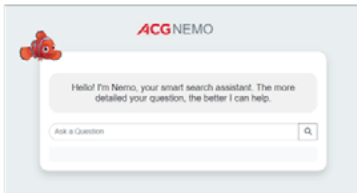
Back in 2019, when applied AI use cases were predominantly pilots and POCs, many factories were still building their data and technology foundations, ascertaining which new skills their workforce needed to have and developing strategies for successful implementation. At the time, the leadership from Lighthouses was in getting new use cases to real impact, even after potentially many pilots. But fast forward to today, and Lighthouses are even further ahead, sometimes skipping pilots altogether. In fact, the time it takes new Lighthouses to implement new AI use cases has fallen by nearly 25% compared with earlier cohorts. This means that the starting line for emerging technologies such as GenAI is far more advanced than it was for applied AI five years ago.

## Accelerated deployment at ACG Capsules

ACG Capsules, a pharmaceuticals contract manufacturer in Pithampur, India, is a prime example of accelerated deployment of GenAI. Seeking to address the changing needs for employee skill sets in manufacturing, the company developed and deployed an SOP- and policy-interfacing GenAI assistant in just two weeks. Within five weeks, after some transfer learning and fine-tuning, the GenAI assistant was already being used by nearly three-quarters of operators and technicians to inform maintenance and compliance actions.

FIGURE 16 **ACG Capsules' speedy deployment of GenAI**

| | Model build (2 weeks) | Deployment and adoption (4–6 weeks) | Key impact |
|---|---|---|---|
| Actions | Open-source LLM base model<br>Context building from 200+ quality, manufacturing and printing SOPs, maintenance instructions and case sheets<br>Transfer learning and fine-tuning | Multi-channel deployment using web, mobile and kiosk<br>Function-wise, staged rollout<br>Training for shop-floor personnel<br>Gamification with leader boards, rewards and recognition | 30–40% reduction in average MTTR |
| Enablers | In-house data science team<br>High-quality SOPs, policies, root cause analysis, artefacts | Low-code UI development<br>On-premise infrastructure for deployment of large language model | |




**Source:** ACG Capsules, Global Lighthouse Network

4

# Shaping the next five years of the Global Lighthouse Network

The manufacturing landscape looks nothing like it did a decade ago. Indeed, it has changed just as radically as the world has in that time.

Pressure-tested by the confluence of global events, Lighthouses have emerged stronger and more resilient than ever. Their pace and progress have brought the manufacturing sector to a definitive Fourth Industrial Revolution inflection point, as they shift from learning to doing, charting a course for the rest of the world's manufacturers to follow.

Lighthouses have reached this inflection point by setting the strategy, building delivery capabilities across talent, agile, technology and data, and implementing change management at the factory level. They are working now at remarkable speed to extend these same capabilities to the network – and in some cases, organizational – level. As they do this, they are rapidly engaging and implementing the latest advances in AI, including GenAI, as well as all other Fourth Industrial Revolution technologies to achieve significant impact at every step in the value chain. Here they are yet again illuminating the path for the world's manufacturers.

### A strategic response to the Fourth Industrial Revolution's acceleration

As Lighthouse companies shift from innovating to accelerating the Fourth Industrial Revolution, the sector faces an inflection. AI and other Fourth Industrial Revolution technologies will continue to proliferate in the coming years, led by those Lighthouses and others focused on network scale.

Manufacturers across the globe will be compelled to make a strategic decision in response to industry acceleration: to be innovators, accelerators or fast followers. The only wrong choice is to do nothing – laggards will not last long. In any approach, capabilities are critical; fortunately, Lighthouses offer a playbook of proven use cases and capability considerations that can provide a roadmap to success, with few of the learning curve's costs. Even those companies just embarking can quickly become fast followers.

## 4.1 Call for applications and engagement

The Global Lighthouse Network aspires to represent leading companies that choose to chart their course following one of these strategic responses. Enthusiastic, forward-thinking innovators, accelerators and fast followers are invited to learn more by emailing LighthouseNetwork@weforum.org.

Applications to join the 12th cohort of Lighthouses will close on 26 January 2024. Details can be found on the Global Lighthouse Network website.

# **Appendix:** Lighthouse use cases, change stories and impact

## Factory Lighthouses

| Site | Change story | Top five use cases | Impact | | |
|---|---|---|---|---|---|
| **ACG Capsules** Pithampur, India | To stay ahead of the curve in an intensely competitive market, pharmaceutical supplier ACG Capsules prioritized manufacturing superior-quality products, improving responsiveness, increasing production yields and enhancing workforce productivity. To achieve this, ACG Capsules implemented 25+ Fourth Industrial Revolution use cases powered by the industrial internet of things (IIoT), machine learning (ML), deep learning (DL), digital twins, extended reality and generative AI. Effective adoption of these use cases has resulted in a reduction in critical defects of 98%, a shortening of production lead times of 39%, a drop in total losses of 51% and a 44% rise in workforce productivity. | Real-time quality batch insights | 39% | ↓ | Batch lead time |
| | | ML-powered first-time-right optimization | 35% | ↑ | First-pass yield |
| | | Digital twin-powered production planning and scheduling | 13% | ↑ | On-time delivery in full |
| | | Virtual reality (VR)-based workforce augmentation and skill management | 39% | ↓ | Worker onboarding time |
| | | Deep learning-driven safety management and behaviour detection | 53% | ↓ | Safety incident rate |
| **Agilent Technologies** Waldbronn, Germany | Amid demand fluctuations – up to seven times more than is typical – strong growth of more than 50%, supply-chain disruptions and evolving product needs, Agilent Waldbronn introduced more than 25 Fourth Industrial Revolution-related roles and 20 associated use cases to address the challenges. Its high-volume and high-mix life-science manufacturing platform benefited from solutions from its Fourth Industrial Revolution toolkit, including AI applications and IIoT for rapid simulation and prediction. The facility has achieved a 35% increase in quality, a 44% boost in productivity and a 48% rise in output, ultimately enabling market share growth. | No-touch shopfloor scheduling system | 47% | ↑ | Direct labour productivity |
| | | Supply-chain reliability prediction and control | 36% | ↑ | Production output |
| | | Predictive quality testing with AI on cloud | 13% | ↑ | Test station throughput |
| | | AI computer vision toolkit and solutions library | 49% | ↓ | Defect rate |
| | | Predictive cost modelling and digital product simulation | 35% | ↓ | Cost of poor quality |
| **AMOREPACIFIC** Osan, South Korea | To stand out in the cosmetics industry, global beauty company AMOREPACIFIC used Fourth Industrial Revolution technologies such as AI and 3D printing to optimize manufacturing process design, accelerate new product introductions and improve flexibility. This reduced new product lead time by 50% and defects by 54%. It also enabled a new business model for manufactured-in-store customized cosmetics, with over 800,000 unique products offered. | AI-based customized cosmetic service | 800K | ↑ | Customized stock-keeping units (SKUs) |
| | | AI-based cosmetic process design optimization | 50% | ↓ | New product lead time |
| | | Self-evolving cosmetic manufacturing | 54% | ↓ | Manufacturing defect rate |
| | | AI-powered fault detection in packaging lines | 344% | ↑ | Packaging line productivity |
| | | 3D printing packaging production | 71% | ↓ | Tooling procurement time |

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| **Aramco**<br>Yanbu, Saudi Arabia | To maintain a competitive edge as one of the leading suppliers of fuels while minimizing its carbon footprint, this 1970s Aramco refinery underwent a five-year strategic Fourth Industrial Revolution transformation, implementing and integrating use cases at scale including an AI-based clean fuels optimizer, an AI-powered operation decision system and a digital twin dynamic model. As a result, on-spec fuel production has reached 99%, greenhouse gas (GHG) emissions have been reduced by 23% and operational availability has improved by 17%. | Digital twin for energy consumption reduction | 159% ↑ | Profitability enhancement |
| | | AI-powered operation decision system | 20% ↑ | Processing capacity |
| | | ML-based catalyst life prediction | 24% ↓ | Waste generation |
| | | AI-based clean fuels optimizer | 14% ↓ | GHG emissions |
| | | VR training for safety and process skills enhancement | 35% ↓ | Training time |
| **CITIC Pacific Special Steel**<br>Jiangyin, China | To meet the fast-growing global demand for customized steel products while navigating volatile raw material and energy-supply issues, CITIC Special Steel's Jiangyin Xingcheng plant deployed 40+ Fourth Industrial Revolution use cases such as advanced analytics-powered process simulation and optimization, as well as AI-enabled energy management. As a result, the plant has been able to increase customized orders by 35.3%, reduce its non-qualified product rate by 47.3% and cut its energy consumption by 10.5% per tonne of steel. | Big data-powered customized design process | 57% ↓ | New product design time |
| | | Blast furnace "black box transparentizing" with multimodal data | 85% ↓ | Operation downtime |
| | | Intelligent closed-loop control-enabled continuous quality improvement | 240% ↑ | Increased field performance of steel |
| | | AI-enabled process optimization of steel rolling | 15% ↑ | Output per machine hour |
| | | Advanced analytics-powered sustainability optimization | 11% ↓ | Average energy consumption |
| **Contemporary Amperex Technology (CATL)**<br>Liyang, China | To address soaring demand and increasing labour costs, and to meet its carbon neutrality commitment, CATL Liyang applied big data to simulate quality-testing, additive manufacturing to reduce changeover times, computer vision to achieve micron-level quality inspection, and deep learning to optimize process controls and energy management. This has resulted in a 320% output increase, a 33% reduction in manufacturing costs, a 47.4% reduction in normalized emissions and a 99% reduction in quality defects. Defect measurement has been upgraded from "per million" to "per billion". | Big data-enabled virtual battery capacity testing and estimation | 80% ↓ | Energy consumption |
| | | Virtual simulation and 3D printing for agile changeovers | 25% ↑ | Output |
| | | Deep learning-powered maintenance system | 41% ↓ | Maintenance cost |
| | | AI-enabled helium leakage detection process | 100% ↓ | Helium gas consumption |
| | | Intelligent digital and sustainable energy management | 43% ↓ | Energy consumption |
| **CR Building Materials Tech**<br>Tianyang, China | To address the requirements of green and low-carbon development, higher quality expectations and cost pressures, Tianyang site, a cement factory under China Resources Building Materials Technology Holdings, has deployed 30+ Fourth Industrial Revolution use cases with advanced analytics, autonomous driving and IIoT to improve energy, labour and equipment efficiency and quality performance. As a result, the site has reduced carbon emissions by 24%, increased labour productivity by 105%, reduced unplanned downtime by 56% and improved quality consistency by 25%. | Smart mining operations with AI and autonomous driving | 68% ↓ | $CO_2$ emissions from mine trucks |
| | | AI control and optimization for key cement production processes | 11% ↓ | Coal consumption per tonne of product |
| | | Intelligent equipment maintenance and scheduling | 56% ↓ | Unplanned downtime |
| | | AI-enabled closed-loop quality control | 87% ↓ | Customer reject rate |
| | | Digitally integrated no-touch order delivery | 321% ↑ | Pickup direct labour efficiency |

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| **GAC AION**<br>Guangzhou, China | To satisfy customers' spiking demand for reliable and customized electric vehicles, GAC AION deployed 40+ Fourth Industrial Revolution use cases to provide customers with more than 100,000 configuration options and ensure timely and qualified deliveries. The fully automated production line supports mixed production of made-to-order and made-to-stock models, increasing production efficiency by 50%, reducing delivery times by 33%, raising first-pass yields by 8% and reducing manufacturing costs by 58%. | Customer-to-manufacturing platform for customized vehicles | 30% ↓ | Order to delivery time |
| | | AI-enabled flexible automation | 67% ↓ | Changeover time |
| | | AI control tower for autonomous material distribution | 67% ↑ | Material handling productivity |
| | | "Vehicle-to-everything" closed-loop quality control | 8% ↑ | First-pass yield |
| | | Smart microgrid for sustainable manufacturing | 48% ↓ | Energy consumption |
| **Haier**<br>Hefei, China | The rise of a new middle class and increased consumer consumption in China have driven upgrades from a split air conditioner (AC) system to a central AC system, which has higher requirements in terms of quality and energy efficiency. Haier's Hefei air conditioner factory applied advanced algorithms, digital twins, knowledge graphs and other cutting-edge technologies in the research and development (R&D), production and testing of household central AC systems, resulting in a 33% increase in energy efficiency, a 58% drop in the defect rate, a 49% increase in labour productivity and a 22% drop in unit manufacturing costs. | Optimal product design with AI for fluid analysis | 63% ↓ | Product design cycle time |
| | | Dynamic, analytics-enabled cross-company allocation of shared labour resources | 60% ↓ | Training cycle |
| | | Digital twin-enabled high-precision changeover | 93% ↓ | Changeover time |
| | | Machine vision-enabled intelligent self-tuning in welding process | 85% ↓ | Welding defect rate |
| | | Knowledge graph-enabled expert system for performance inspection | 67% ↓ | Mean time to repair (MTTR) |
| **Hengtong Alpha Optic-Electric**<br>Suzhou, China | Facing higher cost pressures as well as quality and green production expectations from the international market, Hengtong Alpha accelerated the large-scale application of advanced analytics, machine vision and AI technology across 27 advanced use cases covering the whole production value chain. As a result, unit manufacturing costs have decreased by 21%, the defect rate has reduced by 52% and unit power consumption has fallen by 33%. | ML for product quality prediction | 61% ↓ | Optical parameter defect rate |
| | | AI- and vision-based preform outer diameter optimization | 35% ↑ | Processing speed |
| | | Ultra-high speed drawing control model | 67% ↓ | Operators per line |
| | | ML-powered fibre breaking prediction model | 26% ↓ | Fibre breakage frequency |
| | | Optimized testing with AI-based data inheritance | 39% ↑ | Units per person per hour (UPPH) |
| **Ingrasys, Foxconn Industrial Internet**<br>Taoyuan, Taiwan, China | The rapid development of artificial intelligence (AI) foundation models has brought an explosion in demand for computing power and higher efficiency, quality and iteration speed requirements for AI servers. By deploying AI use cases across order forecasting, warehouse and production scheduling, product design, quality and assembly-testing domains, Foxconn Industrial Internet's Taiwan factory has achieved a 73% increase in production efficiency, a 97% reduction in product defects, a 21% reduction in lead time and a 39% decrease in unit manufacturing costs. | AI-enabled warehouse and logistic scheduling | 44% ↓ | Line changeover time |
| | | AI-driven order forecasting and production scheduling | 8% ↑ | On-time delivery |
| | | AI-enabled product parameter design process | 89% ↓ | Board design time |
| | | AI advanced control quality management analysis | 99% ↓ | Defect rate on SMT lines |
| | | AI-powered automated assembly and testing workshop | 42% ↑ | Overall equipment effectiveness (OEE) |

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| **K-water**<br>Hwaseong, South Korea | The climate crisis has caused significant water-supply concerns, as heatwaves and heavy rains create more volatile and turbid supplies. To address this, K-water launched a next-generation AI water treatment plant to reduce production costs, improve responsiveness and reduce human error. It is being scaled across 40+ other sites and has helped K-water to reduce its chemical usage by 19%, improve labour efficiency by 42% and reduce power consumption by 10%. | Intelligent and autonomous plant operation system | 104% | ↑ | Process labour efficiency |
| | | Demand prediction-based energy optimization | 10% | ↓ | Energy consumption |
| | | ML-based predictive maintenance | 33% | ↓ | Maintenance cost |
| | | Digital twin for training and maintenance | 33% | ↓ | Training time |
| | | AI for CCTV-based safety management | 75% | ↓ | Incident response time |
| **LONGi**<br>Jiaxing, China | Driven by the desire to reduce costs, improve quality and shorten the lead time on solar modules, the Jiaxing site implemented more than 30 Fourth Industrial Revolution use cases, using AI and advanced analytics to boost manufacturing operations. These efforts have had significant impacts, with the site achieving a 28% reduction in unit manufacturing costs, a 43% cut in yield loss and an 84% decrease in production lead time within one year, while also lowering energy consumption by 20%. | AI-enabled real-time inspection root cause analysis and action recommendation | 32% | ↑ | First-pass yield |
| | | Neural network-enabled solar cell production planning and allocation | 46% | ↓ | Product power deviations |
| | | Data-backed career planning for workers | 35% | ↑ | Direct labour productivity |
| | | AI- and machine vision-enabled flexible automation | 96% | ↓ | Changeover time |
| | | Big data-powered order production optimization | 84% | ↑ | Logistic labour productivity |
| **Mondelēz**<br>Beijing, China | Embracing sustainability ambition from both Mondelēz Global and Beijing City while meeting Mondelēz's growth ambitions and addressing operating cost pressures due to year-on-year (YoY) 6% labour cost inflation, Mondelēz Beijing implemented 38 Fourth Industrial Revolution use cases, such as an AI-powered dough-making lights-off workshop and gas consumption optimization by machine learning. As a result, Mondelēz Beijing has achieved a 28% net revenue growth and 53% increase in labour productivity while reducing GHG emissions by 24% and food waste by 29%. | Lights-off autonomous dough workshop | 91% | ↓ | Headcount |
| | | ML-powered baking oven control system | 72% | ↓ | Food waste |
| | | ML-based heating, ventilation and air conditioning (HVAC) system optimization | 24% | ↓ | Electricity consumption |
| | | AI-enabled close-loop defect elimination | 52% | ↓ | Consumer complaints |
| | | Digital lean manufacturing management system | 49% | ↓ | Unplanned downtime |
| **ReNew**<br>Ratlam, India | To maximize productivity , streamline costs and redeploy the existing workforce to help in-source operations and maintenance (O&M) capabilities, renewable energy company ReNew built on and scaled the digital and analytics backbone from its first Lighthouse site, including new proprietary AI models and the rapid scaling of Fourth Industrial Revolution use cases across 70 wind farms, 10 original equipment manufacturers (OEMs) and 22 unique wind turbine models. Ratlam, the company's benchmark site for this scale transformation, has sustained improvements of 1.7% higher energy yield, 17% reductions in operating expenses and 40% less waste. This led to a 20% increase in profitability. | ML-powered automated wind turbine blade inspection | 78% | ↓ | Unplanned maintenance |
| | | AI-based wind wane system for corrective turbine | 90% | ↓ | Defect identification time |
| | | ML-based turbine power curve optimization | 90% | ↓ | Maintenance work hours |
| | | ML-powered failure prediction system | 83% | ↓ | Unplanned maintenance |
| | | Early detection of faults in power transmission lines | 66% | ↓ | Transmission line failures |

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| **VitrA Karo**<br>Bozüyük, Türkiye | Increased energy prices and inflation have affected energy costs and the labour-intensive ceramic tile production process. To sustain competitiveness while responding to higher demands and maintaining a complex portfolio of 4,200+ SKUs, VitrA Karo's Bozüyük site deployed its digital transformation roadmap, focusing on intelligent process and production controls. This has resulted in a 19% increase in OEE, a 56% decrease in scrap, a 14% decrease in energy consumption and a 43% increase in the use of recycled content. | AI-based blending optimization | 44% ↑ | First-pass yield |
| | | AI and IIoT for prescriptive process parameter setting | 17% ↓ | Energy consumption |
| | | AI-based continuous product specifications for quality consistency | 32% ↓ | Scrap ratio reduction |
| | | AI-based quality inspection and root cause analysis | 66% ↓ | Complaints ratio |
| | | Intelligent production control tower | 19% ↑ | OEE |

# End-to-End (E2E) Value Chain Lighthouses

| Site | Change story | Top five use cases | Impact | |
|---|---|---|---|---|
| **DHL Supply Chain**<br>Memphis, United States | Facing a growing e-commerce market and driven by retail promotions and a consumer consumption switch from offline to online orders, in addition to heavy seasonality impacts, DHL Supply Chain in Memphis, Tennessee established a strategic Fourth Industrial Revolution site, equipped with a control tower for centralized planning and execution oversight to manage and control E2E operations. This site has seamlessly integrated robots, analytics and a flexible staffing solution, resulting in a 50% overtime reduction, a 57% shipment cycle time reduction and a 290% increase in capacity, leading to a 28% compound annual growth rate (CAGR) since 2019. Consequently, the site has emerged as a primary training hub for the global adoption of new technologies. | Analytics-powered flexible staffing model | 25% ↓ | Absenteeism |
| | | Predictive inventory replenishment | 65% ↑ | Availability percentage |
| | | Analytics-enabled warehouse visibility platform | 34% ↑ | Productivity |
| | | Digital-enabled picking and transport | 38% ↑ | Throughput |
| | | Digital logistics control tower | 71% ↓ | Pick cycle time |
| **Haier**<br>Qingdao, China | In order to stay ahead of the industry on cost and address common problems of unprofessional and delayed services in the home-appliance industry, Haier deployed 136 Fourth Industrial Revolution use cases for procurement cost savings and improvements in productivity and quality of services, using technologies including 5.5G, advanced algorithms and ready-to-use digital twins. This initiative has resulted in product cost being optimized by 32%, labour productivity increasing by 36% and the service complaint rate being cut by 85%. | One-click should costing and optimization | 21% ↓ | Material cost per unit |
| | | 5.5G-enabled intelligent in-plant logistics | 80% ↓ | Material shortage-based downtime |
| | | IIoT-based optimization of final assembly efficiency | 33% ↑ | Labour productivity |
| | | Intelligent repair request matching and autonomous dispatching | 88% ↑ | Speed to repair |
| | | Digital twins for washing machine parameter optimization | 43% ↓ | Product defect rate |
| **Johnson & Johnson**<br>Xi'an, China | To improve agility and responsiveness, raise quality standards and enhance competitiveness, Johnson & Johnson Xi'an replaced its manual facility with a Fourth Industrial Revolution-enabled new factory in 2019. This facility includes digital twins for technology transfer and material handling, intelligent automation of continued process verification (CPV) and batch execution processes. This has shortened the product transfer time by 64% during site relocation and has enabled a 60% decrease in non-conformance, while improving productivity by 40%, operating costs by 24% and GHG emissions by 26%. | Digital twin-enabled smart technical transfer | 34% ↓ | Cycle time |
| | | Intelligent automation-powered batch execution excellence | 60% ↓ | Batch non-conformance |
| | | Autonomous continuous process verification | 92% ↓ | Time to detect variation |
| | | Digital twin-powered material handling | 100% ↓ | Finished goods inventory footprint |
| | | Intelligent supply chain control tower | 81% ↓ | Slow-moving Inventory |

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| **Kenvue**<br>Shanghai, China | To keep up with the growth in e-commerce, faster speed to market and the fluctuating demands that come from increased cost competitiveness, Kenvue Shanghai deployed more than 25 Fourth Industrial Revolution use cases, including big data analytics on social media, digital twins, additive manufacturing and ML across its E2E value chain. This resulted in a 50% reduction in new product introduction lead times, a 1.3-times improvement in forecast accuracy and 99.8% on-time-in-full deliveries within 48 hours. This enabled the e-commerce business to double from 30% to 60% of overall business. | Big data and AI for customer-to-manufacturer insights on product fit | 50% ↓ | Time to market (new product introduction) |
| | | Process twin for new product speed to market | 30% ↓ | Produce development cost per SKU |
| | | ML-enabled granular demand forecasting | 80% ↓ | Out-of-stock rate |
| | | Smart agile manufacturing through remote data monitoring and 3D printing | 70% ↓ | Changeover time |
| | | Predictive and touchless stock replenishment | 23% ↓ | Inventory days on hand |
| **Unilever**<br>Sonepat, India | To improve agility and cater to diverse product segments, reduce costs in an inflationary environment and improve sustainability, Unilever Sonepat implemented 30+ Fourth Industrial Revolution use cases in its E2E supply chain. Top use cases included boiler and spray dryer process twins, as well as customer data-informed no-touch production planning and inventory optimization. This improved service by 18%, forecast accuracy by 53%, conversion cost by 40% and Scope 1 carbon footprint by 88%. The use of biofuels enabled by a boiler process twin also supports livelihoods for local farmers. | Digital twin for green fuel flexibility in boiler | 88% ↓ | Boiler GHG emissions |
| | | IIoT-enabled spray dryer digital twin | 93% ↑ | Process labour productivity |
| | | Cognitive automation for supply resilience | 18% ↑ | Service levels |
| | | AI-powered real-time inventory optimization | 23% ↓ | Finished goods inventory |
| | | Predictive asset maintenance | 56% ↓ | Maintenance cost |

# Sustainability Lighthouses

| Site | Change story | Top five use cases | Impact | |
|---|---|---|---|---|
| **Johnson & Johnson**<br>Xi'an, China | To address growing energy demands while reducing its environmental impact, Johnson & Johnson Xi'an constructed a state-of-the-art manufacturing site. To meet and surpass its LEED Gold® certification, it implemented a series of Fourth Industrial Revolution technologies, including AI algorithms for process control, IIoT-based intelligent cleaning and digital twins. This has resulted in a 47% reduction in material waste, a 26% decrease in GHG emissions and a 23% reduction in energy consumption. | Digital twin-enabled adaptive process control | 32% ↓ | GHG emissions |
| | | Intelligent cleaning | 72% ↓ | Detergent consumption |
| | | Advanced analytics-powered batch release for waste reduction | 63% ↓ | Hazardous waste |
| **Kenvue**<br>Bangkok, Thailand | In line with Kenvue's Healthy Lives Mission and its commitment to advance the well-being of both people and planet, Kenvue Thailand deployed Fourth Industrial Revolution technologies for more sustainable resource management across site operations. This includes an end-to-end water-to-ecosystem performance management system, a digital twin to optimize chiller system energy consumption and a dynamic scheduling and container loading optimization solution that leverages data analytics and robotic process automation. From 2018 to 2023, the site reduced water utility intake by 35%, energy-related consumption (scope 1&2) by 34%, correlating GHG emissions by 29%, normalized for production volumes, and container utilization improved by 35% leading to more efficient transportation. | E2E water ecosystem dashboard | 29% ↓ | Wastewater |
| | | Cloud-connected digital twin chiller system | 45% ↓ | Chiller system $CO_2$ emissions |
| | | Digital thread for dynamic container scheduling and optimization | 18% ↓ | Scope 3 $CO_2$ emissions |

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| **Schneider Electric**<br>Hyderabad, India | Schneider Electric's Hyderabad site aims to be zero carbon on scope 1 and 2 by 2030, based on a strong Fourth Industrial Revolution core. This includes an E2E closed-loop system with $CO_2$ tracking for strategic suppliers. The system is powered by real-time data generation and cloud analytics for all facility assets that interlink with shop-floor operations using an IIoT-enabled equalizer and AI-based predictive monitoring. This has led to a 59% reduction in energy consumption, 61% decrease in $CO_2$ emissions, 57% cut in water consumption and a 64% reduction in normalized waste generation. | Smart air compressor optimization with closed-loop control | 57% ↓ | Unit energy consumption |
| | | IIoT-driven energy management system | 57% ↓ | Unit water consumption |
| | | Digital control tower for tracking and managing emissions (all scopes) and waste | 64% ↓ | Unit waste generation |
| **Siemens**<br>Chengdu, China | To become a zero-carbon pioneer in the context of 92% growth in production output in the past three years, Siemens' Chengdu factory deployed a holistic digital energy management system, implemented predictive maintenance throughout the manufacturing process, introduced AI-based automation to identify and handle up to 16 types of production waste and applied eco-design features to improve circularity and dematerialization. This has reduced unit product energy consumption by 24% and production waste by 48%. | Automated energy efficiency management | 33% ↓ | Building energy consumption |
| | | AI-enhanced resource recycling | 60% ↓ | Material waste from cartons |
| | | Digital eco-design for resource efficiency | 44% ↓ | GHG emissions on mechanical products |

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# Endnotes


1. "Agile" in this paper is an industry term that refers to a method of project management that was pioneered for software development and is now a critical element in delivering Fourth Industrial Revolution use cases. The method is characterized by the division of tasks into short phases of work and frequent reassessment and adaptation of plans; see, for example, Agile Alliance: https://www.agilealliance.org/agile101/the-agile-manifesto/.
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