TRENDS AND CHALLENGES IN CHEMICAL ENGINEERING RESEARCH-EUROPE

Guy B. Marin

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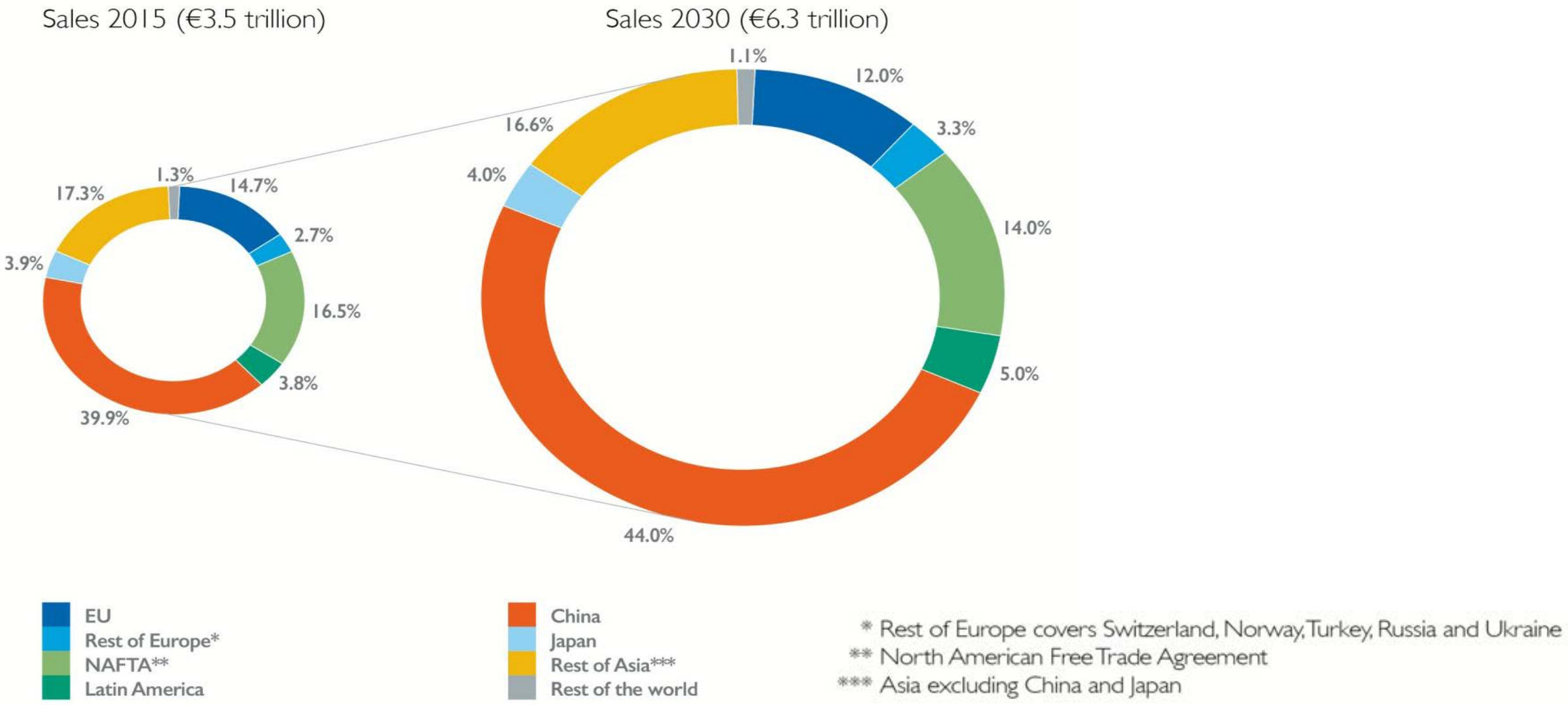
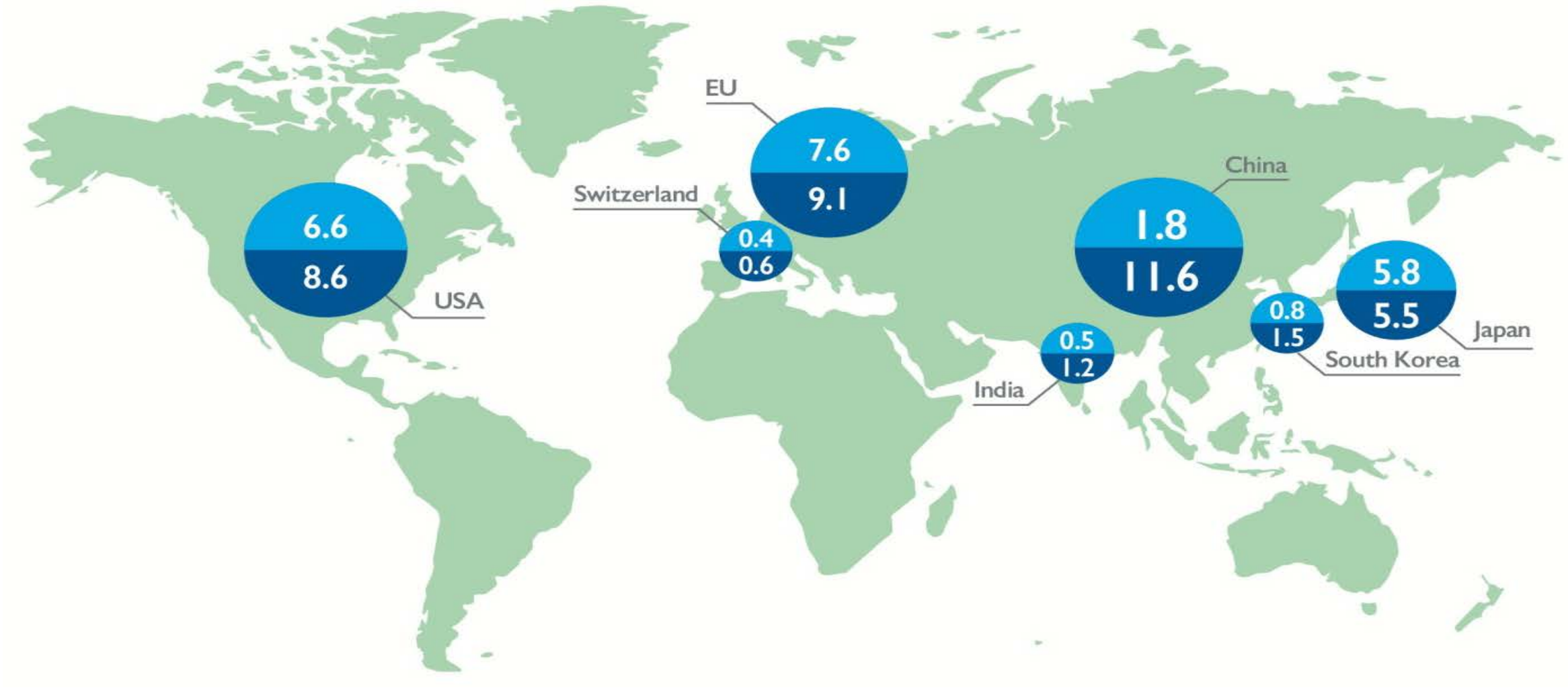
GROWTH WORLD CHEMICAL SALES 2015-2030



Source: Cefic Chemdata International 2016

R&D IN THE EU CHEMICAL INDUSTRY



R&D spending in 2005 (€ billion)

R&D spending in 2015 (€ billion)

Source: Cefic Chemdata International 2016

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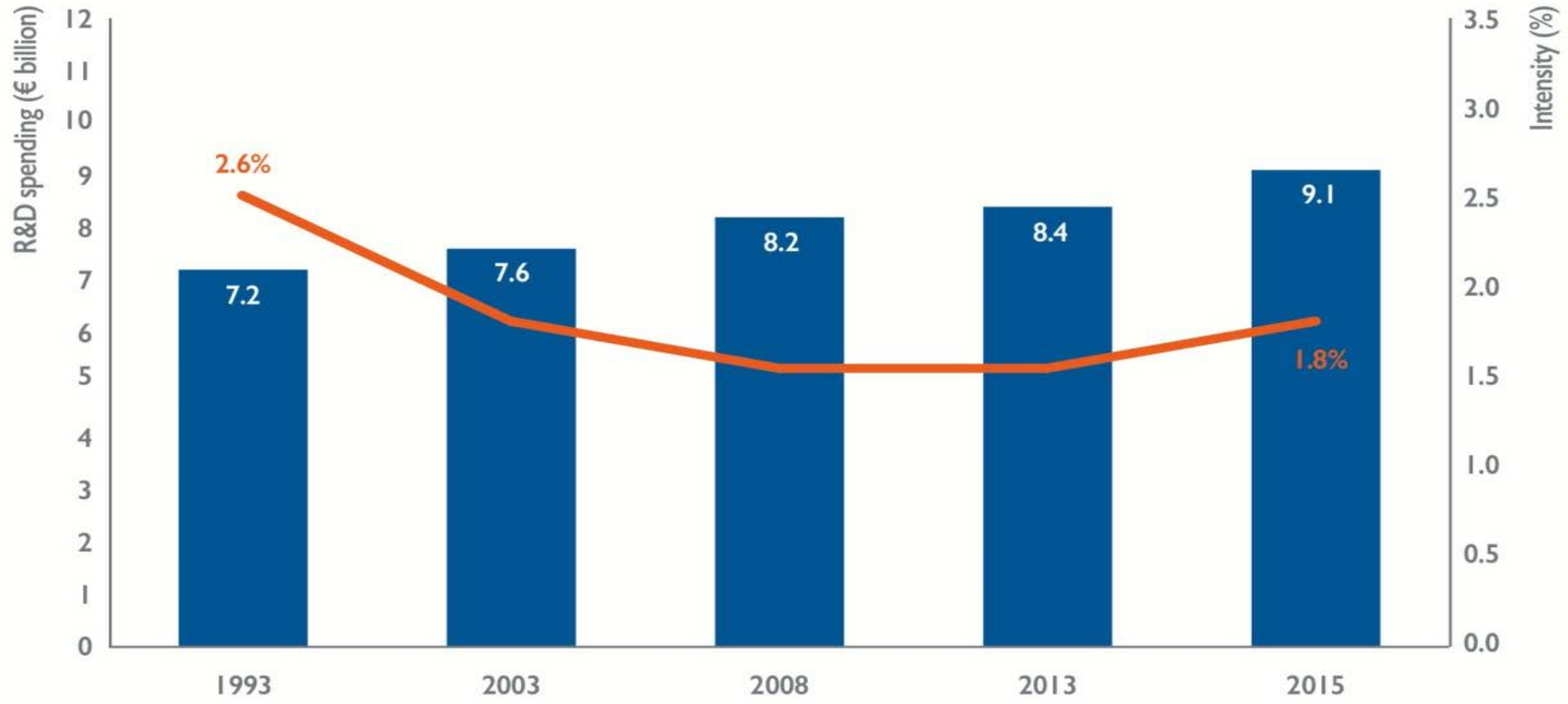
R&D IN THE EU CHEMICAL INDUSTRY



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

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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

Rank	Research institute
1	Alternative Energies & Atomic Energy Commision (France)
2	Fraunhofer Society (Germany)
3	Japan Science & Technology Agency (Japan)
4	U.S. Department of Health & Human Services (U.S.)
5	National Center for Scientific Research (France)
6	Korea Institute of Science & Technology (South Korea)
7	National Institute of Advanced Industrial Science and Technology (Japan)
8	U.S. Department of Energy (U.S.)
9	Agency for Science, Technology and Research (Singapore)
10	French Institure of Health & Medical Research (France)

EPSRC ChE GRANTS (UK)

EPSRC: Engineering and Physical Sciences Research Council

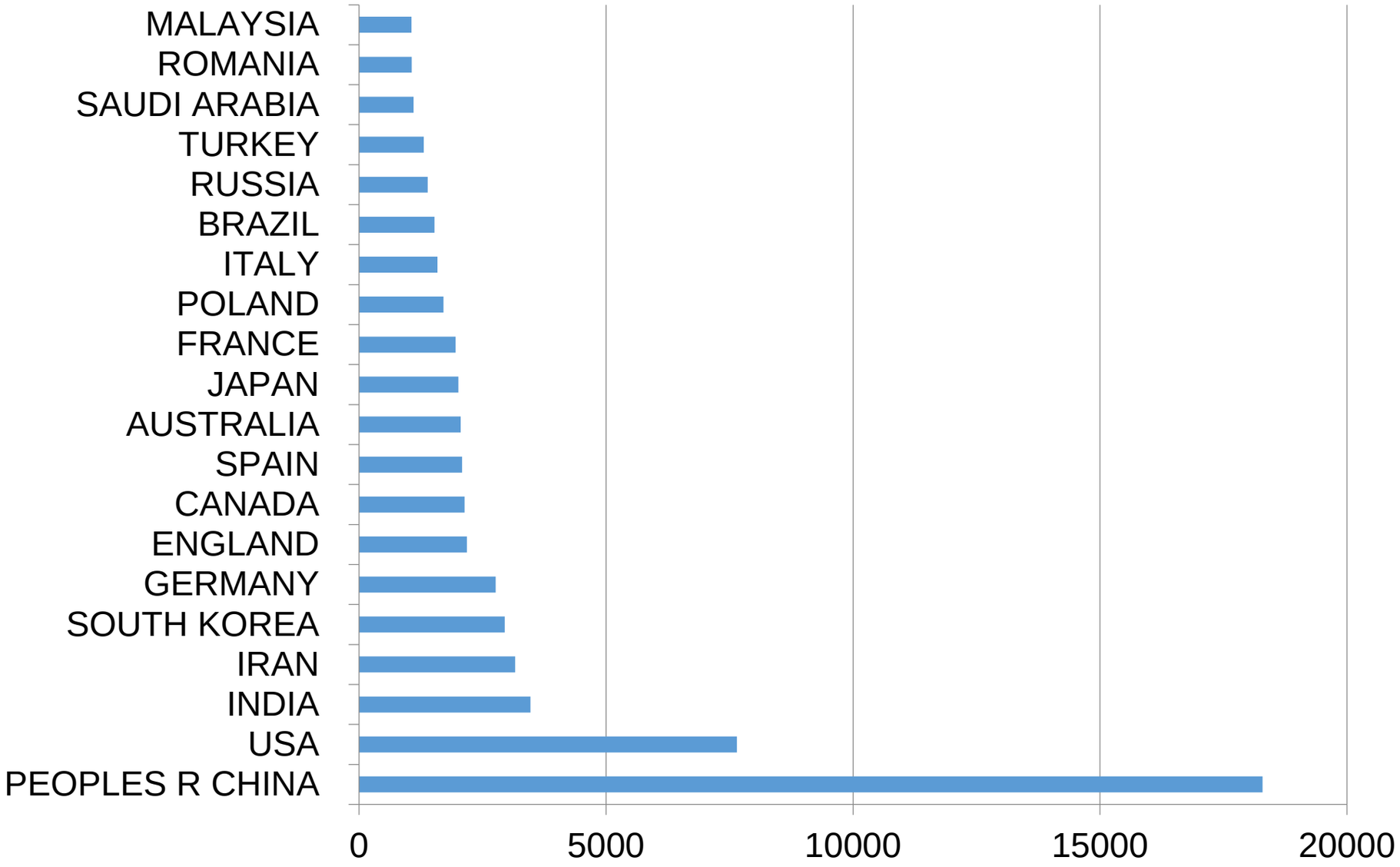
Research area	Value ChE grants (£)
Bioenergy	14 387 203
Carbon capture and storage	7 749 142
Catalysis	1 774 159
Chemical reaction dynamics and mechanism	1 340 153
Chemical structure	566 558
Combustion engineering	1 035 606
Complex fluids and rheology	17 130 678
Fluid dynamics and aerodynamics	2 821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

Grants in Chemical Engineering Departments: £ 58 390 664

Source: http://gow.epsrc.ac.uk

SCIENCE CITATION INDEX: TOP 20 BY COUNTRY

Search on “Chemical engineering”



26% of publications are European

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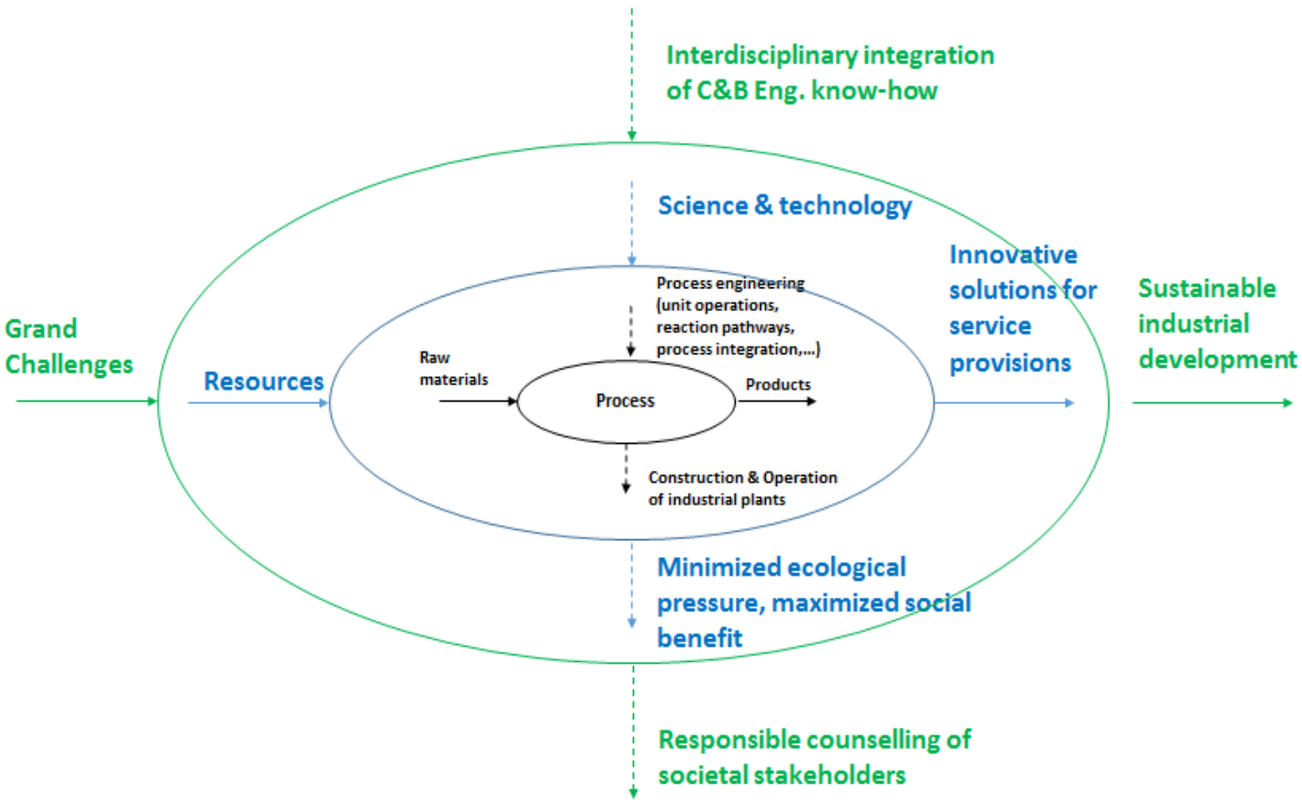
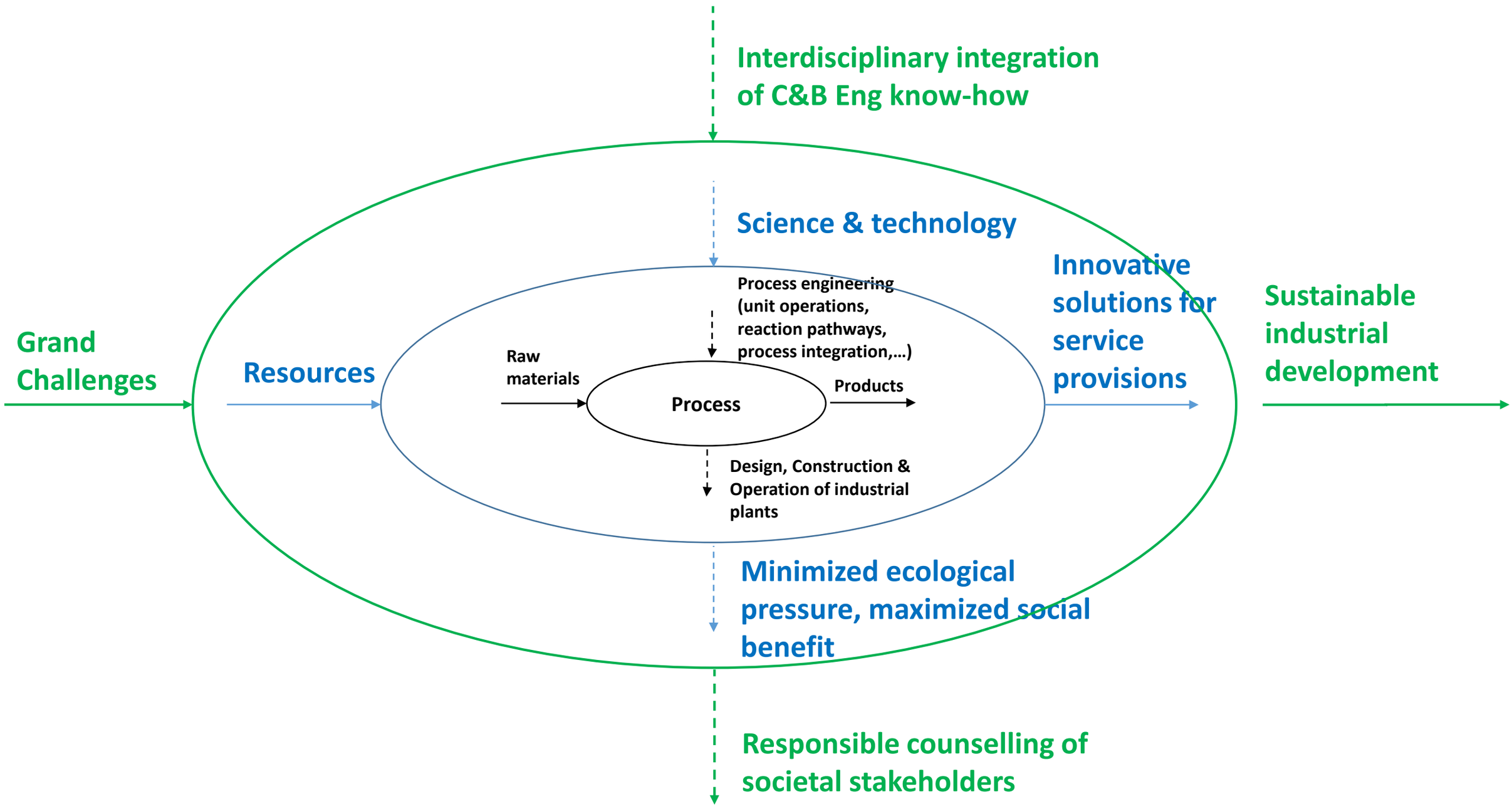
A MULTI-LAYERED VIEW OF CHEMICAL AND BIOCHEMICAL ENGINEERING

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 Narodoslawsky, Patrick Piccione, Manuel Andres Rodrigo, Bent Sarup, Eva Sorensen, Nigel Titchener-Hooker, Luuk van der Wielen, John M Woodley



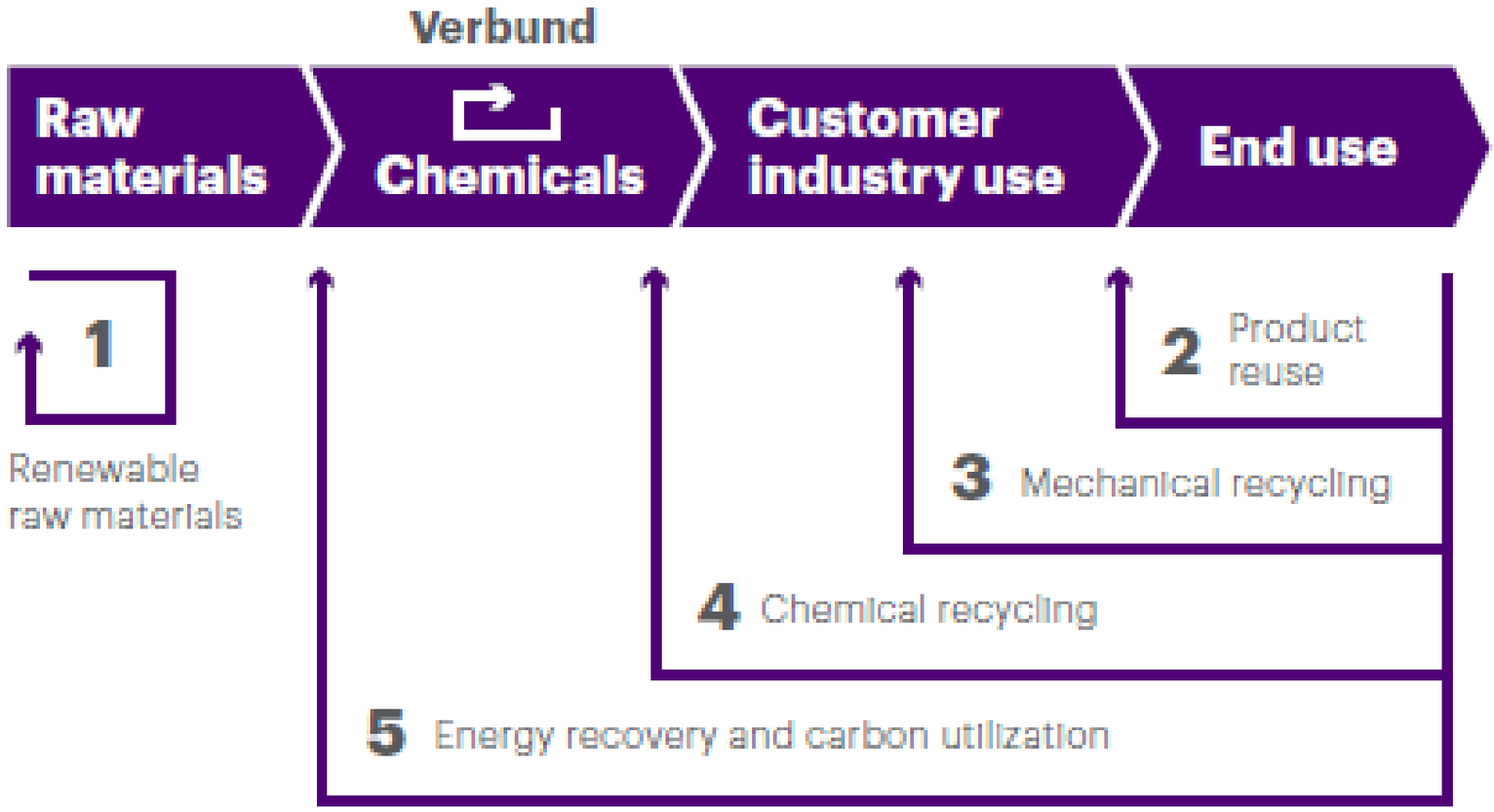
The Outer Unifying Layer



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

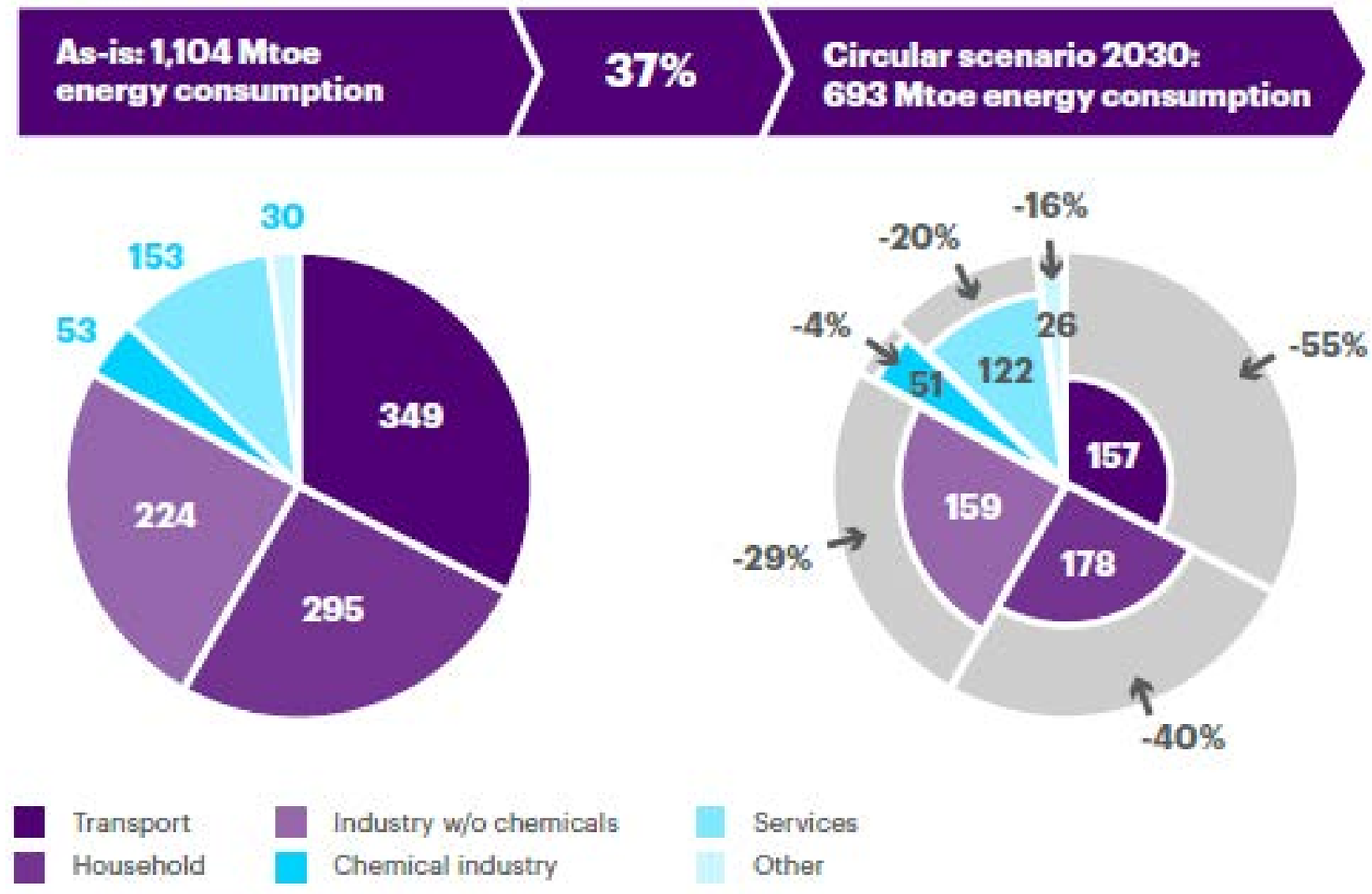
THE CIRCULAR ECONOMY KEEPS PRODUCTS AT HIGHEST UTILITY AND VALUE



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

~ 425 MTOE OF EU ENERGY CONSUMPTION COULD BE REDUCED IN A FULLY FORMED CIRCULAR SCENARIO



Courtesy of Henk van den Berg

FROM PARIS AGREEMENT TO ROADMAP 2050 VNCI – NETHERLANDS CHEMICAL INDUSTRY ASSOCIATION

– 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_2**
  Large scale application of CCS (Carbon Capture and Storage) and CCU (Carbon Capture and Utilisation)

Courtesy of Henk van den Berg

INDICATOR FOR A CIRCULAR ECONOMY

$$\frac{\text{GDP x GDP x recycle rate}}{\text{TPES x population x } CO_2 \text{ emission}}$$

Country	Population	GDP (trillion $)	TPES per capita (toe per capita)	CO_2 emissions (Mt CO_2)	Recycle rate (%)	Indicator value (10^{-2} $\$^2$/toe /capita/tonne CO_2)
USA	314.3 M	14.2	6.8	5.1	37	2.2
Germany	81.9 M	2.9	3.8	755	45	19.0

Sources: European Academies Science Advisory Council data: International Energy Agency (2013)

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ENERGY STORAGE: BETTER, MORE EFFICIENT

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)

CATALYSTS AND ULTRA-CLEAN FUELS

- 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.

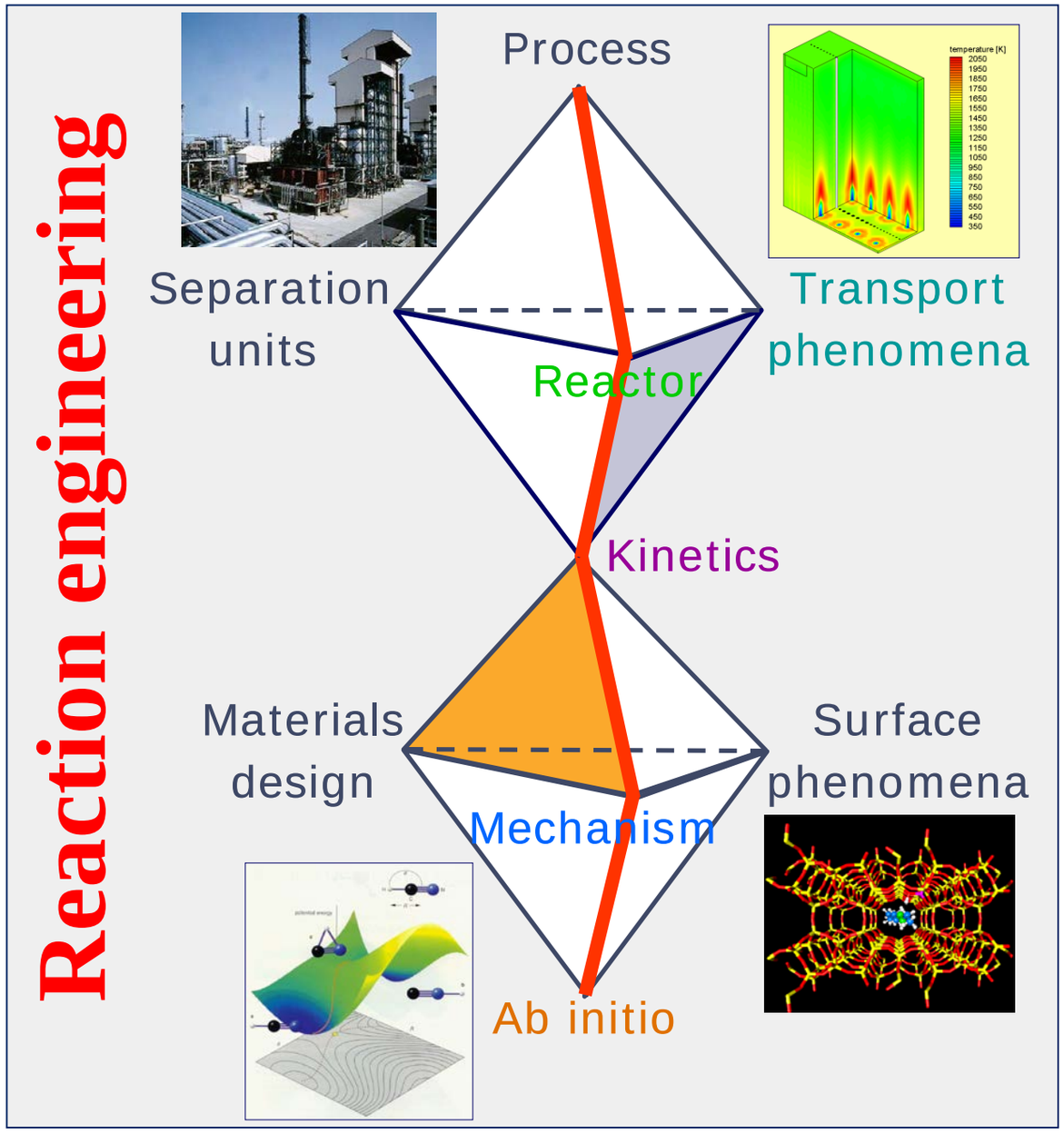
Prof Krijn Pieter DE JONG, Utrecht University

NanoPartCat (Supported Nanoparticles for Catalysis: Genesis and Dynamics in the Liquid Phase), ERC Advanced Grant 2013

ERC story:

Controlled Catalysis for ultra-clean fuels

TRENDS

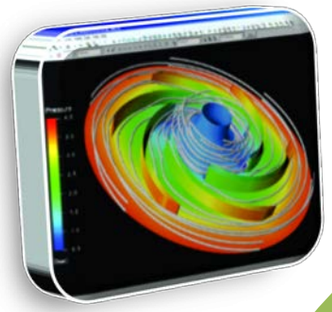


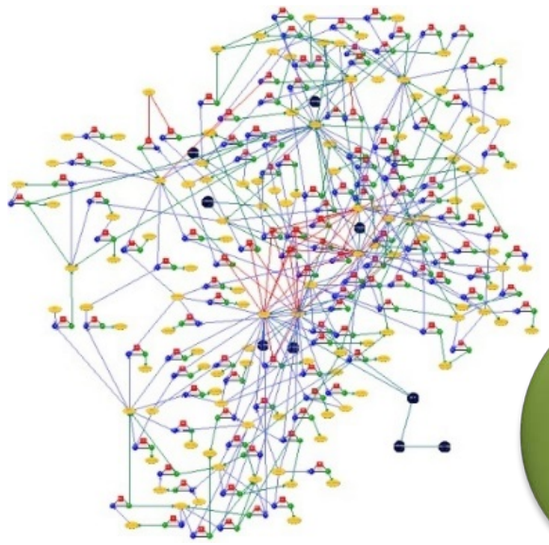
Process level

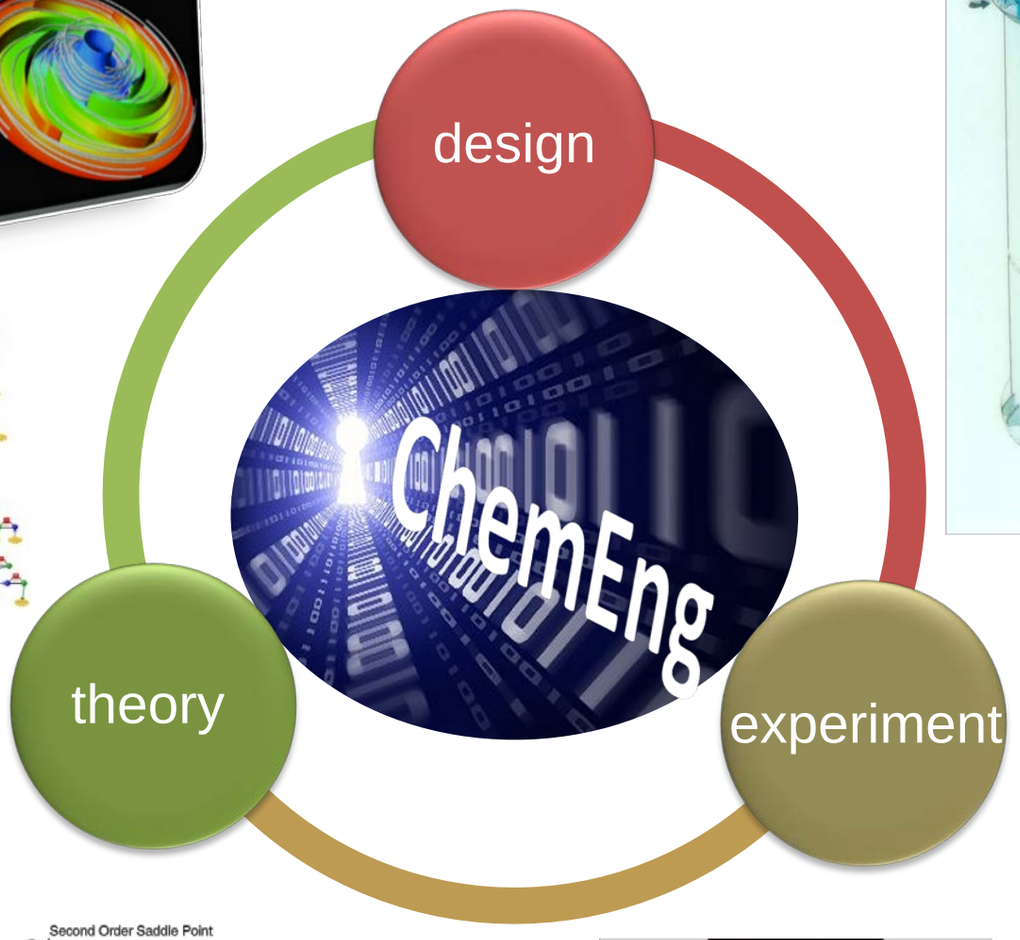
from atom (nm)
to
full process (m)

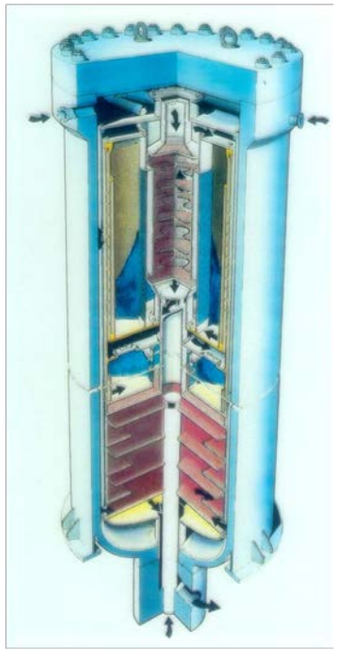
Molecular level

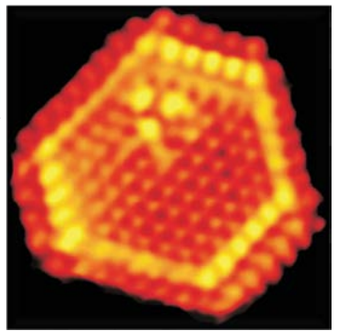
CHEMICAL ENGINEERING IN THE 21ST CENTURY

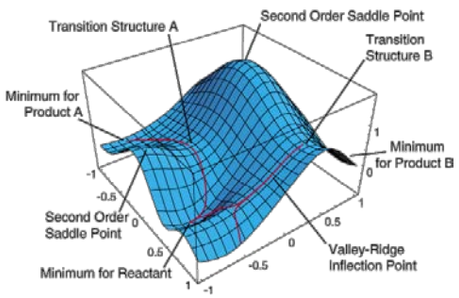


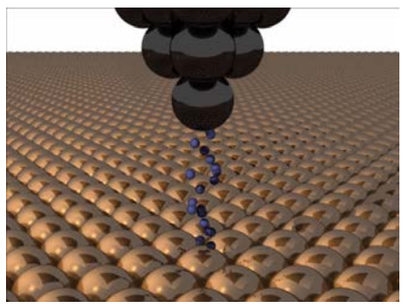


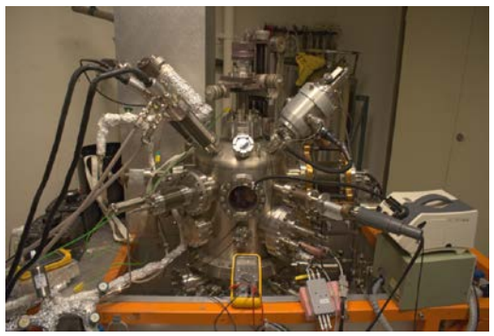












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