TRENDS AND CHALLENGES IN CHEMICAL ENGINEERING RESEARCH

Guy B. Marin
GROWTH WORLD CHEMICAL SALES 2015-2030

Sales 2015 (€3.5 trillion)
- EU: 39.9%
- Rest of Europe*: 3.9%
- NAFTA**: 3.8%
- Rest of the world: 16.5%

Sales 2030 (€6.3 trillion)
- China: 44.0%
- Rest of Asia***: 14.0%
- Japan: 5.0%
- Rest of the world: 14.0%

* Rest of Europe covers Switzerland, Norway, Turkey, Russia and Ukraine
** North American Free Trade Agreement
*** Asia excluding China and Japan

Source: Cefic Chemdata International 2016

World Congress of Chemical Engineering, Barcelona, Oct 1-5 2017
R&D IN THE EU CHEMICAL INDUSTRY

R&D spending in 2005 (€ billion)
R&D spending in 2015 (€ billion)

Source: Cefic Chemdata International 2016
R&D IN THE EU CHEMICAL INDUSTRY

Average growth rate p.a. 1993 – 2015
Sales (+2.9%)
R&D spending (+1.1%)
R&D spending (% of sales) (-1.7%)

Source: Cefic Chemdata International 2016
EUROPEAN RESEARCH COUNCIL (ERC)

• Set up in 2007 by the EU, the ERC funds ambitious projects in frontier research. It aims at:
  • Supporting excellent frontier research throughout Europe in all scientific domains: Life Sciences (LS), Physical Sciences and Engineering (PE), and Social Sciences and Humanities (SH)
  • Retaining and attracting the best scientific talent to Europe, by offering very substantial grants for up to 5 years
ERC IN HORIZON 2020

• The ERC is a key component of Horizon 2020, the EU programme for Research and Innovation
• €13 billion budget for 2014-2020, i.e. 17% of the Horizon 2020 budget
• Over 60,000 applications received and around 7,000 projects funded
• Highly competitive calls: success rate is around 11%
# Reuters Most Innovative Governmental Agencies

<table>
<thead>
<tr>
<th>Rank</th>
<th>Research Institute</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alternative Energies &amp; Atomic Energy Commission (France)</td>
</tr>
<tr>
<td>2</td>
<td>Fraunhofer Society (Germany)</td>
</tr>
<tr>
<td>3</td>
<td>Japan Science &amp; Technology Agency (Japan)</td>
</tr>
<tr>
<td>4</td>
<td>U.S. Department of Health &amp; Human Services (U.S.)</td>
</tr>
<tr>
<td>5</td>
<td>National Center for Scientific Research (France)</td>
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<tr>
<td>6</td>
<td>Korea Institute of Science &amp; Technology (South Korea)</td>
</tr>
<tr>
<td>7</td>
<td>National Institute of Advanced Industrial Science and Technology (Japan)</td>
</tr>
<tr>
<td>8</td>
<td>U.S. Department of Energy (U.S.)</td>
</tr>
<tr>
<td>9</td>
<td>Agency for Science, Technology and Research (Singapore)</td>
</tr>
<tr>
<td>10</td>
<td>French Institute of Health &amp; Medical Research (France)</td>
</tr>
</tbody>
</table>

## EPSRC ChE GRANTS (UK)

<table>
<thead>
<tr>
<th>Research area</th>
<th>Value ChE grants (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioenergy</td>
<td>14 387 203</td>
</tr>
<tr>
<td>Carbon capture and storage</td>
<td>7 749 142</td>
</tr>
<tr>
<td>Catalysis</td>
<td>1 774 159</td>
</tr>
<tr>
<td>Chemical reaction dynamics and mechanism</td>
<td>1 340 153</td>
</tr>
<tr>
<td>Chemical structure</td>
<td>566 558</td>
</tr>
<tr>
<td>Combustion engineering</td>
<td>1 035 606</td>
</tr>
<tr>
<td>Complex fluids and rheology</td>
<td>17 130 678</td>
</tr>
<tr>
<td>Fluid dynamics and aerodynamics</td>
<td>2 821 945</td>
</tr>
<tr>
<td>Hydrogen and alternative energy vectors</td>
<td>11 585 220</td>
</tr>
</tbody>
</table>

### Grants in Chemical Engineering Departments: £ 58 390 664

Source: [http://gow.epsrc.ac.uk](http://gow.epsrc.ac.uk)
26% of publications are European
A MULTI-LAYERED VIEW OF CHEMICAL AND BIOCHEMICAL ENGINEERING

Jerzy Bałdyga, Béatrice Biscans, Elisabetta Brunazzi, Enrico Drioli, Hermann Feise, Andrew Furlong, Rafiqul Gani, Kevin Van Geem, Andrzej Gorak, Jean-Charles de Hemptine, Gurkan Karakas, Antoon J. B. ten Kate, Jean-Marc Lelann, Guy Marin, Flavio Manenti, Michael Narodoslawsy, Patrick Piccione, Manuel Andres Rodrigo, Bent Sarup, Eva Sorensen, Nigel Titchener-Hooker, Luuk van der Wielen, John M Woodley
World Congress of Chemical Engineering,
Barcelona, Oct 1-5 2017

The Outer Unifying Layer

Interdisciplinary integration of C&B
Eng know-how

Science & technology

Innovative solutions for service provisions

Sustainable industrial development

Minimized ecological pressure, maximized social benefit

Resources

Raw materials

Process engineering (unit operations, reaction pathways, process integration,...)

Design, Construction & Operation of industrial plants

Process

Products

Grand Challenges

Responsible counselling of societal stakeholders
SUSTAINABLE PROCESS INDUSTRY THROUGH RESOURCE AND ENERGY EFFICIENCY (SPIRE)

• Public Private Partnerships (PPPs)
• Mission: ensure the development of enabling technologies and best practices along all the stages of large scale existing value chain productions that will contribute to a resource efficient process industry
• It represents:
  • 20% of the total European manufacturing sector more than 130 industrial and research process stakeholders
  • cement, ceramics, chemicals, engineering, minerals and ores, non-ferrous metals, steel and water sectors
THE CIRCULAR ECONOMY KEEPS PRODUCTS AT HIGHEST UTILITY AND VALUE

up to 70% of the European chemical industry molecules provided to customer industries and end-users can be recirculated using all five loops

Courtesy of Henk van den Berg

World Congress of Chemical Engineering, Barcelona, Oct 1-5 2017
~ 425 MTOE OF EU ENERGY CONSUMPTION COULD BE REDUCED IN A FULLY FORMED CIRCULAR SCENARIO
Three transition paths:

- **Circular economy and biomass feedstock**
  Reuse of waste streams (e.g. CO from the steel industries and plastic waste) and application of biomass as raw material and heat source

- **Energy- efficiency and electrification**
  Continuation of energy reduction program and use of electrical energy generated with minimum carbon

- **Maximum storage of CO\textsubscript{2}**
  Large scale application of CCS (Carbon Capture and Storage) and CCU (Carbon Capture and Utilisation)
## Indicator for a Circular Economy

\[
\text{Indicator value} = \frac{\text{GDP} \times \text{TPES per capita} \times \text{Recycle rate}}{\text{GDP} \times \text{TPES} \times \text{population} \times \text{CO}_2 \text{ emission}}
\]

<table>
<thead>
<tr>
<th>Country</th>
<th>Population</th>
<th>GDP (trillion $)</th>
<th>TPES per capita (toe per capita)</th>
<th>CO(_2) emissions (Mt CO(_2))</th>
<th>Recycle rate (%)</th>
<th>Indicator value (10(^{-2}) $^2$/toe/capita/tonne CO(_2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>314.3 M</td>
<td>14.2</td>
<td>6.8</td>
<td>5,074</td>
<td>37</td>
<td>2.2</td>
</tr>
<tr>
<td>Germany</td>
<td>81.9 M</td>
<td>2.9</td>
<td>3.8</td>
<td>755</td>
<td>45</td>
<td>19.0</td>
</tr>
</tbody>
</table>

**Method:** uses of 2-dimensional nanomaterials, including graphene, to create and print batteries

**Result:** could increase the lifetime of a battery of about 5000 times

Valeria Nicolosi, Trinity College Dublin (Ireland)

**3D2DPrint** (3D Printing of Novel 2D Nanomaterials: Adding Advanced 2D Functionalities to Revolutionary Tailored 3D Manufacturing)
The ERC research team developed a technique to produce high-quality diesel fuel that uses feedstock more efficiently, generates fewer by-products and results in much lower emissions.

Prof Krijn Pieter DE JONG, Utrecht University

NanoPartCat (Supported Nanoparticles for Catalysis: Genesis and Dynamics in the Liquid Phase), ERC Advanced Grant 2013
CHEMICAL ENGINEERING IN THE 21ST CENTURY