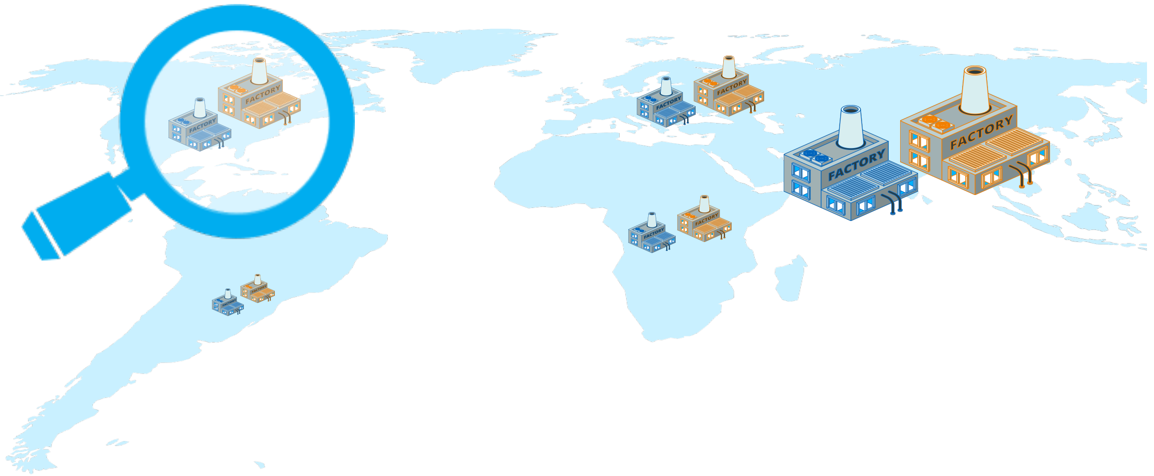
Chemicals Manufacturing 2030+

More of the same…
but different.

The changes in the global asset network will be small …

Production capacity[1] 2017   Production capacity[1] 2030



- Growth rates will likely continue to diverge among China (~4%), US (~2%), and Europe (~1%) will continue; China will build new at-scale assets, Europe and US will continue to use mainly existing assets[2]
- Reliance on existing assets may not necessarily translate into significant disadvantages for Europe and US as “back-regionalization” of markets continues; Western assets tend to be better-performing although Asia is catching up quickly
- To fight labor-cost inflation, China and Eastern Europe will need significant productivity increases by applying Lean and Industry 4.0 techniques
- Integrated sites will still be an advantage, as the basics economic reasons will continue to be relevant in a world of increasing digitization
- Increasing volatility and potential crises will require companies to develop response scenarios emphasizing agile end-to-end optimized supply chains

1 Production capacity based on petrochemicals production (70% of chemicals volume)
2 Estimated CAGR of production capacity petrochemicals until 2030, Source ICIS

SOURCE: McKinsey

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... changes will happen mainly at the plant level along 3 dimensions

DATA MANAGEMENT

Scale will not necessarily be an advantage in terms of the impact from data usage, because each plant will require a tailored optimization model; scale benefits will mainly come from database of failures

Most data lakes will be built on-premise rather than in the cloud; limited comparability of sites, lack of speed, and data-security risks limit benefit of cross-site data pools

Data will be managed by chemicals players, with access granted to externals on a need-to-know basis so they can leverage data to help reduce failures and increase service

PEOPLE'S TASKS

Maintenance technicians will use digital-workflow apps, increasing efficiency and productivity though improved planning, guidance, and performance management; in principle, tasks will stay the same

Control-room operators will remain for safety reasons; their tasks will evolve from “control” to “improve,” creating an enormous upskilling challenge

40-60% of value-adding field operator time can be saved through automation and applied toward more critical tasks that require humans; the limiting factor for reducing resources will be safety regulations

ASSET OPTIMIZATION

Robotics, digital, and advanced analytics (AA) will change activities, not the fundamental design of assets:

- Only a **limited number of solutions with significant impact**—core of creating impact is not building a tool, but implementing and scaling successfully
- Key improvement levers will be AA-based **Yield-Energy-Throughput optimization, predictive asset reliability, and digitally enabled performance management**
- Most solutions have a **better business case when integrated into newly built assets**, but can also be retrofitted easily

Regional consolidation of control rooms will only be implemented for a subset of asset archetypes, mostly because of safety regulations and risk limitations; consolidation of control rooms on site will be a significant improvement lever

LEAN will continue to be the foundation

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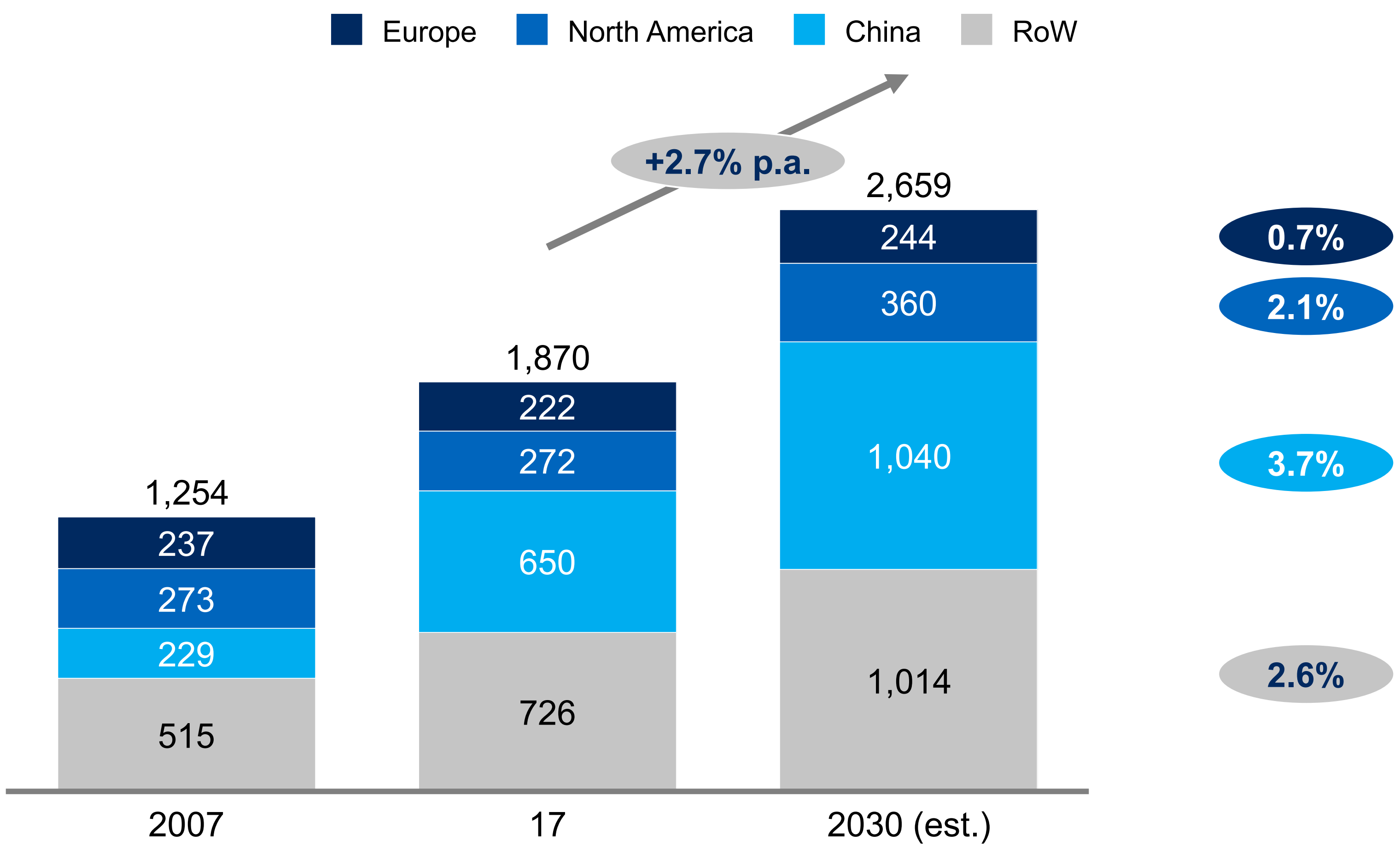
Growth rates show expansion in China while Western hemisphere stays mostly flat

Global chemicals capacity forecast[1], in mtpa[2]



- **China is expected to build new at-scale facilities** while EU/US will mainly keep using existing facilities
- Depreciated assets in Europe and **long pay-back times for new assets** (15-20 years) limit capacity shift toward other markets
- **Long-term shift of capacity** share **to emerging markets expected** in order to meet increasing demand

1 ICIS forecast based on petrochemicals, accounting for 70% of total chemicals market
2 Million tonnes per annum

SOURCE: McKinsey

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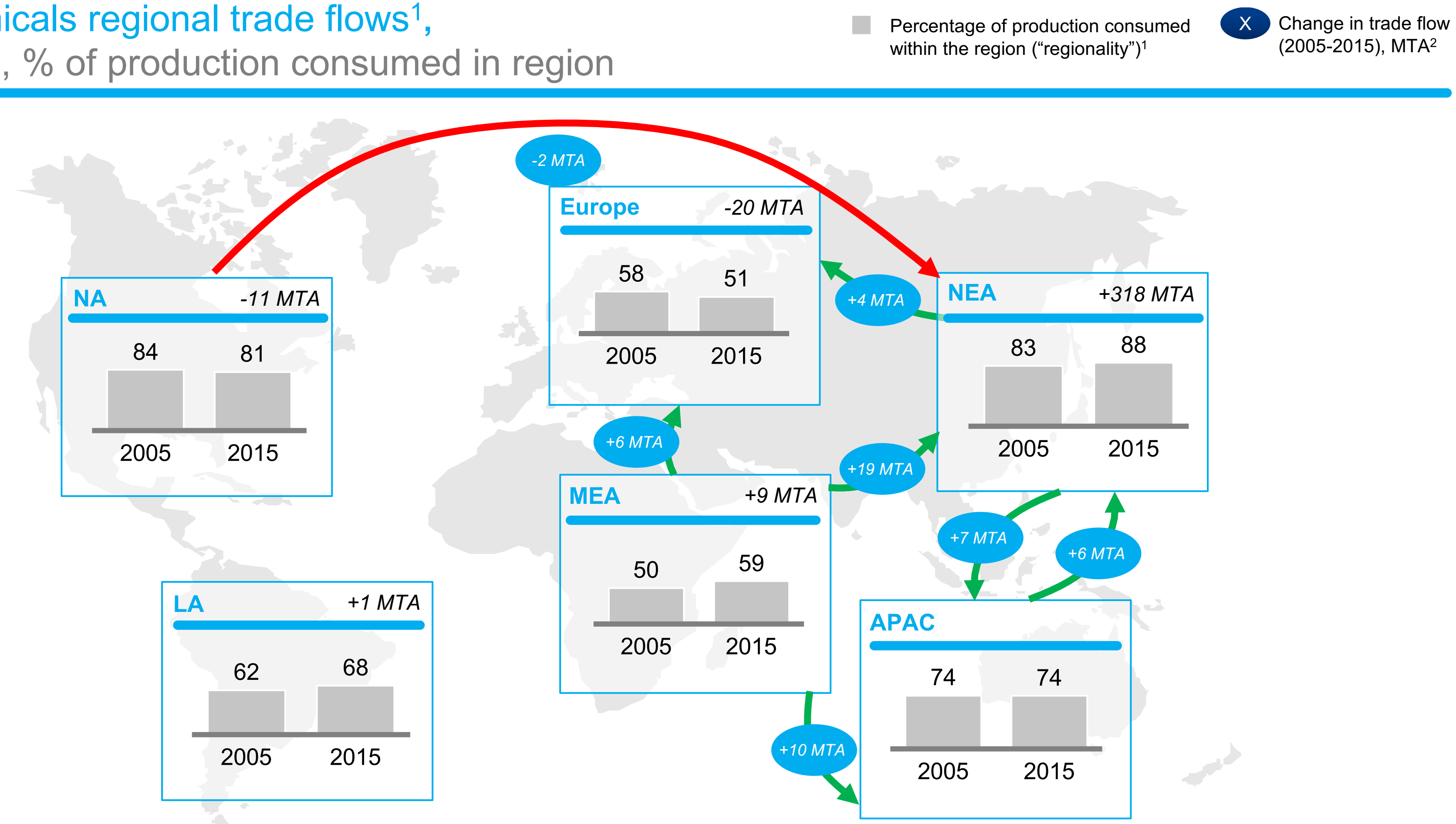
Deep dive—chemicals market is staying regional; share of supply that stays within regions has further increased since 2005

Petrochemicals regional trade flows[1], 2005-2015, % of production consumed in region



Consumption of specialty chemicals is **more global;** however specialty chemicals represent **<30% of the global chemicals market** (volume)

1 Regions: North America, South & Central America, Middle East & Africa, Europe, Former USSR & Northeastern Asia, and Asia & Pacific
2 Million tonnes per annum; trade flow arrows are non-comprehensive—only trade flows where one direction is greater than 7 MTA included

SOURCE: McKinsey, ICIS S&D

- **Northeastern Asia and Middle East and Africa are increasing regionalization**, with increasing production and increased non-import consumption as a percentage of production
- As the **largest demand driver, China is driving the regionalization of the (petro-) chemicals market**

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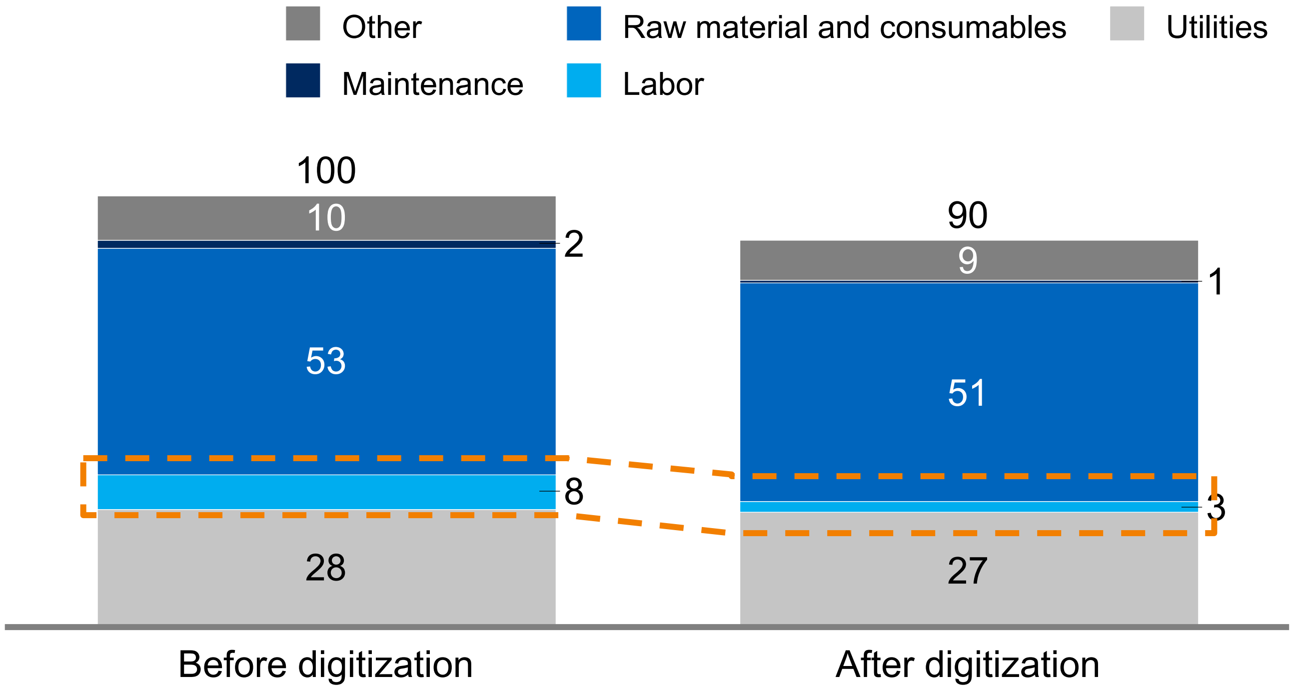
Assets in China and Eastern Europe will need significant productivity increases by applying Lean methodology and Industry 4.0

Revenues and cost structure 2017[1], percent of total cost



- Digitization (advanced analytics, automation and digital central functions) affects all cost drivers
- Labor cost reduction due to automation and robotics has the strongest effect

- Digitization significantly **reduces the share of labor in the total cost** thereby **reducing the competitive advantage** of LCC players
- Also current LCC players need to **implement lean and Industry 4.0** elements to stay competitive

1 Cost structure based on commodity-chemical plant

SOURCE: Annual reports; Newsweek article "Digital transformation – bringing chemicals into the internet age"; McKinsey

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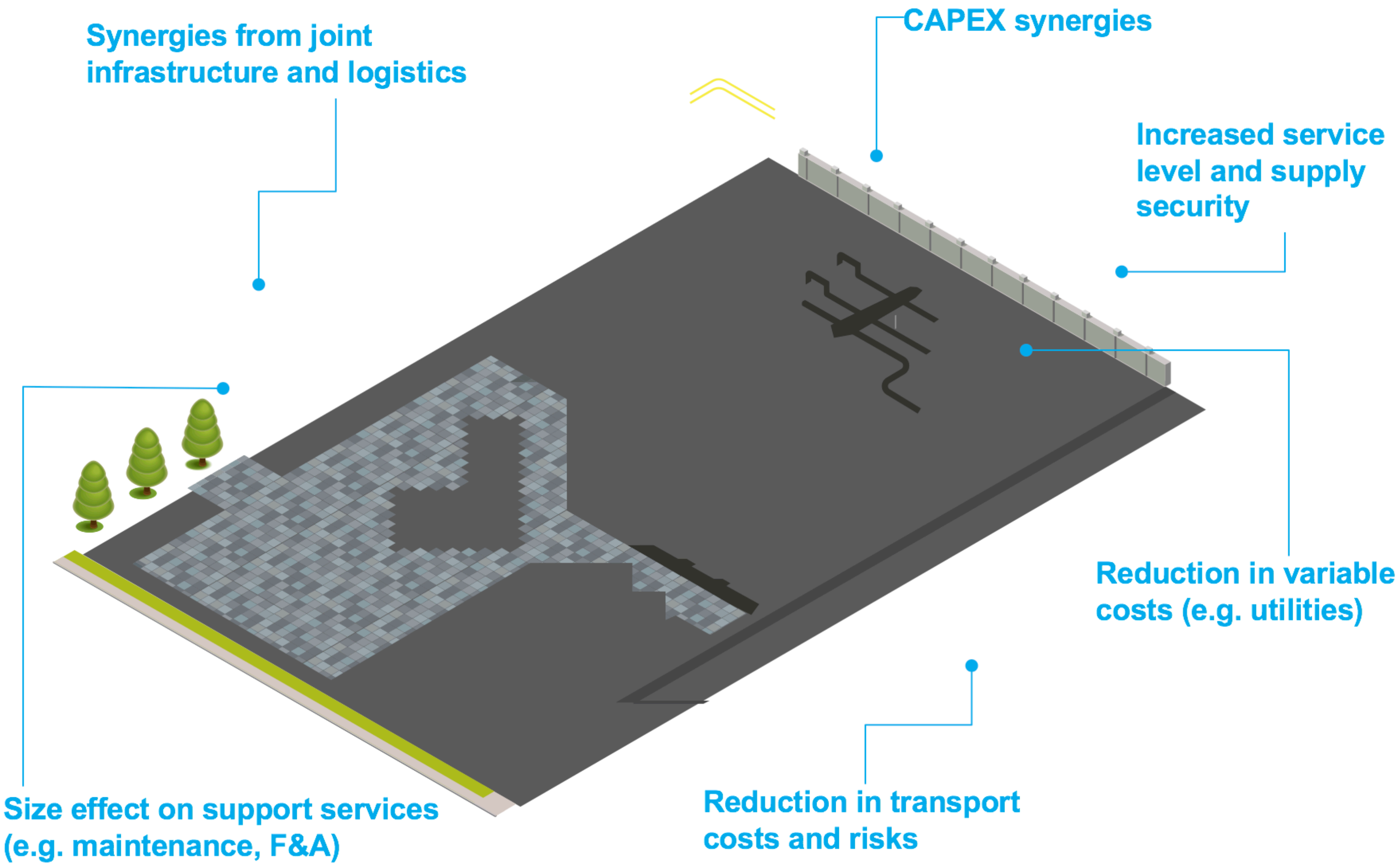
Integrated sites will still be an advantage as the underlying drivers for economies will continue to be relevant in a world of increasing digitization



- **Underlying drivers for economies** (CAPEX synergies, reduced logistics cost, etc.) **will continue to be relevant**
- Increasing use of digital and advanced analytics **will likely challenge the economies of integrated site only to marginal extent**

SOURCE: McKinsey

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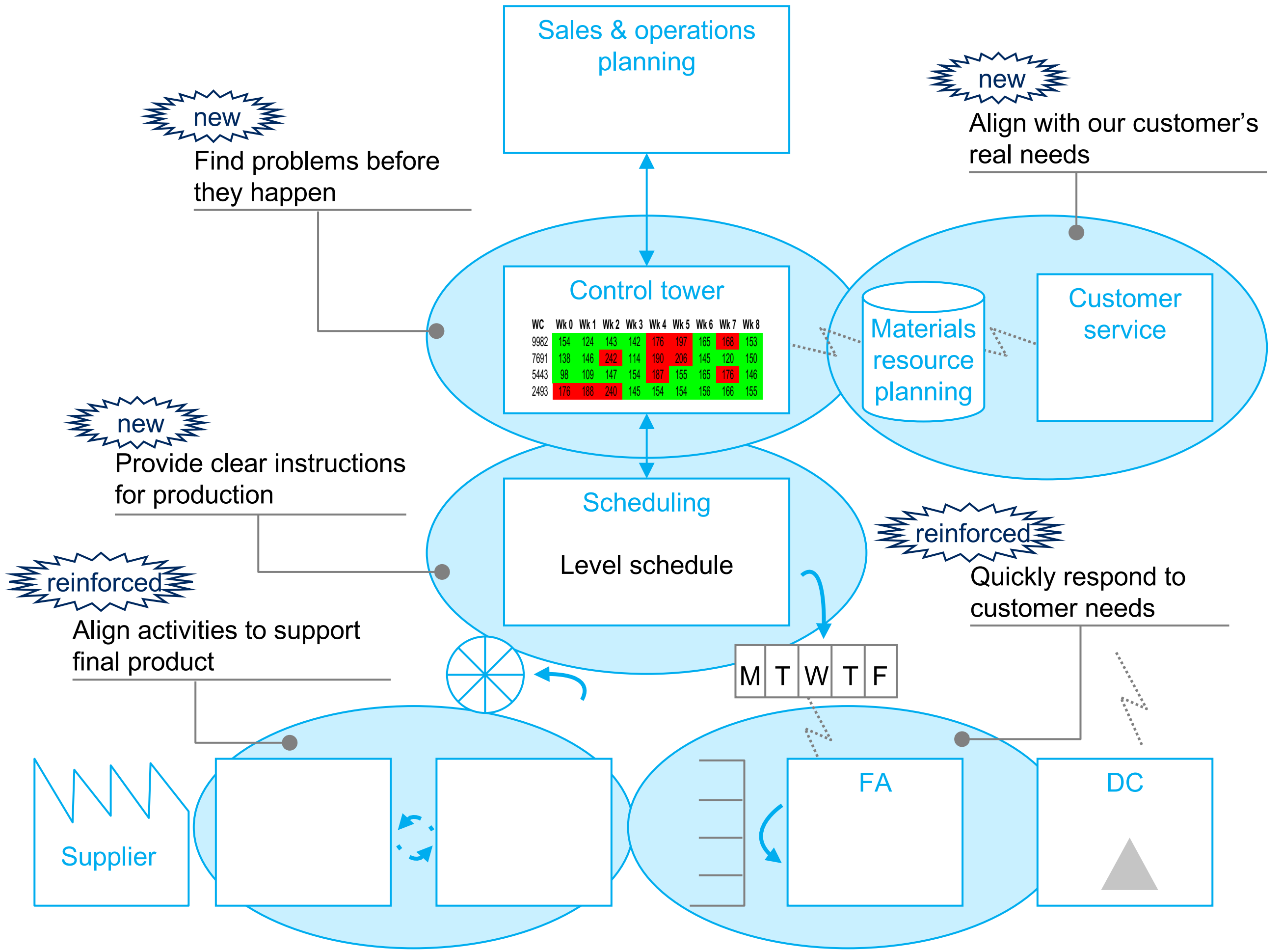
Players need to develop response scenarios with more agile and end-to-end optimized supply chains in order to stay resilient in downturns

End-to-end (E2E) integrated supply chain



Lean foundational tools :

5s+1 | Visual factory | Standard work | QCPC | TPM | VSM | PIM

How does agile E2E supply chain increase reactivity?

Inventory
- **Reduced inventory across the value chain** (incl. raw materials, intermediates and finished goods) due to **instant visibility of stocks**
- Greater opportunity to implement "**make to order**" strategy as lead times in P2P process are reduced

Lead time
- Faster lead times due to reduction of touchpoints leading to **shorter cash-turnaround cycles**

Cost
- **Fewer write-offs and aged stocks**
- **Reduced costs** for holding inventory and redistribution

Customer service
- Improved customer understanding leading **to better alignment of expectations and service as** systems prevent order complications

Market reactivity
- **Better customer service** enabled by faster response times
- Increased ability to **adapt to market changes**
- **Greater opportunity for segmentation**

Agile supply chain coupled with segmentation reduces NWC requirements and improves market responsiveness

SOURCE: McKinsey

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Data management—Scaling advanced analytics (AA) across multiple sites requires tailored optimization at every site

Based on use case of a large cement manufacturer:
- 30+ cement sites with **comparable technology** covering 10+ countries in Europe
- However, there are still **significant differences between sites that limit scalability of the AA algorithm**

Differences
- Process technology details
- Performance levels
- Data sources
- External factors (e.g. temperature, humidity)
- People/ experience levels
- Site age

Implications for scaling up advanced-analytics solutions

- Contextual situation and external factors—such as temperature, humidity, people—**are inherently different for each plant**
- AA modeling has to be done at the plant level, as **highly customized models are required** rather than simple replications or adaptions of a master and data across sites

SOURCE: McKinsey, press search

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Data management—Data lakes will be mostly local given lack of speed, data-security risks, and limited comparability of sites

Hosting decision

	On-premise	Public cloud
Cost	⊖ More capex ⊕ More attractive opex	⊕ Cost of capex more attractive ⊖ Opex on public cloud up to ~1.5 - 2.0 times higher ⊕ More flexible costs
Security	⊕ Encrypted data in safe environment guaranteed	⊖ Challenges for transferring and storing sensitive data on the cloud
Implementation time	⊖ Creating new infrastructure can be a slow process especially HW purchases and integration	⊕ Infrastructure can normally be provided very quickly
Data latency	⊕ Updating data from original systems in real time	⊖ Network latency reduces speed
Technology readiness	⊕ Proven technologies with robust community of developers	⊖ Ensure local and cloud vendor technology remains on par

“ …The executives surveyed clearly see some risk involved with moving to cloud services **(data security, privacy and confidentiality top the list)**. According to one industry senior executive: **“Once the cost becomes compelling then the factors around business criticality will come into play. Even so we are not at a point where we are ready to put our crown jewel information in the cloud.”**

- Most data lakes will be **built “on premise” and not cloud based** given limited gain from data sharing between sites due to:
  - **Risk of data security**
  - **Lack of speed**
  - **Limited comparability of sites**

SOURCE: McKinsey, ChemITC, press search

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Data management—Data will be managed by the players; access by third parties on a need-to-know basis to reduce failures and increase security

Challenges of cloud-hosting and third-party data ownership

Lack of control & flexibility

- Chemical player **no longer has total control** of applications or data
- Some applications, tools, and software **cannot be deployed on cloud infrastructure**

Limited value-add & functionality

- **Limited benefit of data ownership or management** by third parties
- As this typically implies a cloud storage, network latencies and availability **may affect application performance**

Security/legal risks

- Service providers **will have access to chemical player's data**
- Chemical player **will still be liable for data breaches**

- Most data **will be owned and managed by chemical players themselves** due to data concerns and the lack of competitive advantage provided otherwise:
  - **Limited incentives for chemical players to share data without clear need** (e.g., specific project) with other parties
  - Service providers will be given access to the data lake, **presenting security concerns**
  - **Increased security and legal risks** with third-party ownership

SOURCE: McKinsey, press search

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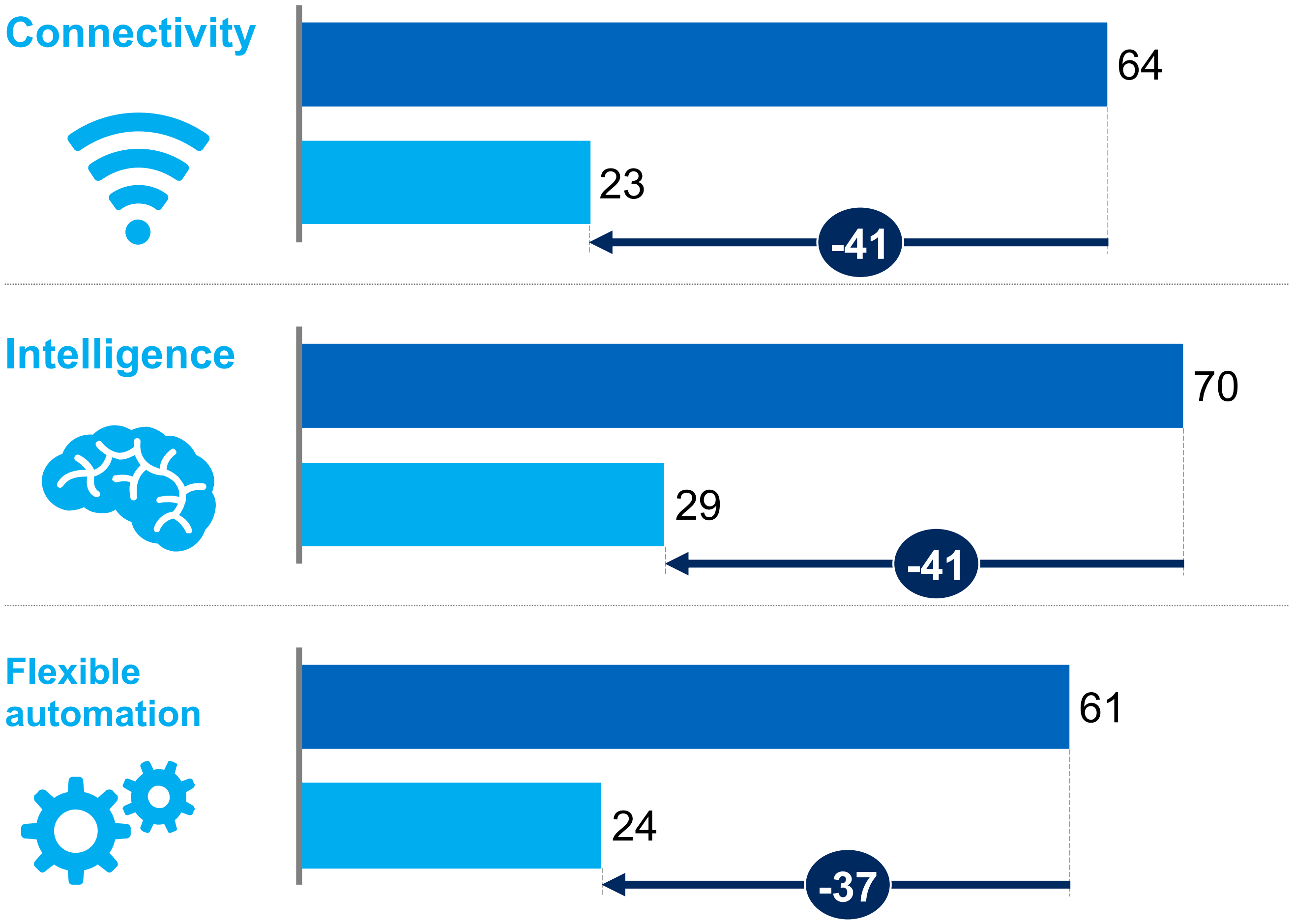
Asset optimization—core of creating impact is not building a tool, but implementing and scaling successfully after pilot

Stage of adopting digital manufacturing solutions
% of relevant solutions

Pilot phase (or advanced) | Rollout phase



Lacking impact at scale—while pilots are common, **only ~30% of organizations adopted rollout-relevant solutions** company-wide

- There is no "silver bullet"—**key is to choose priority elements and scale them across the company**
- **To move successfully out of pilot purgatory:**
  - Approach the opportunity "**bottom-line value backward**" rather than technology forward
  - Build and lead a **focused ecosystem of technology partners**
  - **Drive the transformation from the top** and communicate results and success stories

SOURCE: McKinsey Digital Manufacturing Global Expert Survey 2018

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Asset optimization—Yield, Energy and Throughput with in-line quality control and predictive-asset reliability will be key levers

Case example: Throughput improvement

Situation: Global chemical company had **high variability in throughput** and **low overall output** at one of its plants in Europe

Sensing & capturing—large data set used from client's current sensors (>500,000 samples covering >500 days of production, each with >50 tags → ~40 million data points)

Analysis & modeling—whereas previously the company was aware only of linear correlations, the model has shown the interdependency of key variables, thus better explaining the process

Decision making & actuation—The new approach helped the company set up new experiments for optimal production levels

Impact: 18-33% output increase potential for the processes within the study scope; overall savings and revenue increase opportunities of ~EUR 30mn

Chemical players using **digital solutions to transform their operations** are seeing promising results

- **Maximization of profit/hr of processing plant** by optimizing process parameters
- **Minimization of cost and downtime associated with maintenance/repairs**
- Relatively low required investments, with **payback periods of one to two years**

SOURCE: McKinsey

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Asset optimization—Most solutions are more feasible in a newly built setup but can be also retrofitted

		Value identified, mEUR	Implementation cost, mEUR	Payback	Selected key levers
Recurring	Plant steering	10	~1	<1 yr	▪ Advanced analytics algorithm for steering ▪ Optimization of energy flow at site level ▪ Use manufacturing intelligence
	Reliability & maintenance exec.	5	~2	1-2 yrs	▪ Digitization and automation of recurring maintenance activities ▪ Advanced analytics (AA) for reliability
	Operations	5	~3	1-2 yrs	▪ Automation of manual standard tasks ▪ Digitization of manual non-standard tasks ▪ Real-time performance management
	Capabilities		Low[1]		▪ Enabler
	Core technical enablers				
	Total recurring	20	~6	1-2 yrs	
Capex savings	Digital project management	10-25	3-10		▪ Adoption of 3rd era of project-management practices: project production management ▪ Setup of specific technologies against variability

Based on case study of a chemical company building a new plant:

- All of these levers can also be **retrofitted to an existing plant**, which would lead to a **slight increase in payback times**
- **Payback period** for most AA levers, however, is significantly **less than 2-3 years** and therefore **financially viable even with higher implementation cost**

1 Digital organization and technical infrastructure generally well fit to support prioritized case

SOURCE: McKinsey

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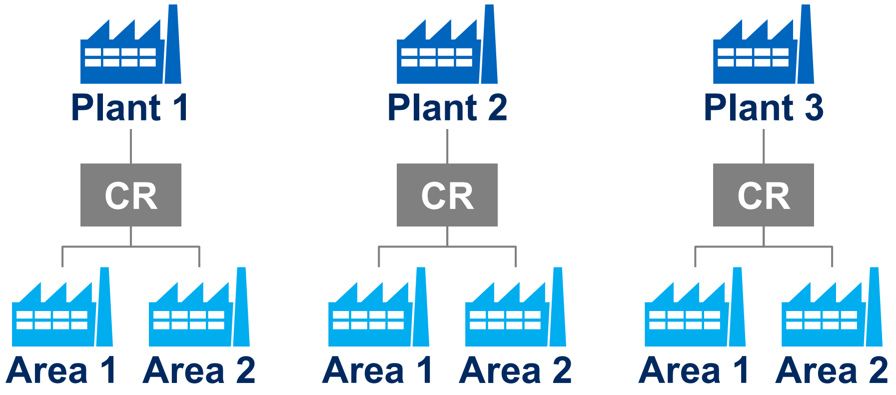
Asset optimization—Regional consolidation of control rooms (CRs) will be implemented for a subset of assets; consolidation at site level for all assets

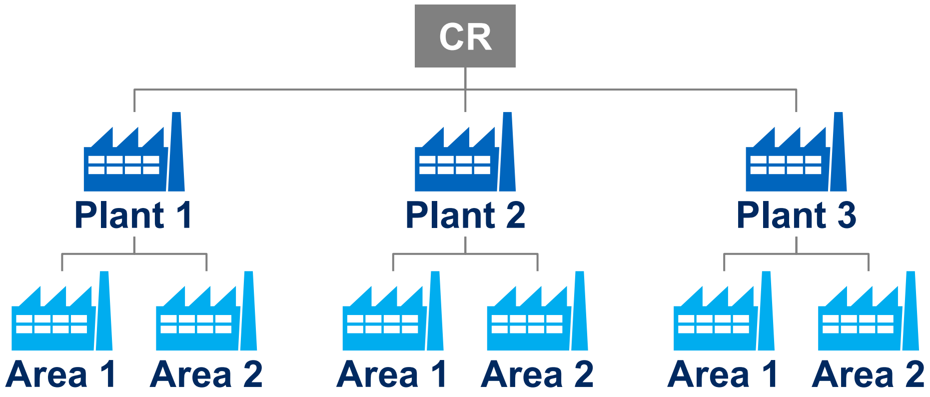
Increasing level of consolidation

Site-level consolidation



- Site-level consolidation can be achieved, **allowing for capture of tangible synergies**
- **High safety regulations/risk barriers** as well as **CAPEX and technical challenges** (e.g. data sharing across sites) **prevent further consolidation**
- **Example:** At one European site, a large manufacturer merged about half a dozen control rooms at into one, leveraging scale and improving communications between areas of the asset

Further consolidation—centralized control room



- **Achievable for a small subset of asset archetypes** (e.g., gas separation assets) **given limitation in safety regulations and risks**
- **Example:** A global manufacturer introduced **remote management** of gas units to boost efficiency
  - Remote management used to adjust capacity or prevent accidents in real time via predictive maintenance
  - Covered more than 15 plants in Europe and 20 in Asia

- **Regional consolidation** of control rooms can work, but **only for select asset archetypes** (e.g., gas separation assets)
- **Consolidation of control rooms** on sites is already **happening and will continue**

SOURCE: McKinsey, press search

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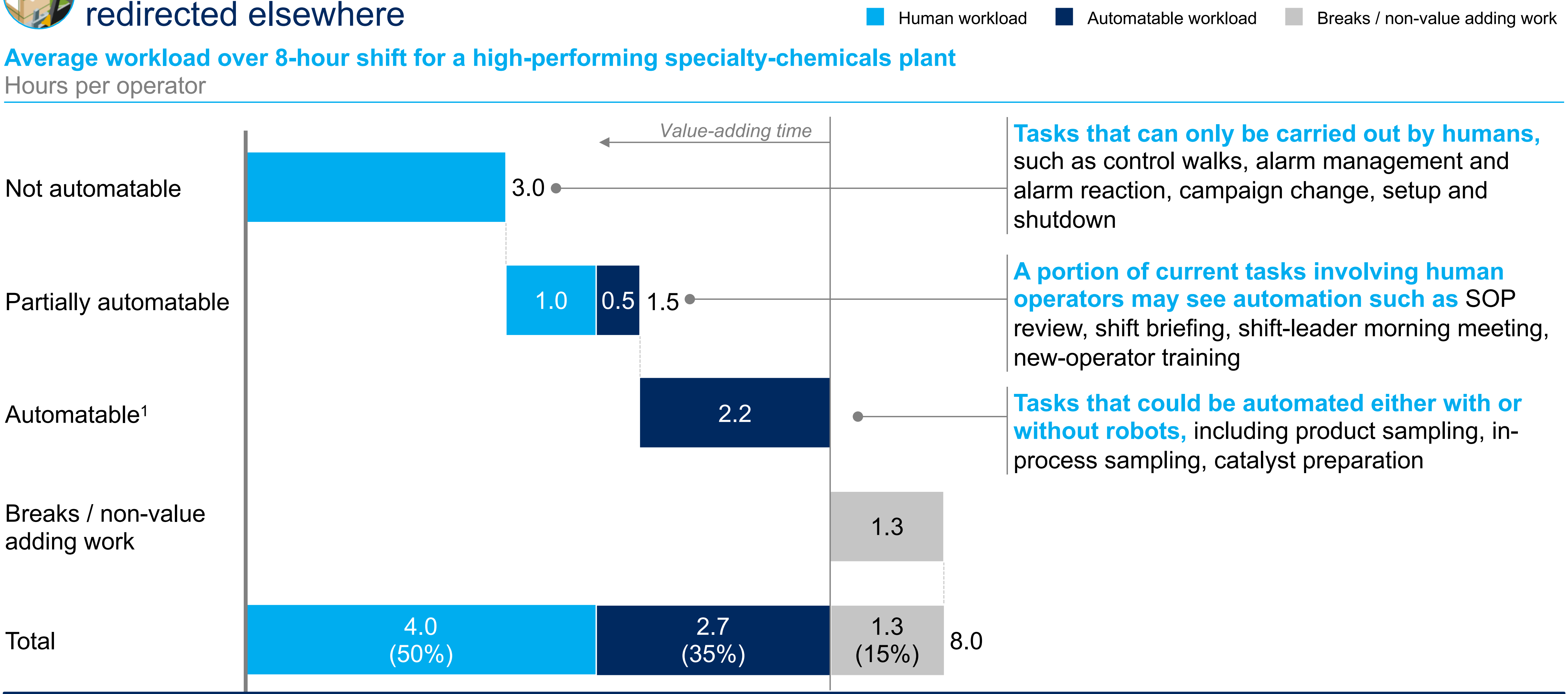
People—40-60% of field- operator workload can by saved by robotics and automation and redirected elsewhere

Average workload over 8-hour shift for a high-performing specialty-chemicals plant

Hours per operator



Tasks that can only be carried out by humans, such as control walks, alarm management and alarm reaction, campaign change, setup and shutdown

A portion of current tasks involving human operators may see automation such as SOP review, shift briefing, shift-leader morning meeting, new-operator training

Tasks that could be automated either with or without robots, including product sampling, in-process sampling, catalyst preparation

~40% of value-adding operator time in specialty chemical plants can be saved through automation and applied towards more critical tasks that require humans, and ~60% in commodity-chemical plant

1 50% could be automated without robots and 50% could be automated with humanoid robots

SOURCE: McKinsey

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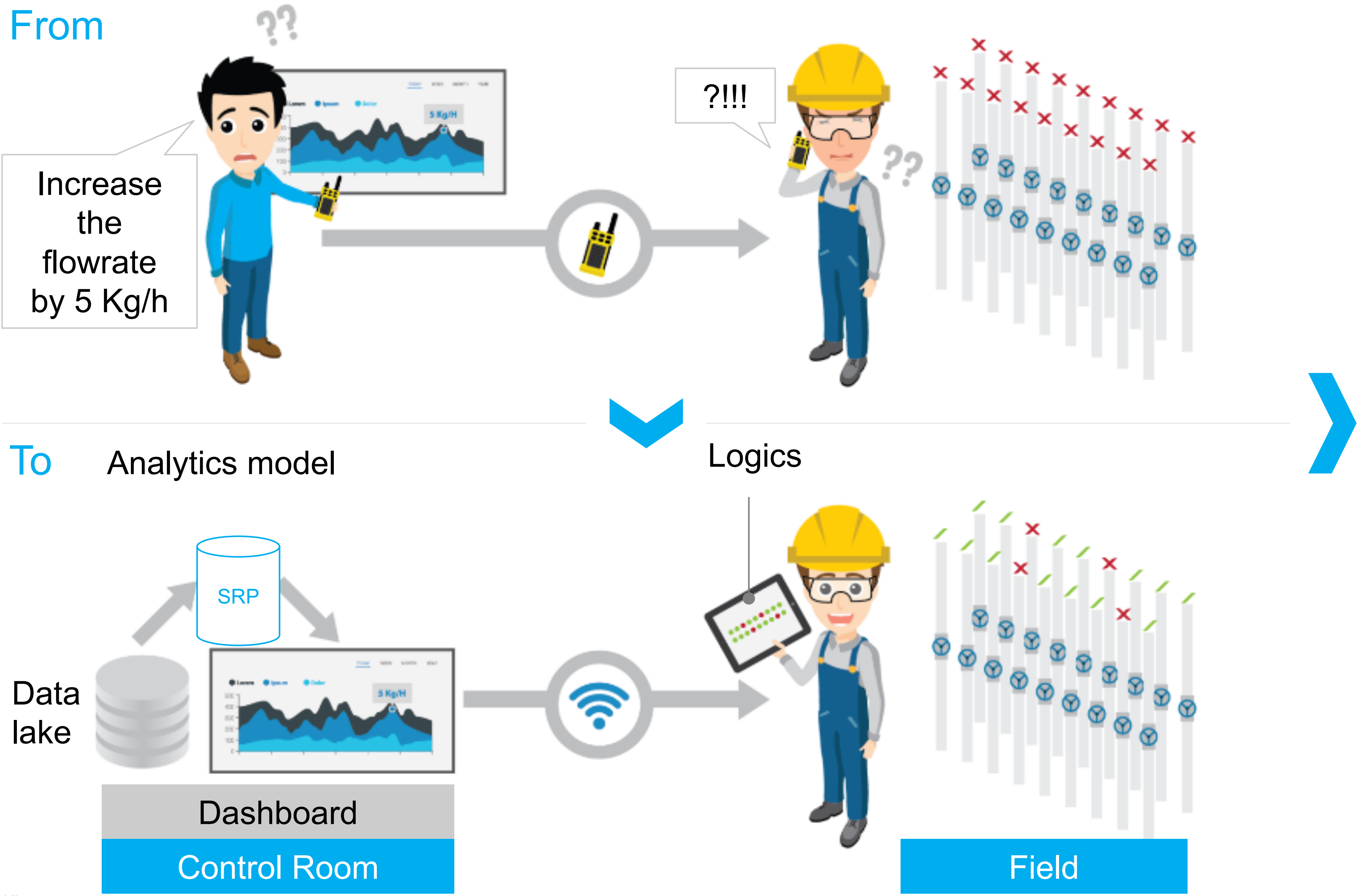
People—Tasks of control room operators will move from "control" to "improve," creating an enormous challenge of upskilling



- Role of the control room operators will shift from **decisions based on "experience" to running analytics based on data**
- Strong **shift in capabilities** necessary, requiring upskiling of labor force

SOURCE: McKinsey

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People—Digital workflow apps will increase efficiency in maintenance processes by improved planning, guidance, and performance management

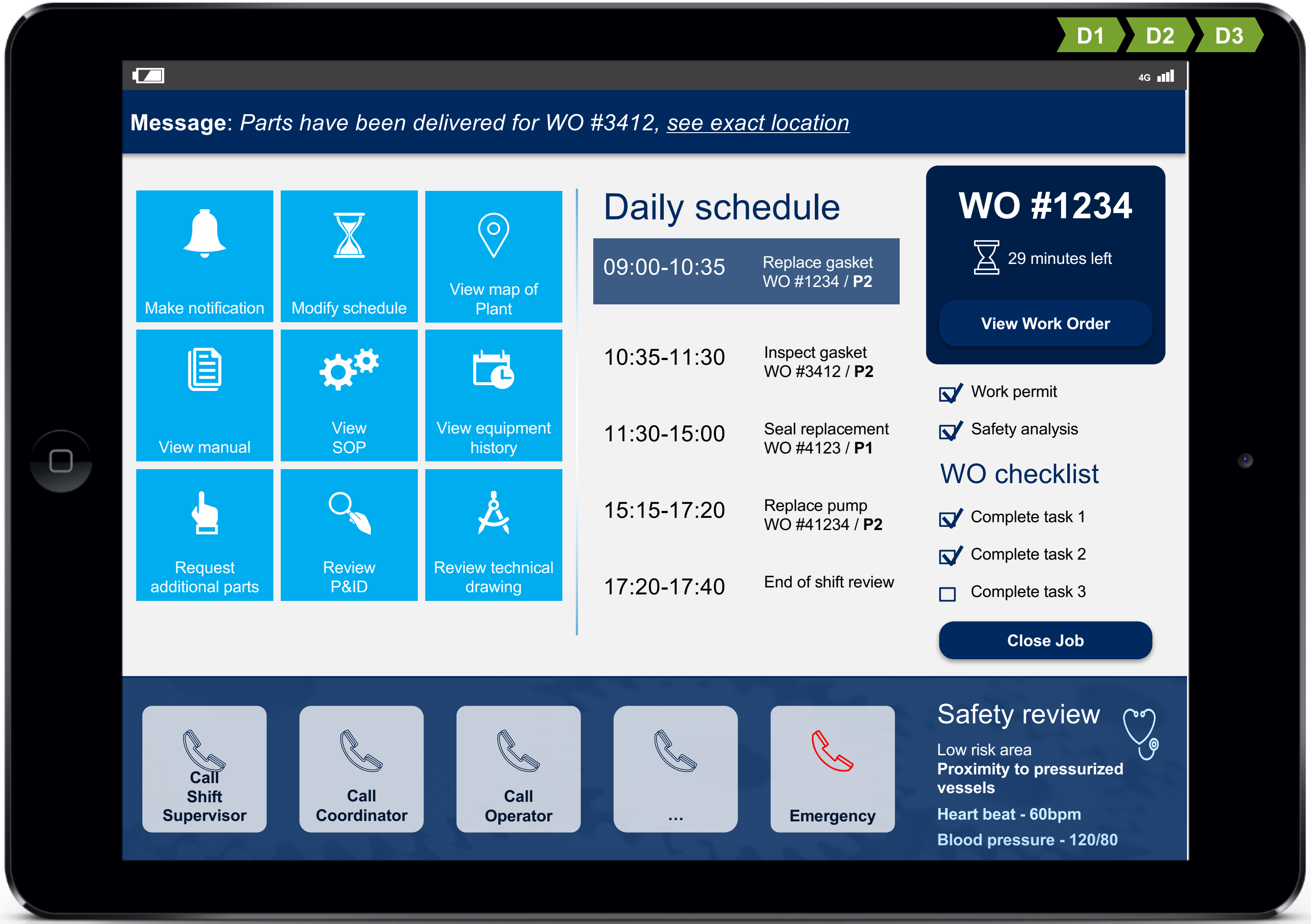
Digital maintenance workflow

What is it?

- Smart device app **regrouping all necessary support tools for maintenance technicians**
  - Digital work permit
  - Job closure
  - Compendium of technical information
  - Dynamic schedule

How does it increase efficiency?

- No **physical work permit to be collect** from/signed by maintenance foreman; reduce waiting times between tasks
- Live **update of workplan** (and potential adjustments of teams) depending on progress at each workorder
- **No missing paperwork**/all technical information and previously conducted work available; preventing unnecessary trips to parts storage



SOURCE: McKinsey