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.

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.

SOURCE: McKinsey

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

**ASSET OPTIMIZATION**

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.

**PEOPLE’S TASKS**

Maintenance technicians will use digital-workflow apps, increasing efficiency and productivity through 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.

**LEAN** will continue to be the foundation.

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.

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**LEAN** will continue to be the foundation.
Growth rates show expansion in China while Western hemisphere stays mostly flat

Global chemicals capacity forecast\(^1\), in mtpa\(^2\)

- Europe
- North America
- China
- RoW

CAGR, %

- China: +2.7% p.a.
- Europe: 0.7%
- North America: 2.1%
- China: 3.7%
- RoW: 2.6%

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

Petrochemicals regional trade flows¹, 2005-2015, % of production consumed in region

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

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

**Revenues and cost structure 2017**, percent of total cost

- Other
- Raw material and consumables
- Maintenance
- Labor
- Utilities

### Before digitization

- Other: 10
- Raw material and consumables: 53
- Maintenance: 28
- Labor: 8
- Utilities: 3

### After digitization

- Other: 9
- Raw material and consumables: 51
- Maintenance: 27
- Labor: 3
- Utilities: 1

**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

---

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

**Synergies from joint infrastructure and logistics**

**CAPEX synergies**

**Increased service level and supply security**

**Reduction in variable costs (e.g. utilities)**

**Size effect on support services (e.g. maintenance, F&A)**

**Reduction in transport costs and risks**

*SOURCE: McKinsey*
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

How does agile E2E supply chain increase reactivity?

<table>
<thead>
<tr>
<th>Inventory</th>
<th>Cost</th>
<th>Customer service</th>
<th>Market reactivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Reduced inventory across the value chain (incl. raw materials, intermediates and finished goods) due to instant visibility of stocks</td>
<td>▪ Fewer write-offs and aged stocks</td>
<td>▪ Improved customer understanding leading to better alignment of expectations and service as systems prevent order complications</td>
<td>▪ Better customer service enabled by faster response times</td>
</tr>
<tr>
<td>▪ Greater opportunity to implement “make to order” strategy as lead times in P2P process are reduced</td>
<td>▪ Reduced costs for holding inventory and redistribution</td>
<td></td>
<td>▪ Increased ability to adapt to market changes</td>
</tr>
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<td>▪ Reduced costs for holding inventory and redistribution</td>
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<tr>
<td>▪ Faster lead times due to reduction of touchpoints leading to shorter cash-turnaround cycles</td>
<td>▪ Fewer write-offs and aged stocks</td>
<td>▪ Improved customer understanding leading to better alignment of expectations and service as systems prevent order complications</td>
<td>▪ Greater opportunity for segmentation</td>
</tr>
</tbody>
</table>

Lean foundational tools:

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

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

**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.

**Differences**

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

**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.

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

### Hosting decision

<table>
<thead>
<tr>
<th>Cost</th>
<th>On-premise</th>
<th>Public cloud</th>
</tr>
</thead>
<tbody>
<tr>
<td>More capex</td>
<td>Cost of capex more attractive</td>
<td>More flexible costs</td>
</tr>
<tr>
<td>More attractive opex</td>
<td>Opex on public cloud up to ~1.5 - 2.0 times higher</td>
<td></td>
</tr>
</tbody>
</table>

| 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 |

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

...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.”
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
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

<table>
<thead>
<tr>
<th></th>
<th>Connectivity</th>
<th>Intelligence</th>
<th>Flexible automation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot phase (or advanced)</td>
<td>64</td>
<td>70</td>
<td>61</td>
</tr>
<tr>
<td>Rollout phase</td>
<td>-41</td>
<td>-41</td>
<td>-37</td>
</tr>
<tr>
<td>%</td>
<td>23</td>
<td>29</td>
<td>24</td>
</tr>
</tbody>
</table>

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.

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

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

<table>
<thead>
<tr>
<th>Value identified, mEUR</th>
<th>Implementation cost, mEUR</th>
<th>Payback</th>
<th>Selected key levers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recurring</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Total recurring</td>
<td>20</td>
<td>~6</td>
<td>1-2 yrs</td>
</tr>
<tr>
<td><strong>Capex savings</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Digital project management</td>
<td>10-25</td>
<td>3-10</td>
<td></td>
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### Payback

- **Plant steering**: ~1 year
- **Reliability & maintenance exec.**: ~2 years
- **Operations**: ~3 years
- **Total recurring**: ~6 years

### Selected key levers

- **Advanced analytics** algorithm for steering
- **Optimization of energy flow** at site level
- **Use** manufacturing intelligence
- **Digitization and automation of recurring maintenance activities**
- **Advanced analytics (AA)** for reliability
- **Automation of manual standard tasks**
- **Digitization of manual non-standard tasks**
- **Real-time performance management**
- **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
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**

- **Plant 1**
  - Area 1
  - Area 2
  - CR
- **Plant 2**
  - Area 1
  - Area 2
  - CR
- **Plant 3**
  - Area 1
  - Area 2
  - CR

**Further consolidation—centralized control room**

- **CR**
  - **Plant 1**
    - Area 1
    - Area 2
  - **Plant 2**
    - Area 1
    - Area 2
  - **Plant 3**
    - Area 1
    - Area 2

- **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**

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

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

<table>
<thead>
<tr>
<th>Not automatable</th>
<th>Partially automatable</th>
<th>Automatable</th>
<th>Breaks / non-value adding work</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value-adding time</td>
<td>3.0</td>
<td>1.0</td>
<td>2.2</td>
<td>4.0 (50%)</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.5</td>
<td></td>
<td>2.7 (35%)</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td></td>
<td></td>
<td>1.3 (15%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.0</td>
</tr>
</tbody>
</table>

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

From

Increase the flowrate by 5 Kg/h

To

Analytics model

• 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 upskilling of labor force
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