INNOCHEM
STATUS QUO ANALYSIS

GREECE

January 2016

Contents of the report

1. Characterization of the chemical sector in the country and the role of SMEs in innovations

The chemical industry is a robust sector in Europe, in terms of productivity and employment, but it is also at the root of all other industries. Innovation in the chemicals sector not only provides Europe with raw materials and consumer products, it also leads to the development of advanced materials (such as hybrid and lightweight materials, materials for tissue engineering, self-cleaning surfaces, and energy recovery and storage), and advanced process technologies that enable more flexible production with more efficient use of energy, feedstock and water. Furthermore, it contributes to improving recyclability and increases the use of renewable feedstock.

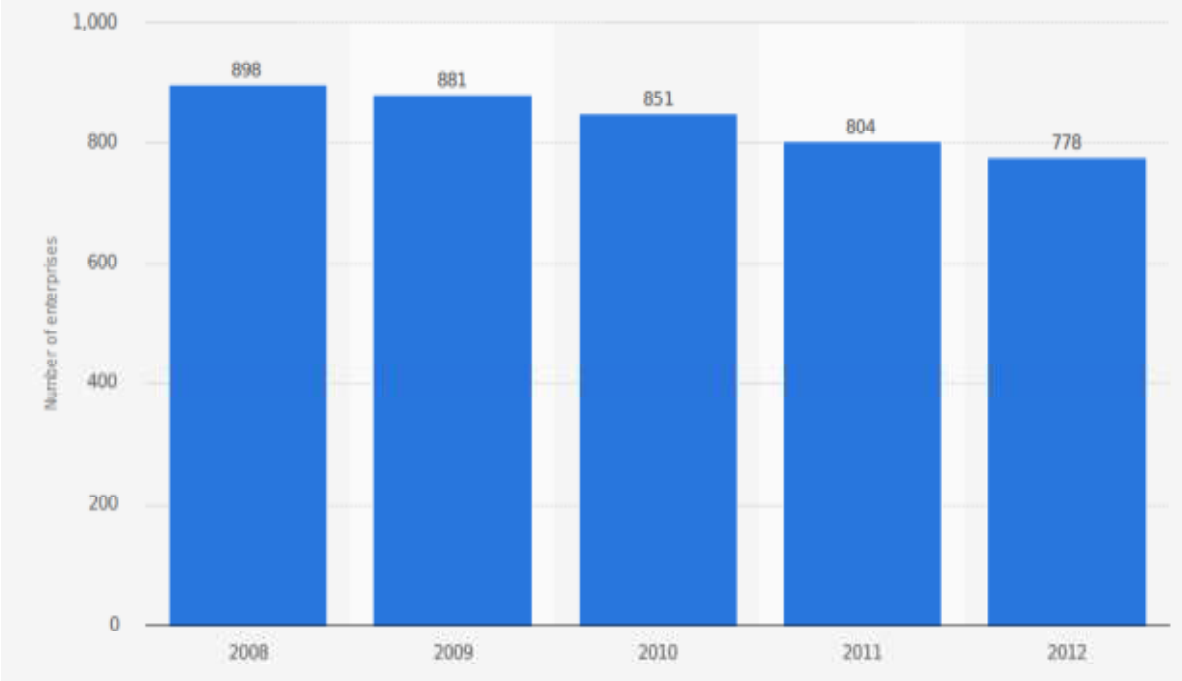
The sector has a pivotal role to play in making Europe 2020 happen and is working in close collaboration with the EU institutions on the best ways to address the present and future challenges.

The chemicals sector – one of the few European industries that still retains world leadership, stands ready to play a leading role in the development and implementation of major EU innovation programs such as:

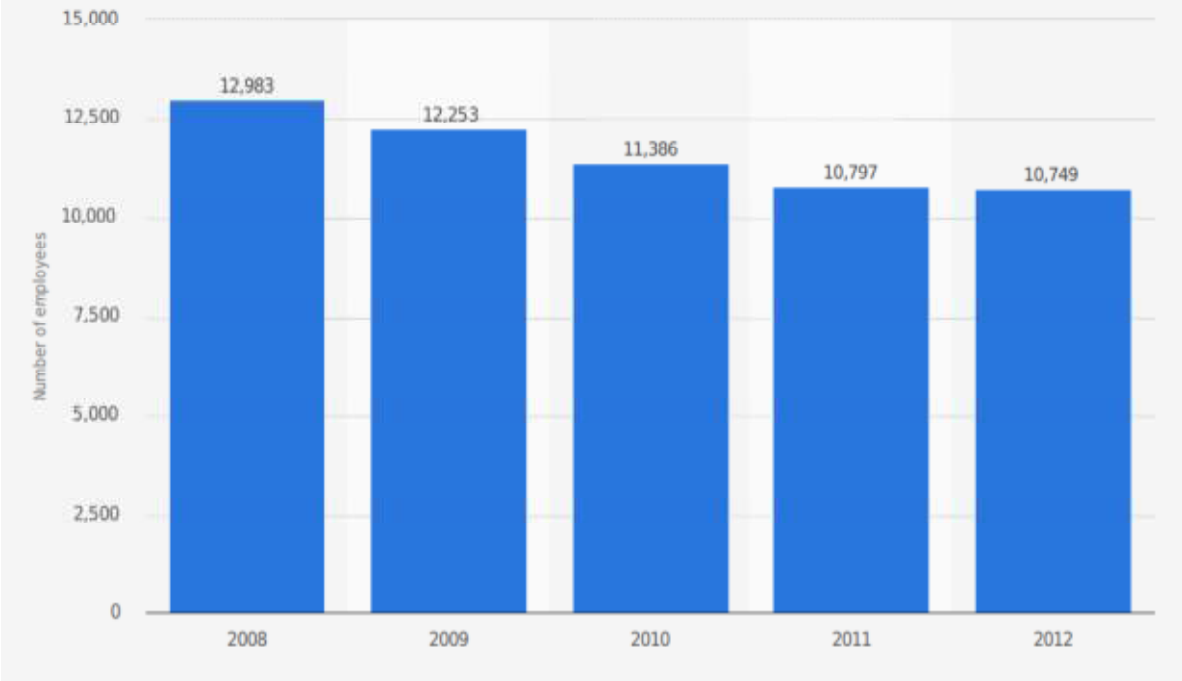
- Sustainable Process Industries for Resource & Energy efficiency
- European Innovation Partnership on raw materials
- European Innovation Partnership on water
- EU High Level Group on key enabling technologies

Chemical Industry is one of the most significant industrial sectors of Greece. Greek chemical industry is rather downstream user of chemicals than basic raw materials producer, providing raw materials to many other important sectors of the national economy such as cosmetics, pharmaceuticals, packaging and food industry. Sub-sectors are the detergents, fertilizers, textiles, paints, construction materials etc. Greek chemical industry contributes to 0.4% of the European chemical industry.

According to EUROSTAT the number of the enterprises in the manufacture if chemicals in Greece has dropped 13.36 % from 2008 to 2012. During the same period the number of the employees in chemical sector has also reduced by 17.21 %.



Picture 1: Number of enterprises in the manufacture of chemicals from 2008 – 2012



Picture 2: Number of employees in the manufacture of chemicals from 2008 - 2012

A percentage of 91.1% of the chemical industries are SMEs. Due to the structure of the Greek economy their role is very important since they have a significant contribution to the employment and the GDP. The majority of the companies since 2008 are facing several problems related to the high demands of legislation and regulations facing the chemical industry, the accessing needed funds, increasingly energy costs, etc. Because of the severe financial crisis, chemical industry has had to cope with a serious decline that has also affected negatively the employment. The sector's turnover in 2009 was €995 million, having decreased by 15.7% compared to 2008, due to the financial crisis. The average change in sales was also negative 15.5%, reflecting the impact of economic recession. SMEs most affected by this recession (mean decline 26.3%). The demand of the chemical industry products was determined directly from the operating characteristics of its clients. During the period 2000 - 2009 the General Index of Industrial Production has dropped almost 1.5%. The strongest decline has been occurred in manufacturing (-2.2%).

According to the latest data of the Hellenic Statistical Authority for 2014, an increase in the volume of production by almost 1% and a marginal decline in revenue has been achieved. The volume of the chemical production in 2014 increased by 0.9% compared to 2013, when it recorded an increase of 2,2%. However, the production index was by 8.6% lower than that of 2010 because of the fall of the biennium 2011-2012. At the same time, according to the same data, the turnover of the sector companies recorded a marginal decline of 0.1%, against a decline of 2.8% in 2013 to levels below those of 2010 by 7.2%.

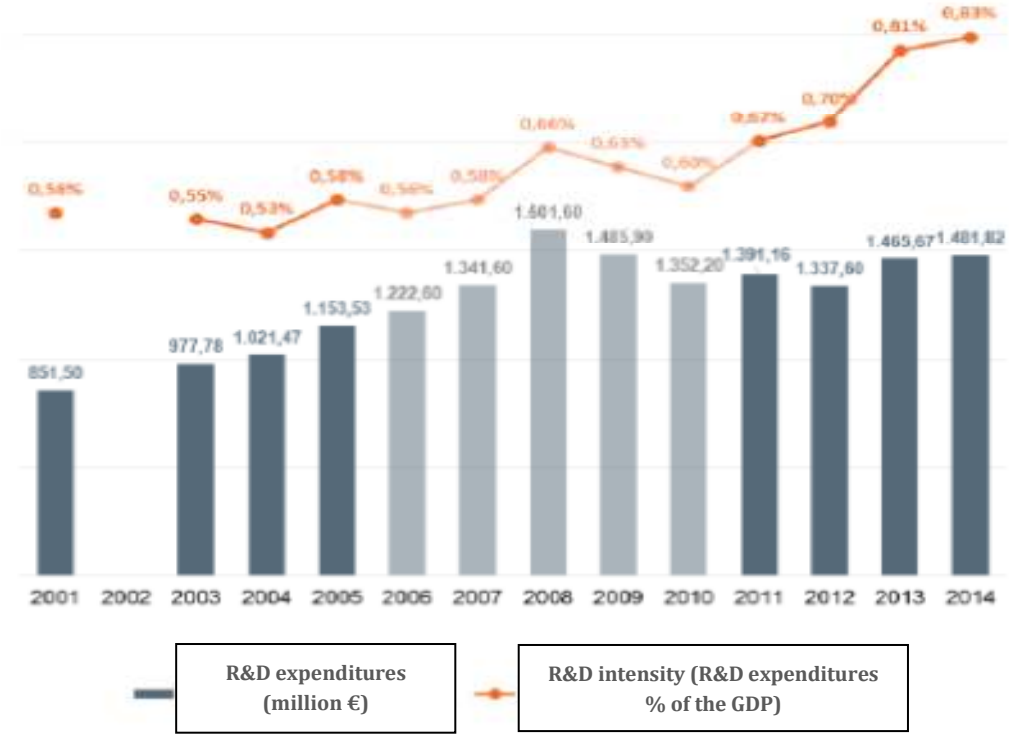
The total revenues of the main companies of the sector (90 % are SMEs), had risen this year to 1.13 billion EUR and were up by 52, 3 million EUR (+ 5%). The 44 % of the sector's enterprises have faced a decrease in their revenues (44.0% of the total). These 159 companies have exclusive or main object the production, processing and packaging of chemicals. Therefore, their income and is not exclusively depending on the production, processing and packaging of chemicals.

These businesses had experienced in 2013, compared to 2012, increased earnings by 26% (125.8 mil. EUR), equal to 11.1% of their total revenues (9.3% 2012), in conditions of increasing revenues by 5% and improve the gross margin by half a percentage point (26.3% in 2013 from 25.8% in 2012). They

showed dramatically improved final results, both before tax (profit 45.8 mil. EUR) and after provision for taxes (profit almost 23.2 mil. EUR).

The own funds of these enterprises (669.2 mil. EUR on 31.12.2013) decreased by 1% (-6.1 mil. EUR) due to outflow of dividends. At the same time, they increased their total capital employed (1.47 bil. EUR at year-end) 1% (9.1 mil. EUR). The ratio of equity to total capital of sector companies fell to 45.5% from 46.2% in 2012. Also, their total liabilities (802.8 mil. Euro at year-end) increased by 2% (15.3 mil. EUR), with lower growth but long-term liabilities (EUR 178.7 mil. euro), despite the short-term (€ 624.1 mil. EUR). Current assets were by 47.5% lower than their short-term liabilities. Their fixed assets were almost unchanged (551.3 mil. EUR).

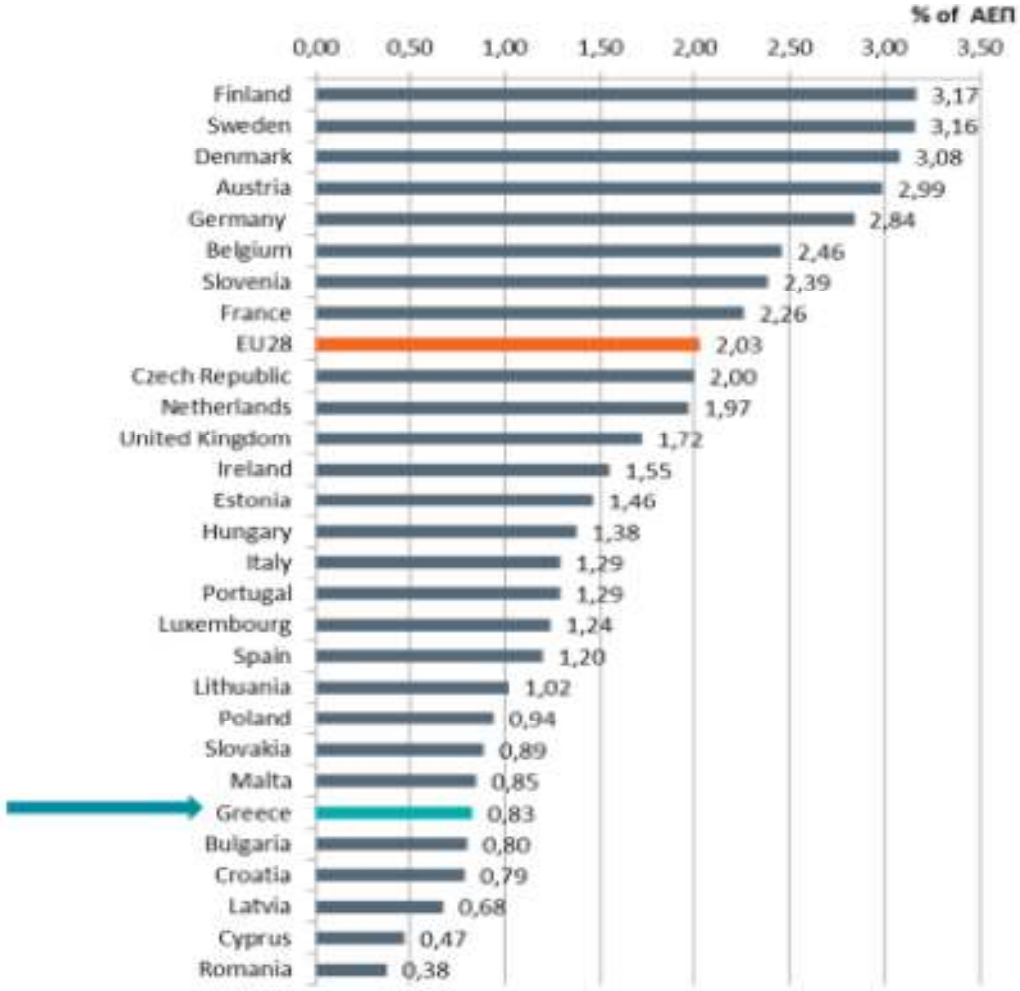
According to the latest data of the National Information System for Research and Technology (the national research e-infrastructure for content and data), the following picture shows the timeline of R&D expenditures and their intensity in terms of the GDP.



Picture 3: R&D Expenditures in Greece 2001 – 2014

Source: National Information System for Research and Technology, 2014 publication

Greece is below the EU 28 average in terms of R&D expenditures for 2014.



Picture 4: R&D ranking, EU 28, 2014

Source: National Information System for Research and Technology, 2014 publication

According to the following table chemicals sector's R&D expenditures represent the 1.66 % of the total R&D expenditures in 2011 which has dropped to 1.29 % until 2013, although the total R&D expenditures from all business sectors has raised during the same period.

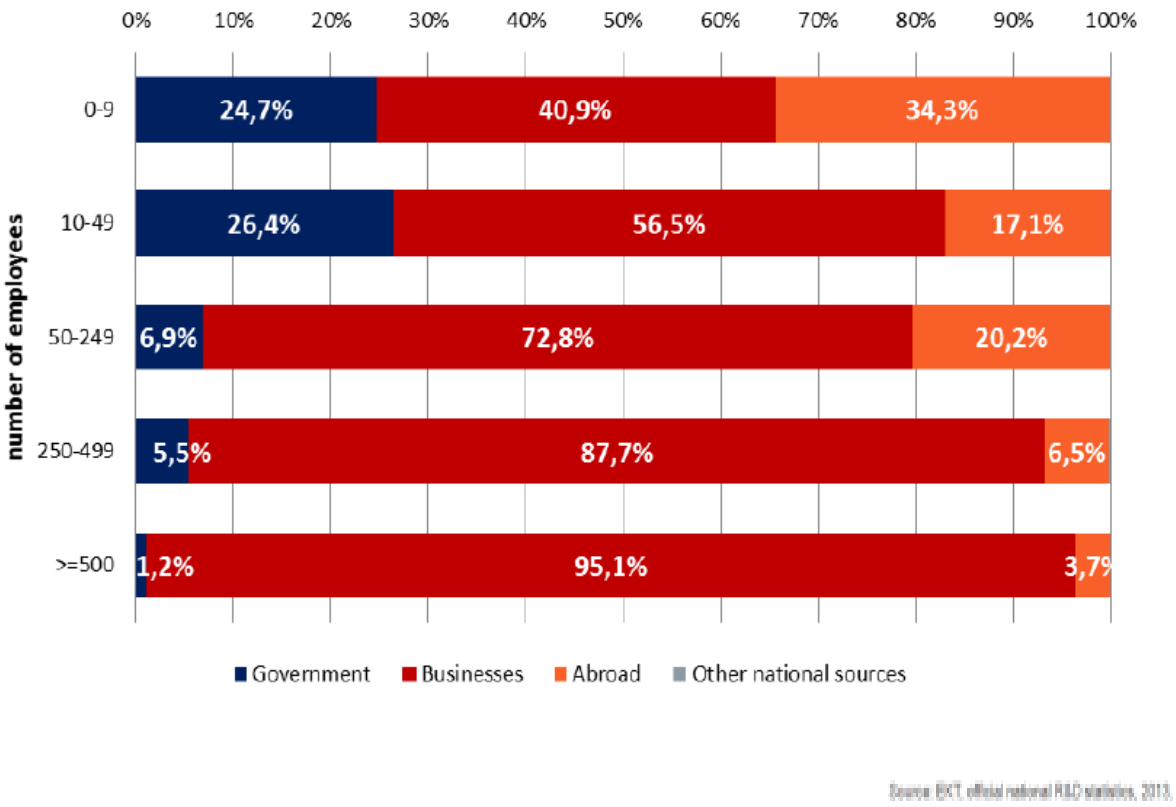
Table 1: R & D expenditure in the business sector (BES) by economic activity (NACE rev. 2) (in mil. Euro)

	2011(2)	2012	2013
Whole country	485,86	458,60	488,69
Agriculture, forestry and fishing (01-03)	1,46	:	0,96
Mining and quarrying (05-09)	0,38	:	0,68
Manufacturing (10-33)	190,58	:	175,84
Food and beverage (10-11)	*16,87*	*:*	*30,19*
Manufacture of chemicals and chemical products (20)	***16,17***	***:***	***12,63***
Manufacture of basic pharmaceutical products and pharmaceutical preparations (21)	*60,31*	*:*	*58,81*
Manufacture of rubber and plastic products (22)	*2,13*	*:*	*2,22*
Manufacture of basic metals (24)	*12,64*	*:*	*11,01*
Fabricated metal products, computer, electronic and optical products, electronic equipment, machinery and equipment, motor vehicles, trailers and semi-trailers, other transport equipment (25-30)	*60,67*	*:*	*48,55*
Other processing activities (12.13 to 19, 23, 31-33)	*21,80*		*12,43*
Providing electronic electricity, gas, steam and air conditioning supply, Water supply, sewerage, waste management and remediation activities (35-39)	6,24	:	6,12
Construction (41-43)	5,36	:	2,37
Services (45-82)	279,83	:	300,11
Wholesale and retail trade; repair of motor vehicles and motorcycles (45-47)	*29,86*	*:*	*65,03*
Transportation and storage (49-53)	*0,18*	*:*	*4,42*
Activities accommodation and food service (55-56)	*:c*	*:*	*0,70*
Information and communication (58-63)	*69,94*	*:*	*73,04*
Financial and insurance activities (64-66)	*102,46*	*:*	*103,21*
Professional, scientific and technical activities (69-75)	*76,83*	*:*	*53,29*
Administrative and support service activities (77-82)	*:c*	*:*	*0,42*
Public administration and defense - Compulsory Social Security Education (84-85)	1,20		1,30
Activities related to human health and social work activities (86-88)	0,36		1,10
Arts, Entertainment and Recreation (90-93) Other service activities (94-99)	0,46		0,20

(1)Estimates (2) Stopping the time series (break in series), (c) protected value due to confidentiality

Source: National Information System for Research and Technology, 2013 publication

The sources of the R&D activities from the Greek SMEs (all sectors) are given in the following picture.

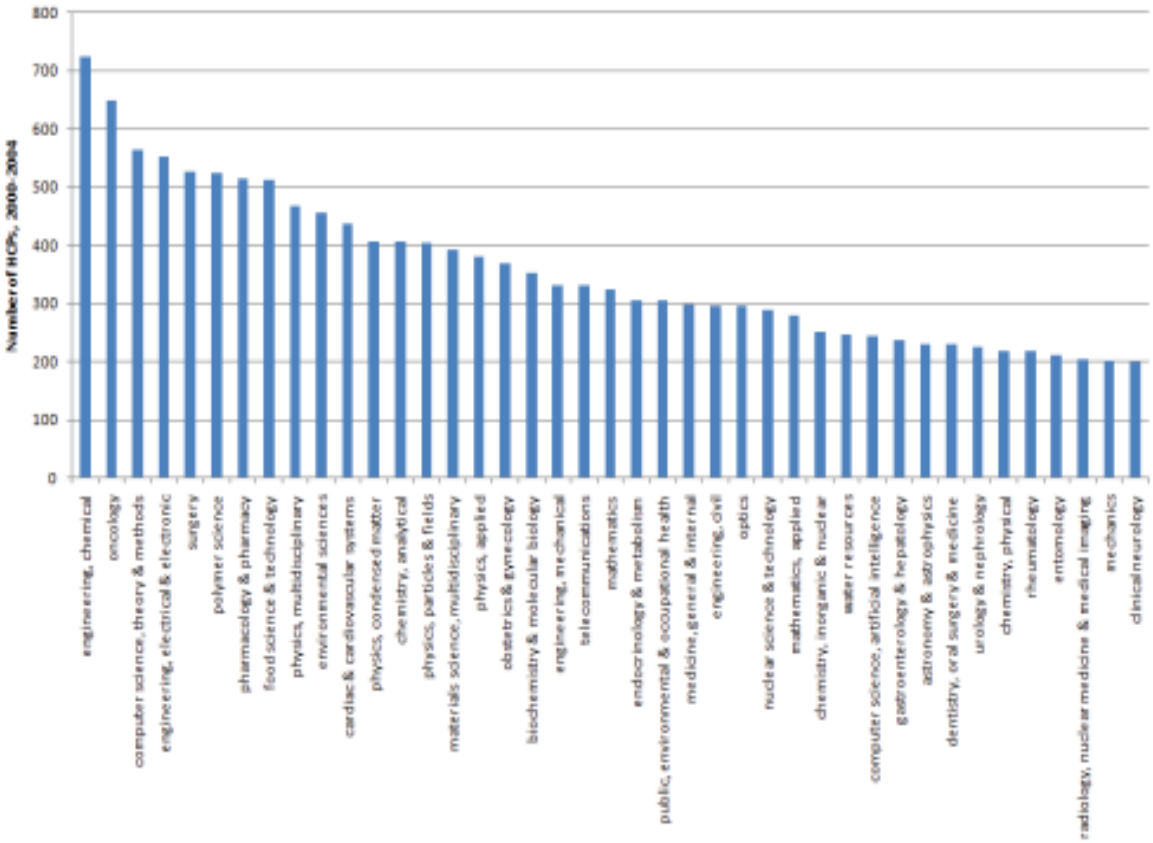


Picture 5: Greek SMEs – R&D Funding in 2013

Results are also representing how things are going in chemical sector concerning the R&D funding. Data shows that the SMEs mostly use their own funding for R&D activities and innovation.

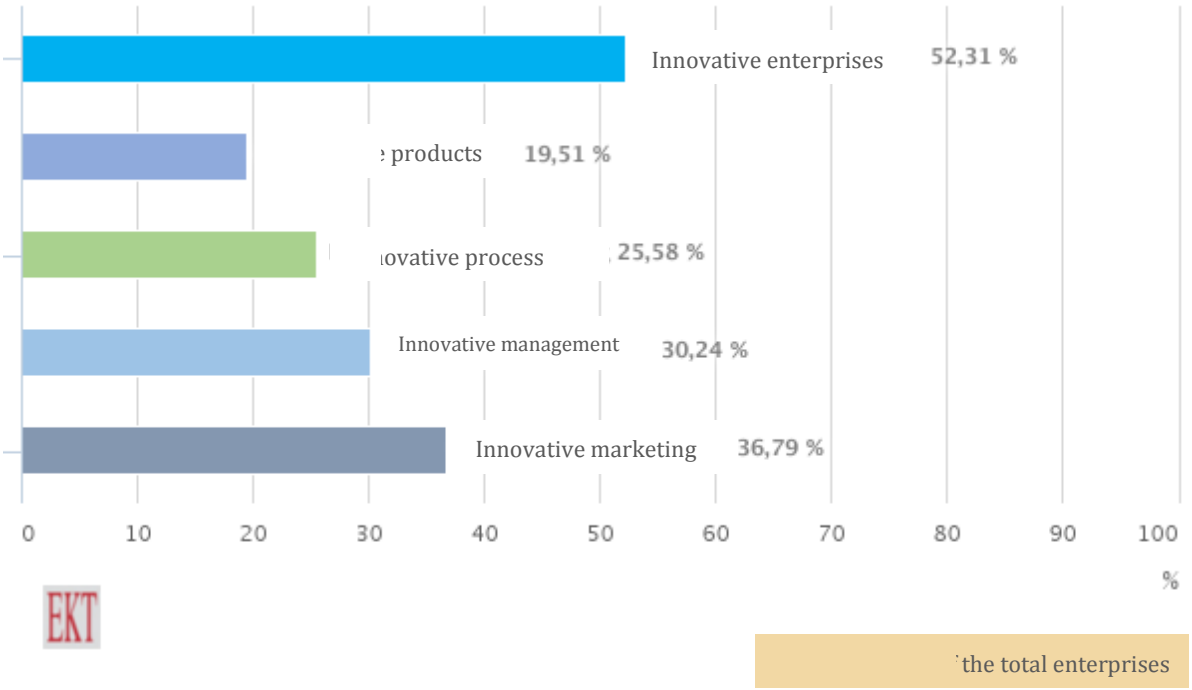
The ten fields with the highest number of HCPs (papers that are in the top 20% of citations for their field worldwide) are: chemical engineering, oncology, theory and methods in computer science, electrical and electronic engineering, surgery, polymer science, pharmacology and pharmacy, food science and technology, multidisciplinary physics, and environmental sciences. In is interesting to note the overlap with the volume of papers; five fields – oncology, theory and methods in computer science, electrical and electronic engineering, surgery, and environmental sciences – appear in the first ten in both lists, indicating the critical mass is being achieved and at internationally competitive level, whilst the remaining five fields with the highest number of HCPs are niche areas of excellence that could be developed for the future.

The fact that "chemical engineering" is usually at the top of the HCPs proves that there is a significant potential for the sector's innovation and competitiveness. That's why the bridge between academia and chemical industry is very important issue to overcome recession and to reach the European targets and European convergence.



Picture 6: Number of HCPs by research field

In order to create a clear picture of the innovation in Greece, it is very important to study the shares of the different types of innovation. The majority of the SMEs invest in organization and marketing innovation rather that product and process innovation. This result is explained due to the structure of the Greek economy (services sector is the biggest sector in Greece).



Picture 4: Innovative enterprises by type of innovation, according to the ECB & ELSTAT, Innovation Survey in Greek businesses the three years 2010-2012

As shown by the results, the three-year period 2010-2012, the 52.31% of Greek companies appear innovative at least one of the above types of innovation. The majority of enterprises are innovative in marketing (36.79%) and in the organization of the company (30.24%). The 25.58% of the companies develop innovation process, while the 19.51% develop innovations in products, either goods or services.

2. Product innovation trends and their perspectives in the country

The structure of the chemical sector and the Greek economy in general, play an important role for the product innovation. The basic trends of product innovation are:

- **Nano-materials, nano-intermediates, nano-enabled products**
- **Composite materials**
- **Biobased chemicals**
- **Polymers and resins**
- **Packaging materials**
- **Materials for energy efficiency of buildings**
- **Lithium-ion batteries**
- **Products for renewable energy and carbon storage**
- **Products for alternative energy**
- **Water treatment chemicals**
- **Agricultural products**
- **Pharmaceuticals**
- **Biotechnology products**
- **Cosmetics**
- **Agri-products**

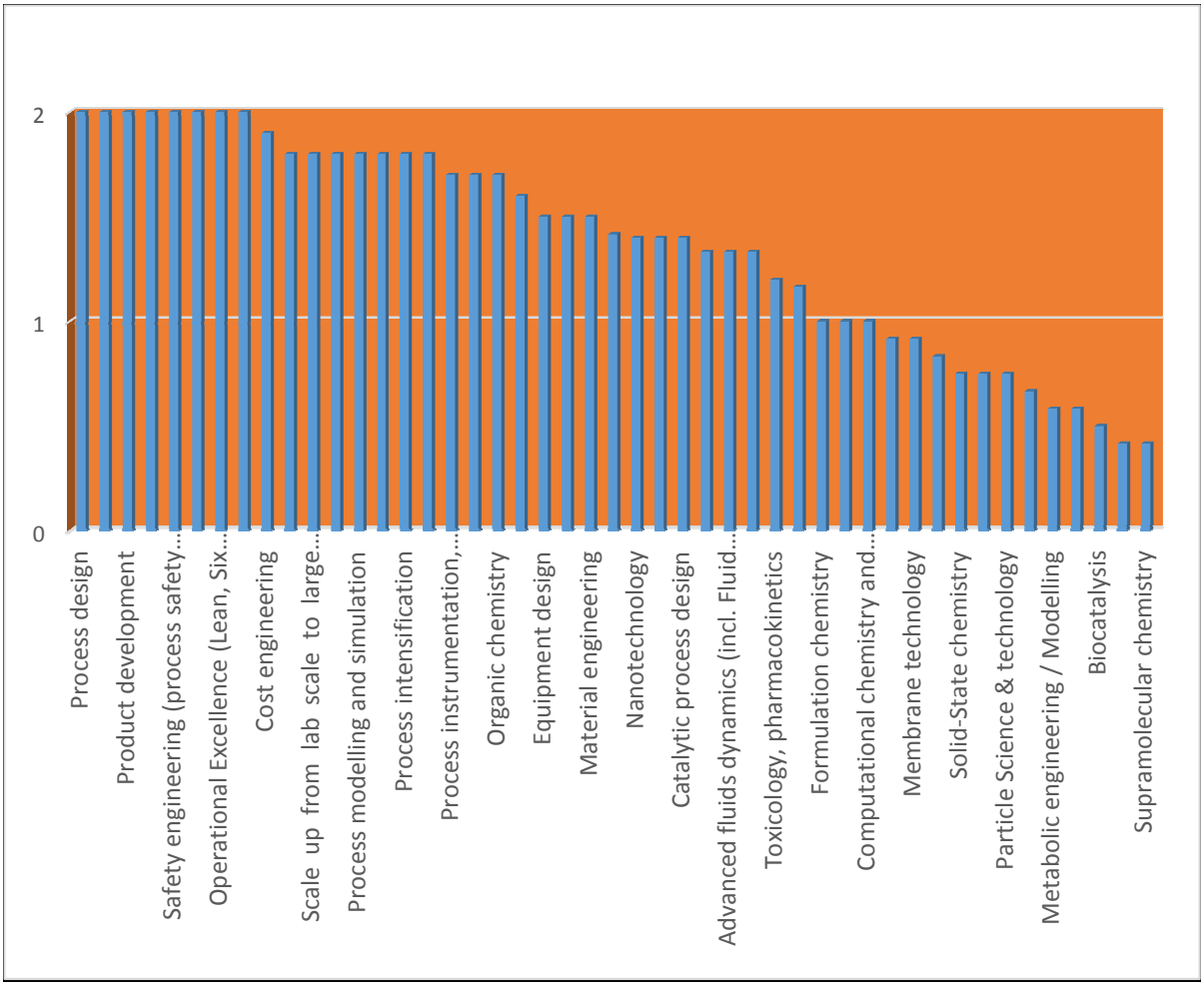
The above mentioned innovation trends are linked with the national strategy for innovation and smart specialization. The perspective is to boost the extroversion of the economy, to boost investments and to create new jobs for young scientists by reducing the distance on the ranking between Greece and EU average concerning innovation.

3. The critical skills needs for innovations with particular emphasis on development of SMEs

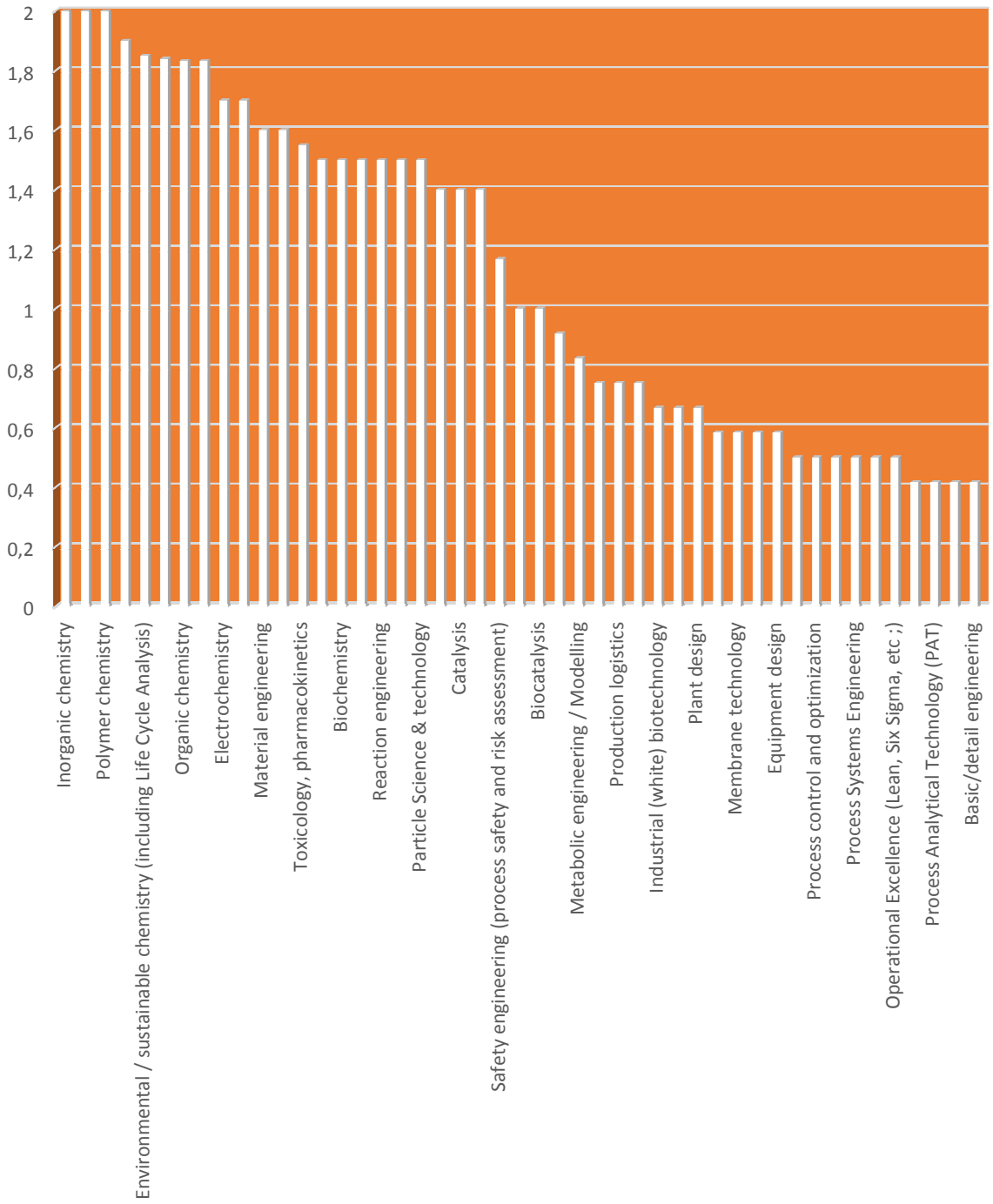
The critical skills needed for innovations in chemical industry sector have been collected among the Hellenic Association of Chemical Industry members and other industries and enterprises non-members of the association. The questioners have been sent to more that 94 companies of the sector. The collected surveys are from 21 enterprises in different fields of chemical industry such as: Paintings – Coatings and Inks, Environmental Management, Process Design, Biocides, Fertilizers, Industrial Gases, Construction materials, Polymers, Cosmetics, Certification Bodies, Consulting companies, Inorganic chemicals, Surfactants, Water Treatment Chemicals.

The results from the survey are summarized to the following graphs (separate graphs for engineers and scientists):

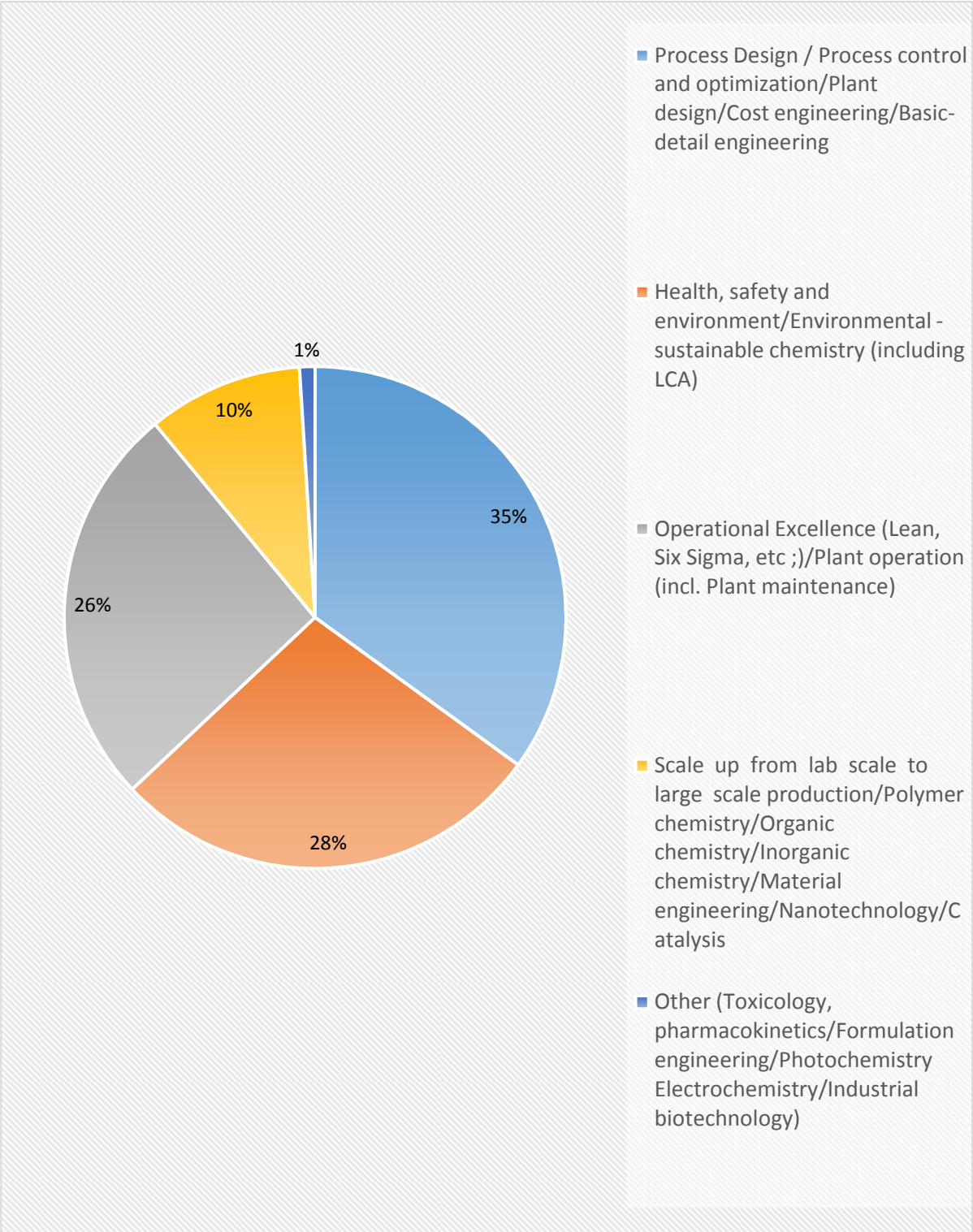
- **Skills of critical importance for engineers:**



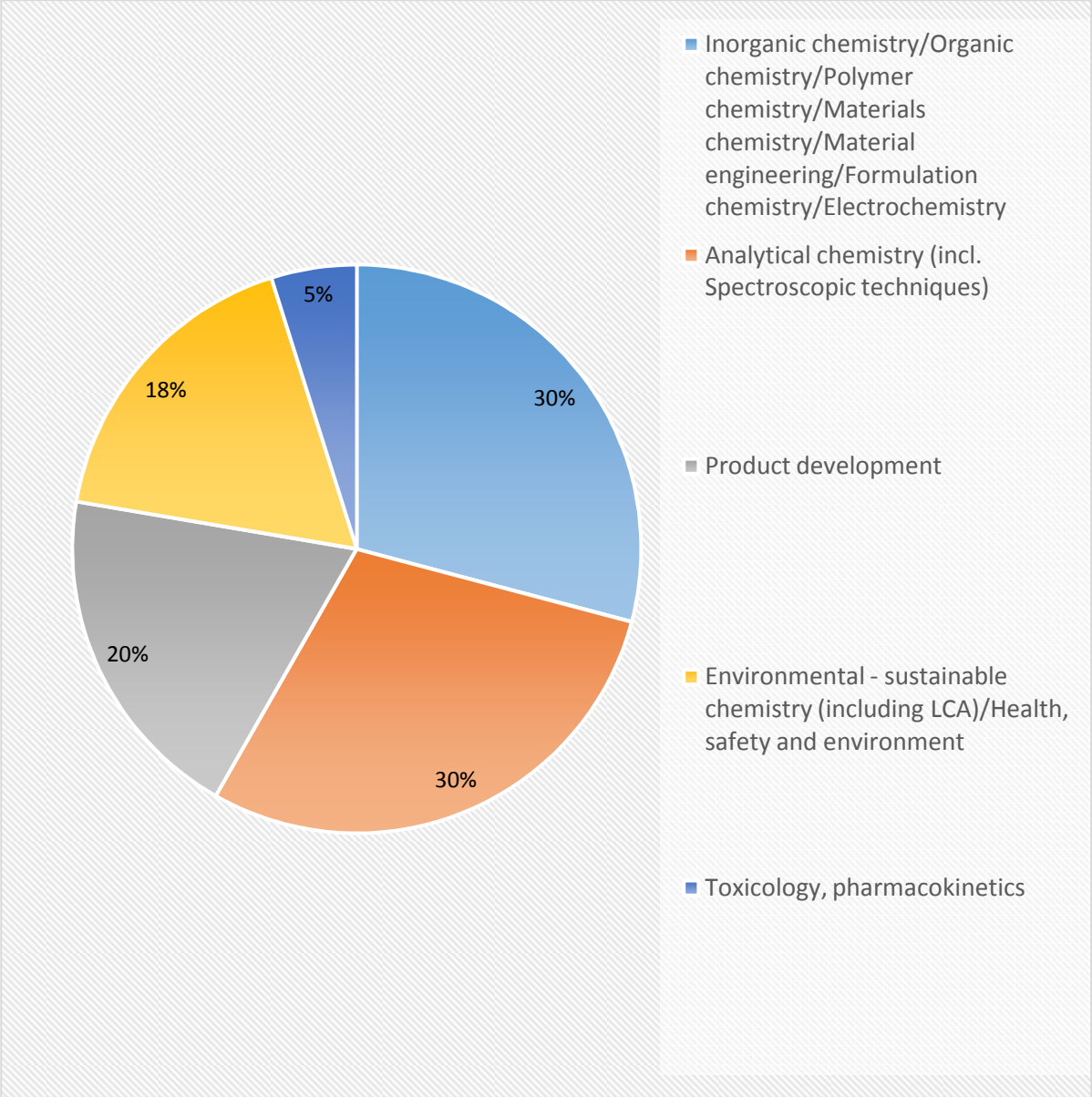
- **Skills of critical importance for scientists:**


2
1,8
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
Inorganic chemistry
Polymer chemistry
Environmental / sustainable chemistry (including Life Cycle Analysis)
Organic chemistry
Electrochemistry
Material engineering
Toxicology, pharmacokinetics
Biochemistry
Reaction engineering
Particle Science & technology
Catalysis
Safety engineering (process safety and risk assessment)
Biocatalysis
Metabolic engineering / Modelling
Production logistics
Industrial (white) biotechnology
Plant design
Membrane technology
Equipment design
Process control and optimization
Process Systems Engineering
Operational Excellence (Lean, Six Sigma, etc ;)
Process Analytical Technology (PAT)
Basic/detail engineering

- **Five most important scientific and technical skills for future engineers:**



- **Five most important scientific and technical skills for scientists:**

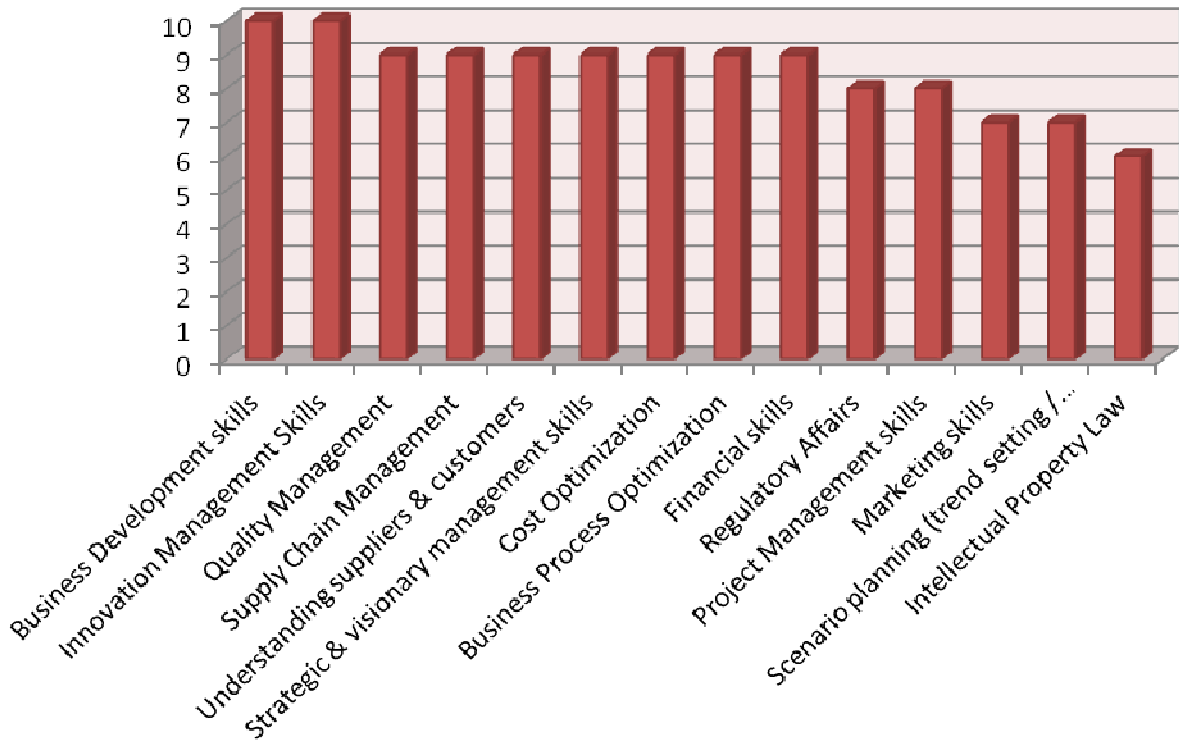


Results:

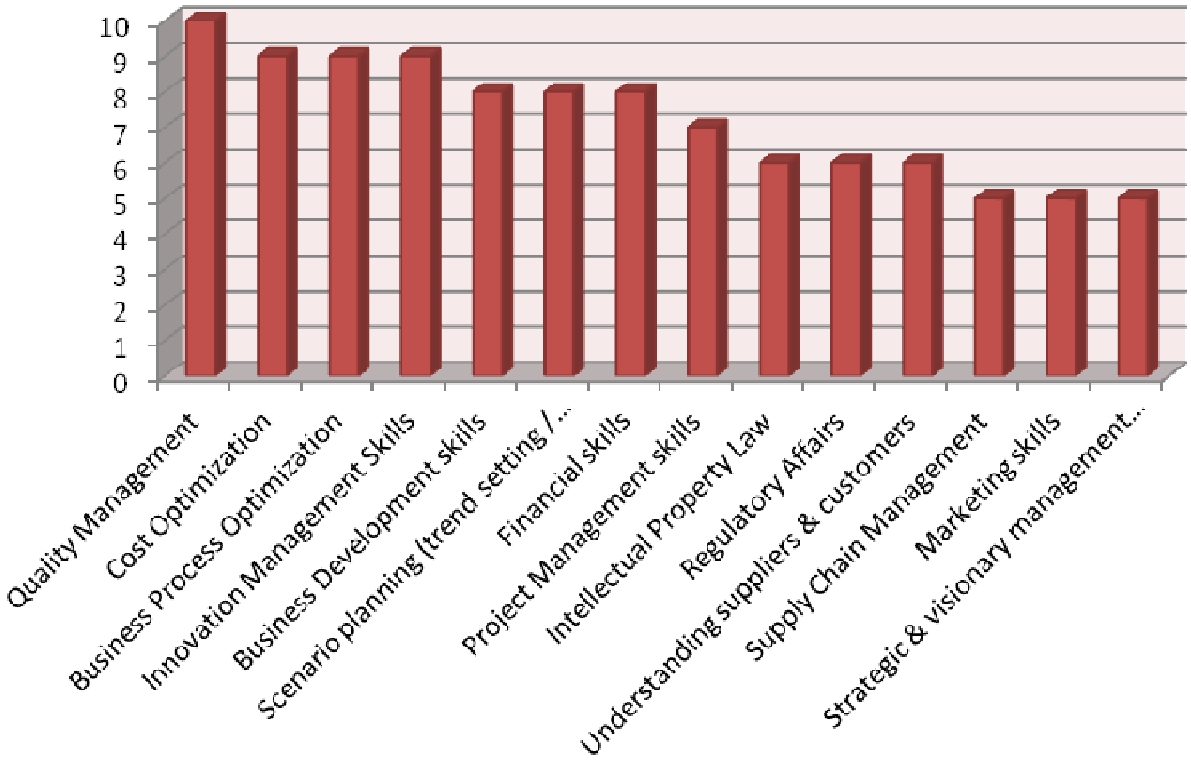
- ✓ Skill requirements for engineers are mostly focused on process mechanics (process design, process control and optimization, cost engineering etc). Findings from the top 5 skills are in total agreement with the previous cumulative results for engineers.
- ✓ Most necessary skills for scientists are considered these associated with chemistry (polymer, inorganic and materials chemistry). Polymer chemistry and in general chemistry is the most crucial skill that industries require from scientists to successfully implement their tasks.

The survey results concerning the business skills for future engineers and scientists are summarized in the following graphs:

Business skills for future engineers:



Business skills for future scientists:

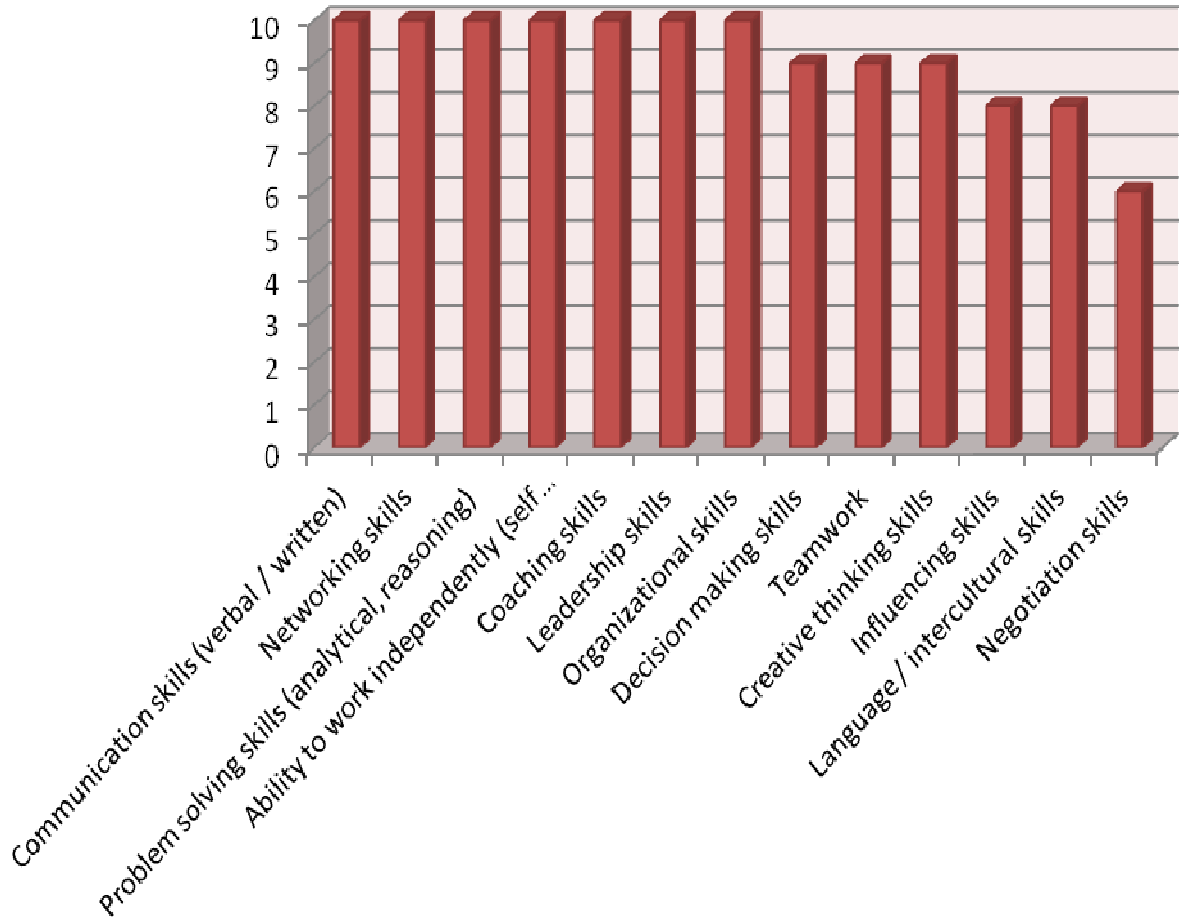


Results:

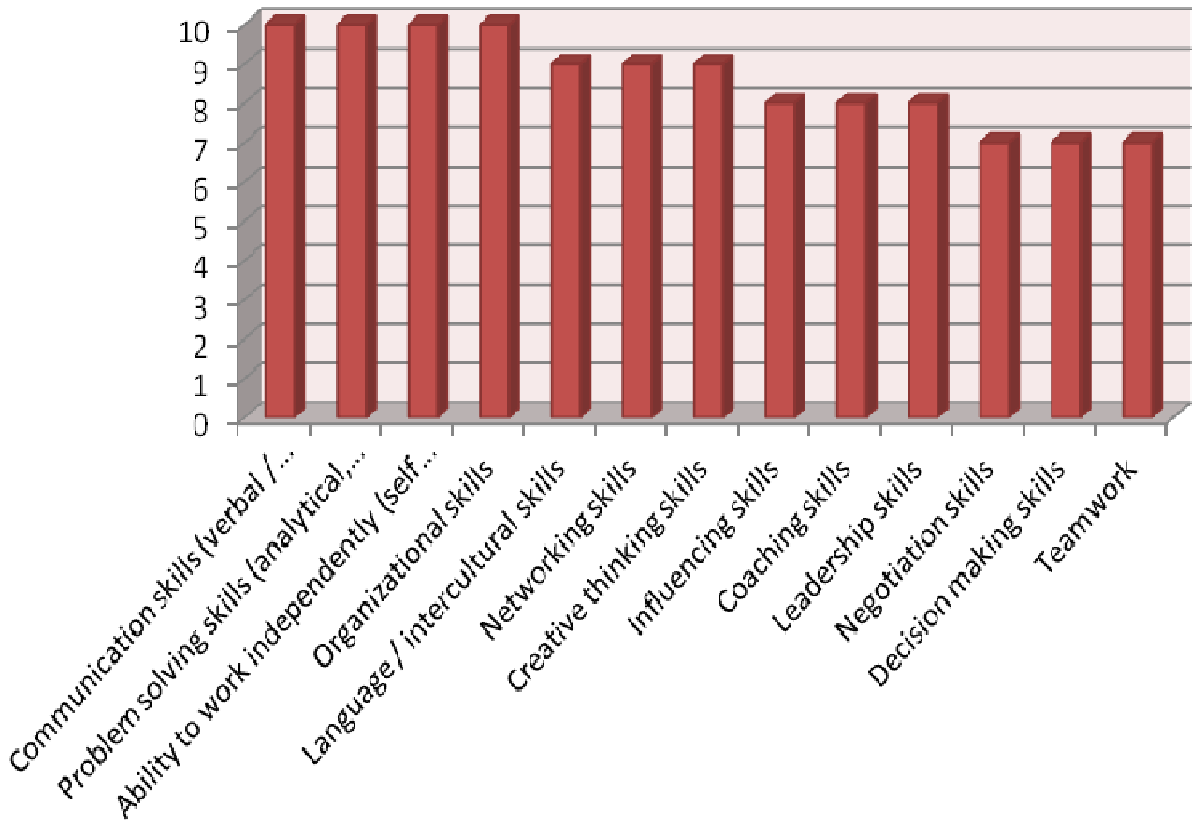
- ✓ Engineers should have a vast knowledge of multidisciplinary skills ranging from business development up to regulatory affairs and marketing skills.
- ✓ Quality management and the other required features focus on cost and process optimization as well as other managerial skills.
- ✓ Generally, engineers are responsible in a greater degree for turning ideas into sustainable markets.
- ✓ Quality management and Business development skills are equally distributed for engineers.
- ✓ Quality management is a essential skill that industries demand for scientists.

The results from the survey concerning the personal skills for future engineers and scientists are summarized in the following graphs:

Personal skills for future engineers:



Business skills for future scientists:



Results:

- ✓ Communication skills, problem solving skills and ability to work independently are most important in both cases.
- ✓ Successful collaboration is crucial to support high quality scientific and technological breakthroughs and promotes innovation in the European industry.
- ✓ Both engineers and scientists should focus on different personal skills to support effective interdisciplinary work.
- ✓ Problem solving and communications skills will be critical for engineers in order to promote innovation ideas.
- ✓ High quality communication skills for scientists will be required to respond to the existing needs and future actions.

4. State of affairs in current education

Chemical Engineering has 5-years studies with 10 semesters (thesis and internships included) which lead to a Diploma. The same scheme applies to all faculties of Engineering in Greece. There are 3 Schools of Chemical Engineering (Athens, Thessaloniki, Patras). The National Organization for the Certification of Qualifications and Vocational Guidance (E.O.P.P.E.P.) includes the engineering diploma in the 6th Level of the Qualification Types, although the majority of the European universities recognize the engineering diploma from the Greek Polytechnics as a Master degree.

A student of Chemical Engineering develops a physicochemical process from laboratory "bench", through pilot / semi-industrial tests until the mass production. The challenge in modern education of Chemical Engineering is to understand the process from the molecular to the macroscopic level. The core of the Chemical Engineering curriculum includes: Applied mathematics, mass and energy balances, physics and properties of gases, liquids and solids, fluid mechanics, heat and mass transfer, thermodynamics, kinetics of chemical and biological reactions and design reactors as well as the subjects of integration such as process design, adjustment and optimization. Due to the broad base of the subjects and the focus of the studies in basic and engineering sciences, Chemical Engineers internationally regarded as "universal" (or manifold) engineer (universal engineer).

The scientific and professional breadth of Chemical Engineering provides the specifications of the physiognomy of the studies. The educational objectives of the curriculum and the desired "footprint" of the educational process the student have the following characteristics:

- ✓ Ability to identify, formulate and solve engineering problems.
- ✓ Ability to design and carry out experiments and analyze and interpret experimental measurements
- ✓ Ability to apply synthetic mathematical knowledge, physics, chemistry, biology and engineering, using and developing their skills to the particular requirements of his work, looking for creative / innovative solutions to technical problems.
- ✓ Ability to design a system, as a whole and its individual components, or process to meet specific needs but realistic specific restrictions, such as

economic, environmental, social, political, ethical, security, constructibility and sustainability.

- ✓ Ability to effectively participate in multi-collector groups, communicatively effective and exercising leadership.
- ✓ An understanding of occupational and ethical responsibility and use of knowledge for the benefit of the community, of society, of the country.

The Chemical Engineering School of the NTUA

There are 5 Schools of Chemists in Greece (Athens, Patras, Ioannina, Thessaloniki and Irakleio). The aim of the departments is to train scientists capable to take care of the study and research of the structure, composition and transformations of organic and inorganic matter.

The Departmental or Inter-Departmental Postgraduate Courses, are leading to the respective "Post Graduate Specialization Diploma", with a minimum duration of 17 months. After the acquisition of the "Post Graduate Specialization Diploma", the student can proceed towards submitting a Doctorate Thesis.

The Postgraduate Courses offered by the Schools of Chemical Engineering or by cooperation with other Schools are:

- Programs offered by the School of Chemical Engineering:
- Materials Science and Engineering
- Computational MechanicsProtection of Monuments, Sites and Complexes
- Automation SystemsAthens Postgraduate Program in Business Administration
- Energy Production and ManagementProtection of Monuments, Sites and Complexes
- Environment and Development
- Mathematical Modeling in Modern Technologies and Economics
- Chemistry Education and New Educational Technologies
- Postgraduate Course on Industrial Management

Chemistry has 4-years studies with 8 semesters (thesis included) which lead to the Diploma. Each year the courses are taught in two semesters and examinations are held three times a year. In the curriculum are compulsory and elective compulsory subjects. Many of the mandatory or elective courses

accompanied by practical training of students in laboratories, which are mandatory.

During chemistry studies, the student acquires an important knowledge base, obtained by pooling the necessary theoretical data of the science of chemistry (structure of matter, analysis, synthesis, production) in laboratory techniques, general and specialized, as well as many elements of technological knowledge. A chemist after his graduation is specialized in the fields which are directly connected to his future professional career, or personal interests.

The Postgraduate Courses offered by the Schools of Chemistry or by cooperation with other Schools are:

- The Departmental Postgraduate Programme in Chemistry
- The Postgraduate Programme in "Polymer Science and its Applications"
- The Postgraduate Programme in "Education in Chemistry - Novel Teaching Technologies"
- The Postgraduate Programme in "Chemical Analysis - Quality Control"
- The Postgraduate Programme in "Organic Synthesis and its Applications in Chemical Industry"
- The Postgraduate Programme in "Catalysis and its Applications"
- The Interdepartmental Postgraduate Programme in "Oceanography - Management of Marine Environment" coordinated by the Department of Geology
- The Interdepartmental Postgraduate Programme in "Clinical Biochemistry - Molecular Diagnostics" coordinated by the Department of Biology

5. Support of stakeholders (particularly relevant authorities and institutions) needed for innovating tertiary education of scientists to include the critical skills identified

During the courses timeline, several visits of students to key industrial sector (companies/SMEs) are foreseen, so as to boost the innovating tertiary education of scientists to include the critical skills. Industrial sector is also involved in funding various scientific social event and activities (e.g. Researcher's night 2014 and 2015), also with support from European Commission. Being a main part of Chemical Engineering current Curriculum, internship (2 months, SCE curriculum) activities are also included.

There are no obligations arising from applicable laws for introducing innovating curricula in Greece.

The evaluation of the Chemical Engineering Schools of Greece based on the international ranking "QS - Top Universities / World University Ranking" for the last three years (2012-2014) proclaimed the international recognition of the Schools, which are among the 150 best Schools of Chemical Engineering worldwide and among the 50 best European Schools.

The ranking of the various schools is based on four indicators (Academic Reputation, Employment Reputation, Citations per Paper, h-index citations). The first 2 indicators, with 40 weight% and 30% respectively) are determined based on a large volume of questionnaires in academic and enterprises respectively. O 3rd and 4th index gravity of 15% each, based on objective criteria determined by the circumstances of bibliographic database Scopus. The index CPP, which emphasizes its international impact of work) is the ratio of total citations in year N (into which the evaluation) to the overall operations of the year (N-6) to (N-2). Correspondingly determined and the ratio HIC, which takes into account both productivity and impact of the published work.

Both Schools of Chemical Engineers in Thessaloniki and Patras have recently updated their curriculums.

The Chemical Engineering School of the NTUA has recently started the procedure to update its curriculum with support from the industry sector (for example with the Hellenic Association of Chemical Industries – HACI) and the Hellenic Association of Chemical Engineers (HACE). The timeline which has been

set by the Undergraduate curriculum committee for the new curriculum is to finish consultations in 2016 and to adopt the new curriculum from 2017. Thus INNOCHEM objective and its deliverables are very important for the new curriculum.

HACE is also in close cooperation with Chemical Engineering Schools and especially with the Chemical Engineering School of NTUA (due to the fact that most of the chemical engineers live and work in Attica region), providing vocational training for young professionals in terms of new processes, new innovative products, chemical legislation, environmental – health and safety standards, project management, innovation, intellectual properties legislation etc.

Lavrion Technological and Cultural Park (LTCP), is a body of scientific research, education, business and culture. Founded in place of the old French Mining Company of Lavrion (Compagnie Francaise des Mines du Laurium) in 1992, as a result of the initiative undertaken from the National Technical University of Athens. LTCP aims at linking scientific and technological research conducted in Athens with the needs and interests of the business world to the realization of cultural events related to the promotion of the history and culture of the wider area of Lavreotiki and the emergence of the history of activities in the past had developed in the maintenance of premises. The LTCP area is a unique monument of industrial architecture and archeology and placed him in a series of housing facilities for business and research excellence. The services provided by LTCP as well as its renovated facilities, continue to support research, education and technology. Today, LTCP is essentially the only Technology Park in Attica, which specializes in areas - keys of modern applied technology, such as information technology, electronics technology, telecommunications, robotics, technology laser, environmental technology, energy, shipbuilding, marine technology, production of nano-structures etc.

The Innovation and Entrepreneurship Unit of the National Technical University of Athens, will also establish a new scheme to promote entrepreneurship of students through start-ups and spin-offs during 2017.

6. Administrative procedures and time-line for implementing a new curricula

As already stated above the new curriculum for Chemical Engineering School of NTUA is under development and it will be adopted from 2017. The responsible committee for the new curriculum is in close cooperation with the Hellenic Association of Chemical Engineers and the Hellenic Association of Chemical Industries. There will be several meetings of the Undergraduate curriculum committee during this year (including with the external stakeholders like the related associations) in order to finalize the draft proposal for the new curriculum which will be introduced to the General Assembly of the School which will take the final decisions.

The main obstacles for innovating curricula for tertiary education are:

- Underfunding of the Tertiary education from the State. For example the state funds has been reduced more than 80% since 2010 for Chemical Engineering Schools!
- Lack of communication between universities and industry sector.
- Limitations from the State in the recruitment of new professors and research staff for the public universities due to the financial crisis.
- Universities endogenous problems relating to compliance with strategic plans, to the refusal of evaluation process etc.

There are no legal or administrative obstacles for innovating curricula.

The general obstacle that affect negatively attractiveness of careers in chemical science and chemical engineering is the deindustrialization of the Greek economy.

Annex I – Questionnaire

Interviewee and company information

Please complete the table below

Name			
Job title			
Company			
Country			
Address			
Telephone number			
E-mail			
Role	☐ Global	☐ European	☐ Local
If local, please specify country			

Please indicate in the table below which sub-sectors of the chemical industry you will be providing information about.

Chemical sub-sectors	Activity
1. Petrochemicals	
2. Polymers	
2.1 Plastics	
2.2 Synthetic rubber	
2.3 Man-made fibres	
2.4 Biomass-based	
3. Basic inorganics	
3.1 Industrial gases	
3.2 Fertilizers	
3.3 Other inorganics	
4. Specialty chemicals	
4.1 Dyes &pigments,	
4.2 Crop protection	
4.3 Paints & inks	
4.4 Auxiliaries for industry	
4.5 Oleo chemicals, organic acids, amino acids	
5. Consumer chemicals	
6. Pharmaceuticals	
Other [Please Specify]	

Please indicate which percentage of the total turnover of your company is spent on Research & Development & Innovation.

Percentage of annual turnover spent on R&D&I	..... %

Scientific and technical skills of future Engineers and Scientists

This section of the interview focuses on the scientific and technical skills which will gain importance to drive innovation in 2015 - 2025 for Scientists and Engineers. The answers provided should relate to the importance of the skills in the future (i.e. 2015 and beyond) and not based on the current situation.

The table below provides an overview of selected skill categories for chemical engineers and scientists.

2.1 Please indicate which of these skills are likely to be of critical importance for engineers and scientists to support innovation in your sub-sector(s) of the chemical industry using the following scale of 0 to 2 with:

- 0: being not important
- 1: skill set is desirable
- 2: skill set is essential

2.2 After you completed the rating (2.1), please indicate which will be the 5 most important scientific and technical skills for engineers and scientists for your sub-sectors in 2015 and beyond. Please rank them in order of importance (1 = most important) and provide a reason or comment.

2. SCIENTIFIC AND TECHNICAL SKILLS SETS	2.1 Skill Set Rating 0 -2		2.2 Five most important skills (1= most important)		Comments
	Engineers	Scientists	Engineers	Scientists	
Inorganic chemistry					
Organic chemistry					
Polymer chemistry					
Formulation chemistry					
Solid-State chemistry					
Materials chemistry (including corrosion)					
Industrial (white) biotechnology					
Biochemistry					
Catalysis					
Biocatalysis					
Computational chemistry and modelling (incl. Structure and property relationships, theoretical chemistry, quantum chemistry)					
Metabolic engineering / Modelling					
Analytical chemistry (incl. Spectroscopic techniques)					
Interface chemistry					

2. SCIENTIFIC AND TECHNICAL SKILLS SETS	2.1 Skill Set Rating 0 -2		2.2 Five most important skills (1= most important)		Comments
	Engineers	Scientists	Engineers	Scientists	
Electrochemistry					
Photochemistry					
Supramolecular chemistry					
Nanotechnology					
Particle Science & technology					
Reaction engineering					
Biochemical engineering					
Formulation engineering (incl. Emulsification)					
Material engineering					
Catalytic process design					
Membrane technology					
Separation and purification technologies					
Advanced fluids dynamics (incl. Fluid dynamics, micro fluidics, computational fluid dynamics (CFD))					
Process design					
Process control and optimization					
Process intensification					
Process modelling and simulation					
Process Analytical Technology (PAT)					
Process Systems Engineering					
Process instrumentation, automation & IT					
Scale up from lab scale to large scale production					
Plant operation (incl. Plant maintenance)					
Plant design					
Basic/detail engineering					
Equipment design					
Product development					
Production logistics					
Cost engineering					
Operational Excellence (Lean, Six Sigma, etc ;)					

2. SCIENTIFIC AND TECHNICAL SKILLS SETS	2.1 Skill Set Rating 0 -2		2.2 Five most important skills (1= most important)		Comments
	Engineers	Scientists	Engineers	Scientists	
Environmental / sustainable chemistry (including LCA[1])					
Health, safety and environment					
Safety engineering (process safety and risk assessment)					
Toxicology, pharmacokinetics					
Other [Please Specify]					

Business skills of future engineers and scientists

Business skills include competencies in areas such as Finance, Intellectual Property Law, Regulatory Affairs, Supply Chain Management, Business Development, Cost Optimization, etc.

The table below provides an overview of the business skills.

3.1 Please indicate which of these business skills are likely to be of critical importance for engineers and scientists to support innovation in your sub-sector(s) of the chemical industry using the following scale of 0 to 2 with:

- 0: being not important
- 1: skill set is desirable
- 2: skill set is essential

3.2 After you completed the rating, please indicate which will the 5 most important business skills be for engineers and scientists for your sub-sectors in 2015 and beyond. Please rank them in order of importance (1 = most important) and provide a reason or comment.

3. BUSINESS SKILLS	3.1 Skill Set Rating 0 -2		3.2 Five most important skills (1= most important)		Comments
	Engineers	Scientists	Engineers	Scientists	
Intellectual Property Law					
Regulatory Affairs					
Quality Management					
Supply Chain Management					
Understanding suppliers & customers					

[1] LCA = Life Cycle Assessment

3. BUSINESS SKILLS	3.1 Skill Set Rating 0 -2		3.2 Five most important skills (1= most important)		Comments
	Engineers	Scientists	Engineers	Scientists	
Business Development skills					
Marketing skills					
Scenario planning (trend setting / spotting)					
Strategic & visionary management skills					
Project Management skills					
Cost Optimization					
Business Process Optimization					
Financial skills					
Innovation Management Skills					
Other [Please Specify]					

Personal skills of future engineers and scientists

This section of the survey focuses on the personal skills for Scientists and Engineers which will gain importance in 2015 and beyond. It is important to answer the questions from a future perspective (i.e. 2015 and beyond) and not based on the current situation.

Intrapersonal and interpersonal skills determine a person's ability to excel or at least fit in a particular social structure, such as a project team, partnerships, etc. These skills include competencies in areas such as communication, leadership ability, conflict resolution, decision making, self-motivation, self-discipline, persuasion, etc.

The table below provides an overview of selected intrapersonal and interpersonal skills. Which of these skills are likely to be of critical importance, for continued innovation in 2015 and beyond in your sub-sector(s) of the chemical industry?

4.1 Please indicate which of these personal skills are likely to be of critical importance for engineers and scientists to support innovation in your sub-sector(s) of the chemical industry using the following scale of 0 to 2 with: a scale of 0 to 2 with:

- 0: being not important
- 1: skill set is desirable
- 2: skill set is essential

4.2 After you completed the rating, please indicate which will the 5 most important business skills be for engineers and scientists for your sub-sectors in 2015 and beyond. Please rank them in order of importance (1 = most important) and provide a reason or comment.

4. PERSONAL SKILLS	3.1 Skill Set Rating 0 -2		3.2 Five most important skills (1= most important)		Comments
	Engineers	Scientists	Engineers	Scientists	
Communication skills (verbal / written)					
Negotiation skills					
Language / intercultural skills					
Networking skills					
Influencing skills					
Creative thinking skills					
Problem solving skills (analytical, reasoning)					
Decision making skills					
Ability to work independently (self management)					
Teamwork					
Coaching skills					
Leadership skills					
Organizational skills					
Other [Please Specify]					

Suggestions for skills improvement

This section of the survey is related to the importance of the educational curricula in 2015 and beyond.

Higher educational curricula

Please provide at least 3 suggestions on what universities or other higher educational institutions could do to ensure chemical science and engineering graduates will be able to contribute effectively to improve innovation in your sub-sectors
Suggestions can refer to:

- the relative importance or required balance of the different skills sets (scientific and technical, business, personal),
- and/or the needs for additional subjects that should be included in science and engineering, science degree courses.

Please rank your suggestions in order of importance (1 = most important)

Suggestions for scientists		Suggestions for engineers	
Suggestions	Ranking (1 = most important)	Suggestions	Ranking (1 = most important)

Life Long Learning Programmes

Please provide at least 3 suggestions regarding the content of life long learning programmes for updating the skills set of Scientists and Engineers in your sub-sector(s).

Please rank your suggestions in order of importance (1 = most important).

Suggestions for scientists		Suggestions for engineers	
Suggestions	Ranking (1 = most important)	Suggestions	Ranking (1 = most important)

Additional comments

Are there any other skills issues with regard to improving innovation in your sub-sector(s) of the industry that we have not addressed?

Additional Comments: