Digitalization of the European Chemical Industry

The Chemical Industry at the Heart of the Fourth Industrial Revolution

Dr. Martin Winter
Cefic Innovation
SPIRE cPPP Industrial R&I Advisory Board
PRACE HPC Industrial Advisory Committee – Materials/Chemistry
Challenges of globalization

✓ Climate Change & Energy
✓ Complex Security Challenges
✓ Demography
✓ Need for further Consolidation, Competitiveness and Cohesion
✓ Digital (Industrial) Revolution 4.0

The Future of European Economy

✓ Carbon-Neutral Economy
✓ Circular Economy
✓ Digital Economy
Digitization transforms the Chemical Industry rapidly across its entire horizontal value chain

**Big-data/advanced analytics in OpEx/CapEx:**
- Big data-driven raw material analytics to optimize feedstock costs

**End to end supply chain integration:**
- Production data sharing with suppliers/
- real-time supply tracking

**Process automation:**
- Sensor-based production control and real-time optimization of YETQ

**Integrated lean system:**
- IT-based integrated lean system to drive manufacturing excellence

**Engineering/R&D 4.0:**
- Machine-learning-driven recipe and formulation improvements

**New roads to market:**
- Using online/marketplace sales channels

**Digital procurement tools:**
- Digital tools enabling more efficient procurement processes

**Predictive maintenance**
- Advanced analytics-based predictive and risk-based maintenance

**Digital manufacturing:**
- Production automation by application of autonomous logistics, drone inspections

**Risk management:**
- Advanced analytics-based risk management/cyber security

**G&A 4.0**
- Back office automation, e.g., no touch orders

**Commercial engines**
- Use advanced analytics for lead generation, etc.

**Digitization of customer experience:**
- Customer self-service platform

**THE DIGITAL CHEMICAL COMPANY**

**PLUS: new, radically different business models**

1 Yield, energy, throughput, and quality
Chemicals have lagged behind other industries in terms of digitalization.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Early</th>
<th>Developing</th>
<th>Maturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telecoms</td>
<td>15%</td>
<td>40%</td>
<td>46%</td>
</tr>
<tr>
<td>Media</td>
<td>23%</td>
<td>42%</td>
<td>35%</td>
</tr>
<tr>
<td>Automotive</td>
<td>26%</td>
<td>39%</td>
<td>33%</td>
</tr>
<tr>
<td>Tourism</td>
<td>25%</td>
<td>44%</td>
<td>31%</td>
</tr>
<tr>
<td>Oil and Gas</td>
<td>35%</td>
<td>39%</td>
<td>26%</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>22%</td>
<td>52%</td>
<td>26%</td>
</tr>
<tr>
<td>Agriculture</td>
<td>32%</td>
<td>45%</td>
<td>23%</td>
</tr>
<tr>
<td>Banking</td>
<td>23%</td>
<td>54%</td>
<td>23%</td>
</tr>
<tr>
<td>Retail</td>
<td>25%</td>
<td>53%</td>
<td>22%</td>
</tr>
<tr>
<td>Healthcare</td>
<td>34%</td>
<td>47%</td>
<td>19%</td>
</tr>
<tr>
<td>Chemicals</td>
<td>27%</td>
<td>60%</td>
<td>13%</td>
</tr>
</tbody>
</table>

1 Business executives were asked to assess digital maturity of their org along dimensions of digital strategy and state of digital implementation. 4,800 respondents; 52 chemicals players.

Source: McKinsey & Company
Profitability potential in functional areas - probably most in manufacturing and M&S

We see the biggest potential in commercial and operations but also in other functional areas.

**EBITDA improvement potential by lever, p.p. (rough estimate – on top of what you can do already today, i.e., digitally enabled)**

1. **Manufacturing (4-6%)**
   - "Transform Operations leveraging advanced analytics and design"
   - Yield, Energy, Throughput management
   - Predictive maintenance
   - Robotics & automation
   - Digital performance management

2. **Marketing & Sales (4-6%)**
   - "Leverage advanced analytics to better understand customer demands and increase return on sales & growth"
   - Digital & omni-channel management
   - AA-driven growth and margin improvements
   - Digital customer experiences
   - Digital commercial backbone

3. **Procurement (1-2%)**
   - "Use big data to improve spend effectiveness"
   - Spend visibility
   - AA-enabled Sourcing
   - Automation in purchase-to-pay
   - Digital performance management

4. **Supply Chain (0.5-1%)**
   - "Use big data to improve supply efficiency end-to-end"
   - Predictive supply chain analytics in demand planning
   - Advanced robot-based logistics
   - Digital warehouse
   - End-to-end network optimization

5. **Innovation (0.5-1%)**
   - "Push innovation capabilities and reduce complexity through AA"
   - Digital-enabled innovation
   - Lab Research 4.0
   - Smart formulation
   - Digital ROI performance management

6. **G&A Automation (0.5-1%)**
   - "Automate G&A functions and improve decision support systems"
   - AA-based decision support system
   - RPA-based automation of G&A activities
   - Digital performance management

Source: McKinsey & Company
Expected development of disruptive digital technologies by 2018 - 2025 – Modeling/Data/AI

Source: VCW/DDCh, Berufe 4.0 – Wie Chemiker und Ingenieure in der digitalen Chemie arbeiten, 2018
Data-driven technologies in chemical industry – value creation through advanced data analytics

“Long-term competitive advantage will come through a combination of proprietary data and the software used to extract that data.”

**DATA SOURCES**
- PCS
- LAB DATA
- NON DIGITAL
- PERFORMANCE
- MES

**DATA AVAILABILITY**
- Accessibility
- Connectivity

**DATA STORAGE**
- Data aggregation
- IT Infrastructure
- Platforms
- Cloud/web based
- Data security

**DATA ANALYTICS**
- Visualization
- Modelling
- Process Optimization
- Predictive Maintenance
- Performance prediction

"Value from Data"
Chemical Industry: Government issued “Intelligent Manufacturing Development Plan (2016-2020)”, encouraging (petro)-chemical industry to develop Intelligent Manufacturing
Going digital structured: digital playgrounds and initiatives in the chemical industry

Digital Initiatives

- Digitalize the Enterprise
  - Digital R&D
  - Digital Plant
  - Digital Supply Chain
  - Augmented Workforce

- Go beyond the Molecule
  - Digitally enabled Offerings and Business Models
  - Advanced Customer Interaction
  - Accelerated Circular Economy

- Collaboration in Ecosystems
  - Innovative Ecosystem
  - Value Chain Collaboration

Digitalize the Enterprise - more efficient manufacturing chain

a. **Real-time sensing capability** - provide correct process information to authorized users in real-time

b. **Feedback control** to detect deviations and adjust operations immediately decision support

c. **Asset performance management**/predictive maintenance

d. Advanced **operator support** (e.g., smart data visualization, augmented reality, gamification)

e. ‘**Digital Twin**’ (dynamic virtual plant/process models) to predict the of impact of (design) decisions and to anticipate bottlenecks

f. **Integrated production** planning

g. Information **integration across operations** and enterprise technology layers

h. End-to-end **(financial) visibility** from top-floor to shop-floor

- ✓ Higher plant availability and throughput
- ✓ Better predictability of manufacturing
- ✓ Reduced lead-times
- ✓ Higher flexibility and agility/remote operations
- ✓ Less product quality issues
- ✓ Less consumption of energy and raw materials
- ✓ Less costs for lab-analyses
- ✓ More efficient plant maintenance
- ✓ More efficient allocation of staff

Source: SusChem/SPIRE Working Groups, Accenture
Go beyond the Molecule – new revenue opportunities by enabling radically different business models

- **Pricing** excellence
- **Sales and service** excellence
- **Marketing** excellence
- **Marketing & sales channel** optimization

- New business models
- Increase revenue/decrease cost-to-serve
- Seamless multi-channel experience
- Better understanding of evolving market needs
- Improved insight into the competitive landscape
- Ability to more quickly react to market demand and cyclicality
- Tailored products
- Customer awareness

Source: SusChem/SPIRE Working Groups, Accenture
Digital enabled offerings and business models – examples of going beyond the molecule

<table>
<thead>
<tr>
<th>TODAY’S SELL</th>
<th>TOMORROW’S GUARANTEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Products/formulations such as cosmetics ingredients</td>
<td>optimum skin care through a digital service</td>
</tr>
<tr>
<td>Products such as seeds, fertilizer etc.</td>
<td>a certain yield</td>
</tr>
<tr>
<td>Water-treatment chemicals</td>
<td>quantity of clean water</td>
</tr>
<tr>
<td>Industrial lubricants</td>
<td>guaranteed machine hours</td>
</tr>
<tr>
<td>Paints</td>
<td>years of preservation</td>
</tr>
<tr>
<td>Treatment chemicals</td>
<td>quantity of noxious substances removed</td>
</tr>
<tr>
<td>Fixed pricing</td>
<td>value-based pricing depending on outcome</td>
</tr>
<tr>
<td>Fixed quantities</td>
<td>automatic refill, fluid as a leased service</td>
</tr>
</tbody>
</table>

Source: Accenture, 2017, Cefic
Example: personalized skin care for consumers
Companies moving into B2B chemical sales platforms, both existing and new

CheMondis

Alibaba for chemicals

Source: ICISChemicalBusiness 2018
New skills are required to reap the full benefits of digital technologies

Technologies
- 5G
- Cloud Technology
- Digital Twins
- Internet of Things (IoT)
- Virtual Reality
- Data Fusion
- Track & Trace
- PAT
- Big Data
- Deep Learning
- Digital Plant Logistics
- Social Media
- Deep Learning

New Job Profiles
- Digital Brand Manager
- Digital Workplace Consultant
- Data Scientist
- Digital Project Engineer
- Intellectual Property Counsel Digital Technologies
- Digital Transformation Director
Different strategies/operating models are implemented by industry to go digital

1. **Decentralized model**
   - Digital embedded into Business Units
   - BU
   - Digital Team

2. **Centralized model**
   - BU
   - BU
   - BU
   - Chief Digital Officer

3. **Hybrid model**
   - Digital anchored at Multiple Points
   - BU
   - BU
   - BU
   - Chief Digital Officer
   - Digital Excubator
   - Digital Team
   - Digital Team
   - Digital Team

4. **Excubator model**
   - Digital separated from core
   - BU
   - BU
   - BU
   - Digital Excubator
Horizon Europe: evolution not revolution

Specific objectives of the Programme

Support the creation and diffusion of high-quality knowledge
Strengthen the impact of R&I in supporting EU policies
Foster all forms of innovation and strengthen market deployment

Optimise the Programme’s delivery for impact in a strengthened ERA

Pillar 1
Open Science
€ 25.8 B
- European Research Council
- Marie Skłodowska-Curie Actions
- Research Infrastructures

Pillar 2
Global Challenges and Industrial Competitiveness
€ 52.7 B
- Health
- Inclusive and Secure Society
- Digital and Industry
- Climate, Energy and Mobility
- Food and natural resources
- Joint Research Centre

Pillar 3
Open Innovation
€ 13.5 B
- European Innovation Council
- European innovation ecosystems
- European Institute of Innovation and Technology

Strengthening the European Research Area
€ 2.1 B
- Sharing excellence
- Reforming and Enhancing the European R&I system

v. 25 June 2018
## Horizon Europe – proposal by the EC

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Areas of intervention</th>
</tr>
</thead>
</table>
| **Digital and Industry**      | * Manufacturing technologies  
                              | * Advanced materials  
                              | * Next generation internet  
                              | * Circular industries  
                              | * Space  
                              | * Key digital technologies  
                              | * Artificial intelligence and robotics  
                              | * Advanced computing and Big Data  
                              | * Low carbon and clean industry  |
| **Climate, Energy and Mobility** | * Climate science and solutions  
                                | * Energy systems and grids  
                                | * Communities and cities  
                                | * Industrial competitiveness in transport  
                                | * Smart mobility  
                                | * Energy supply  
                                | * Buildings and industrial facilities in energy transition  
                                | * Clean transport and mobility  
                                | * Energy storage  |
| **Food and Natural Resources** | * Environmental observation  
                               | * Agriculture, forestry and rural areas  
                               | * Food systems  
                               | * Circular systems  
                               | * Biodiversity and natural capital  
                               | * Sea and oceans  
                               | * Bio-based innovation systems  |

€ 15 B

€ 15 B

€ 10 B
Digital Europe Programme

€9.2 billion

- Supercomputers €2.7 billion (29%)
- AI €2.5 billion (27%)
- Cybersecurity €2 billion (22%)
- Public services €1.3 billion (14%)
- Digital skills €700 million (8%)

Main innovation initiatives on European level supporting R&I funding in the area of technology the chemical sector

European Technology Platform

Public-Private Partnership

Horizon 2020

Horizon Europe
The SPIRE (Sustainably Process Industry through Resource and Energy Efficiency) Public/Private Partnership

2014 – first-ever PPP with process industry comprising 8 sectors

2015 – first SPIRE projects launched, today project portfolio of 81 projects

EC budget (7 years period) – €900 million

Participation under Horizon 2020 rules
“An integrated and digital European process industry fostering a “well-below 2°C” scenario and a fully circular future for our planet and society.”

SPIRE 2050
Our Value Proposition

SPIRE VISION 2050
An integrated and digital European process industry fostering a well below 2 degrees planet and a fully circular economy
2015-2019: SPIRE cPPP ‘Digital Project’ portfolio >100 M Euro EC funding

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Icon" /></td>
<td>✓ production in <strong>flexible, intensified continuous and batch plants</strong> by introducing novel <strong>online sensing equipment</strong> and self learning <strong>closed-loop control systems</strong></td>
</tr>
<tr>
<td><img src="image2" alt="Icon" /></td>
<td>✓ Integration of local control into overarching <strong>real-time plant optimization and scheduling</strong> systems through online data analytics and model based predictive control (data- and first-principle models), <strong>symbiosis of operators and computer-based control algorithms</strong></td>
</tr>
<tr>
<td><img src="image3" alt="Icon" /></td>
<td>✓ <strong>Process intensification design and optimization</strong> in processes in which solids are an intrinsic part</td>
</tr>
<tr>
<td><img src="image4" alt="Icon" /></td>
<td>✓ <strong>Model-based optimization</strong> for efficient use of resources and energy</td>
</tr>
<tr>
<td><img src="image5" alt="Icon" /></td>
<td>✓ <strong>Advanced modelling and 3D-printing</strong> of reactors</td>
</tr>
<tr>
<td><img src="image6" alt="Icon" /></td>
<td>✓ <strong>Management systems and platforms</strong> enabling industrial symbiosis</td>
</tr>
</tbody>
</table>
Example innovation in process digitization

Advance the production of high-value products that meet high quality demands in flexible intensified continuous plants: Not possible without fast and accurate online sensing of key product and process parameters including closed-loop control and online optimization.

**Characteristics**
- Miniaturized equipment
- Intensified heat & mass transfer
- Possibly modular setup

**Benefits**
- Product uniformity
- Sustainability
- Fast adaption to market demand
- Innovative products

Source: CONSENS
Example: SPIRE cPPP project

Individual units often are already automated and operated efficiently

Inefficiencies result from lack of coordination

Better coordination of production means improved energy and resource efficiency
INEOS in Cologne CoPro use case – network optimisation

Generation of an optimal schedule for the operation of the plants in the ammonia network

• Time horizon one month or more
• Includes logistics
• Optimization of plant loads and cold storage
• Improved resource usage
• Demand side response

Improving the coordination of strongly coupled production plants

Source: VCW/DDCh, Berufe 4.0 – Wie Chemiker und Ingenieure in der digitalen Chemie arbeiten, 2018
CoPro use-case: INEOS in Cologne– NH$_3$ network optimisation

The optimisation model contains:

✓ Mass balances
✓ Operational constraints
✓ Equipment limitations
✓ Logistic constraints
✓ Production targets
✓ Negotiated deliveries

Simulation results were obtained for a 31 days scenario

Large saving potential identified if the network operations are performed in an optimal fashion compared to recorded data

Source: Prof. S. Engell/TuDo - SPIRE Digitalization Workshop Brussels Oct. 1, 2018
CoPro use-case: Lenzing spinbath recovery system

Cross-unit and cross-functional coordination of the recovery cycle in Europe’s biggest cellulose fiber plant

Objectives:
- Efficient load allocation in the multi-unit evaporator network
- Cleaning sequence coordination for the evaporator and heat recovery section
- Optimized cooling water distribution in the recovery cycle

The recovery cycle of Lenzing’s viscose fibre plant in Upper Austria

Source: Prof. S. Engell/TuDo - SPIRE Digitalization Workshop Brussels Oct. 1, 2018
Lenzing USE CASE: Decision support system

Lenzing & TUDO developed a **model based decision support system** for a more efficient evaporator load allocation

- Fully implemented in the control room in August 2018
- 1.8% more efficient operation
- Steam savings around 1200 t/month
- ≈ 250,000 €/year savings
- v2.0 Update with semi automatic control currently under development

HMI of the Decision Support System implemented in Lenzing control room

Source: Prof. S. Engell/TuDo - SPIRE Digitalization Workshop Brussels Oct. 1, 2018
Example: Process Intensification through adaptable catalytic reactors made by multi-level modeling and by 3D-Printing

PRINT CREDIT

first European initiative purely dedicated to study the effect of 3D printing of (reactors) in the chemical industries

Coordinator: www.printcr3dit.eu

7m (!) reactor tube with 3D-printed catalyst

www.printcr3dit.eu
Example: Industrial Symbiosis platforms

IS implies that information must be shared between process sites: site blueprints which characterize and visualize typical processes, units and utilities for each sector including virtual profiles for heat, electricity and material streams represent a plant in operation in a given sector, thus prompting for options to collaborate.

EPOS developed virtual sector profiles for rapid screening of nearby industry sites spotting unaware opportunities to collaborate. It drives the search for new business potential in and across process sectors.

powerful software calculation engine:

uses optimization to calculate and quantify a set of optimal integration scenarios amongst symbiosis partners
Conclusions

1. **Digital** is seen by most chemical players as **clear growth opportunity** - chemical value chains known by today might change completely through digitalization, products and related process getting more personalized creating and delivering **higher value for customers** through empowering of local, **more specialized value chains**

2. Digital will further **improve operations**, e.g. **cognitive plants**, advanced maintenance, **digital process** and **plant design** through dynamic digital twins, **plant/site wide control**

3. Many companies have **built-up significant resources** and additional organizational **structures** to start capture the full range of digital opportunities - but **different digital operating models** in place. **New technologies** and **collaboration** is becoming a key success factor

4. New type of **education and job profiles** will be required to transform the industry, digital is not limited to the use of digital tools and devices, but must become a **company mindset** instead

➢ **Innovation policy and funding in Horizon Europe**: Investments in further **industrial innovation is required** to support the **development/demonstration/implementation** of fast emerging digital technologies related to a **industrial competitiveness, circular economy, higher energy- and resource-efficiency**

➢ **SusChem and SPIRE cPPP** have both initiated processes to develop their HE roadmaps together with experts from academia, RTOs and industry
Thank you for your attention

Dr Martin Winter

Cefic Innovation
SPIRE cPPP Research and Innovation Advisory Group
Working Group Leader Digital Technologies

mwic@cefic.be | Tel: +32 (2) 676 72 94

Cefic (The European Chemical Industry Council)
Avenue E. Van Nieuwenhuyse, 4
B-1160 Brussels – Belgium

www.cefic.org/About-us
www.twitter.com/Cefic