Bioeconomy in Catalonia

Juny 2018

Sector Report

ACCIÓ

Generalitat de Catalunya

Amb la col·laboració de: S3Chem Interreg Europe

European Union
European Regional
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Strategy and Competitive Intelligence Unit

Bioeconomy in Catalonia

Catalonia Trade & Investment
Government of Catalonia

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1. Project goals

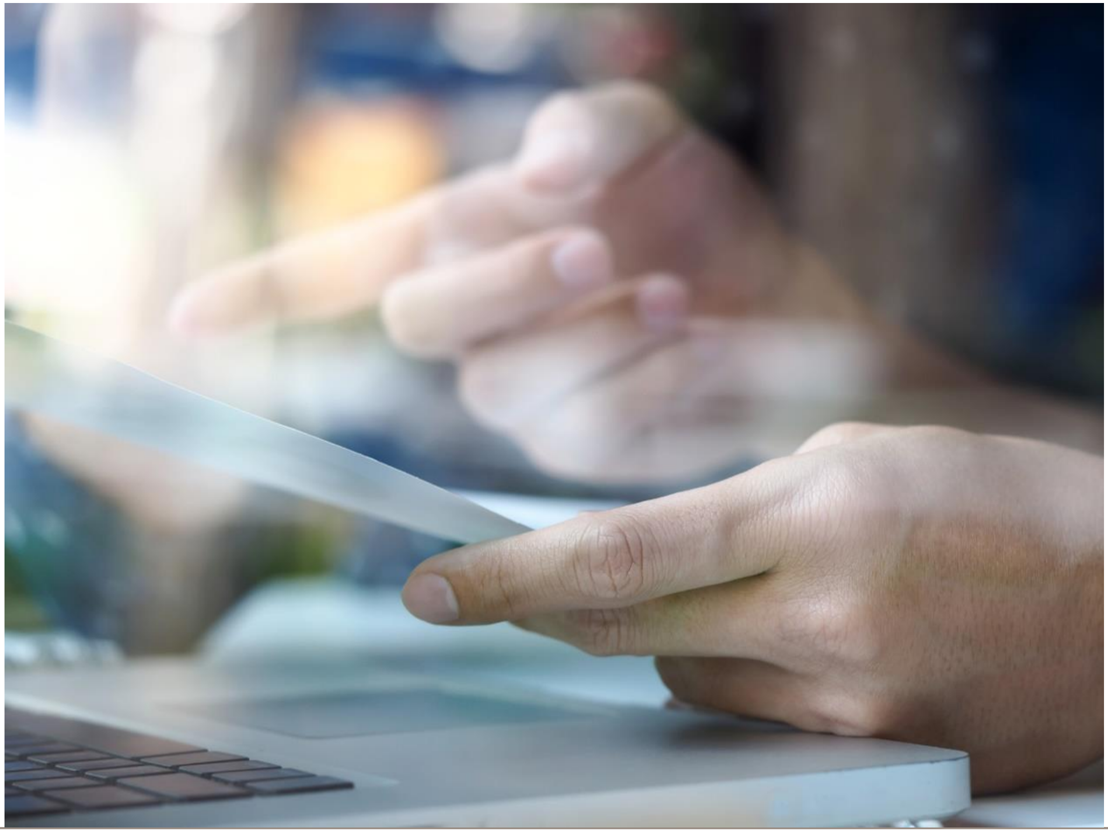
Project goals

The aim of the project is to **define the bioeconomy sector in Catalonia and its relationship with the circular economy and the chemical industry.** It also aims to analyse the tendencies and future challenges of these two paradigms, as well as their deployment in Catalonia.

More specifically, the project focuses on:

- Description, definition, scope and characterization of the Bioeconomy and the Circular Economy and the role of industrial chemistry in Catalonia.
- Definition of the concept of Bioeconomy in Catalonia, and identification of its main demand sectors.
- Identification of business and innovation opportunities, as well as strategic challenges that bioeconomy can generate for Catalan companies.
- Links between the concepts of Bioeconomy and the Circular Economy.

2. Main concepts, actions & strategies



Main concepts

Circular Economy & Bioeconomy

A **circular economy** is **a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops**. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling.

As part of its continuous effort to make Europe's economy more sustainable and to implement the ambitious **Circular Economy Action Plan**, in January 2018 the European Commission adopted a new set of measures. The potential socio-economic and environmental benefits are impressive. However, these benefits will be truly felt if the **bioeconomy – the renewable part of the circular economy concept –** is made to play its important and growing role.

Source: Refinity, 2017.

Circular economy: characteristics

The following fundamental characteristics describe a pure circular economy:

- **Design out waste:** Products are designed to fit within a biological or technical materials cycle in order not to produce waste. The biological materials are non-toxic and can be simply composted. Technical materials -polymers, alloys and other man-made compounds- are designed to be reused with minimal energy expenditure and highest quality retention.

- **Build resilience through diversity:** Nowadays systems are required to be efficient but other features such as modularity, versatility, and adaptiveness also need to be prioritized in a fast-evolving world. Diverse systems with many connections and scales are more resilient to external shocks than systems built simply for efficiency -throughput maximization driven to extreme results in fragility.

- **Work towards energy from renewable sources:** Systems should ultimately aim to run on renewable energy -enabled by the reduced energy threshold levels required by a restorative, circular economy.

- **Think in systems:** The ability to understand how parts within a whole influence one another, and the relationship of the whole to the parts, is crucial. Elements are considered in relation to their environmental and social contexts. While a machine is also a system, it is clearly narrowly bounded and assumed to be deterministic. Systems thinking usually refers to the overwhelming majority of real-world systems: these are non-linear, feedback-rich, and interdependent.

- **Think in cascades:** For biological materials, the essence of value creation lies in the opportunity to extract additional value from products and materials by cascading them through other applications. In biological decomposition, material is broken down in stages by microorganisms like bacteria and fungi that extract energy and nutrients from the carbohydrates, fats, and proteins found in the material.

Source: According to The Ellen MacArthur Foundation

Circular economy: principles

According to The Ellen MacArthur Foundation, the circular economy provides multiple value creation mechanisms that are decoupled from the consumption of finite resources. **In a true circular economy, consumption only takes place in effective bio-cycles; elsewhere use replaces consumption**. Resources are regenerated in the bio-cycle or recovered and restored in the technical cycle. In the bio-cycle, life processes regenerate disordered materials, despite or without human intervention. The set of business activities that entail the bio-cycle are the ones considered in the concept of **Bioeconomy**. In the technical cycle, with sufficient energy available, human intervention recovers materials and recreates order. Maintaining or increasing capital has different characteristics in the two cycles.

The circular economy rests on three principles, each addressing several of the resource and system challenges that industrial economies face:

- **Principle 1: Preserve and enhance natural capital**
- **Principle 2: Optimize resource yields**
- **Principle 3: Foster system effectiveness**

Principle 1: Preserve and enhance natural capital

Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows.

This starts by dematerializing utility -delivering utility virtually, whenever possible. When resources are needed, the circular system selects them wisely and chooses technologies and processes that use renewable or better-performing resources, where possible. A circular economy also enhances natural capital by encouraging flows of nutrients within the system and creating the conditions for regeneration of, for example, soil.

Principle 2: Optimize resource yields

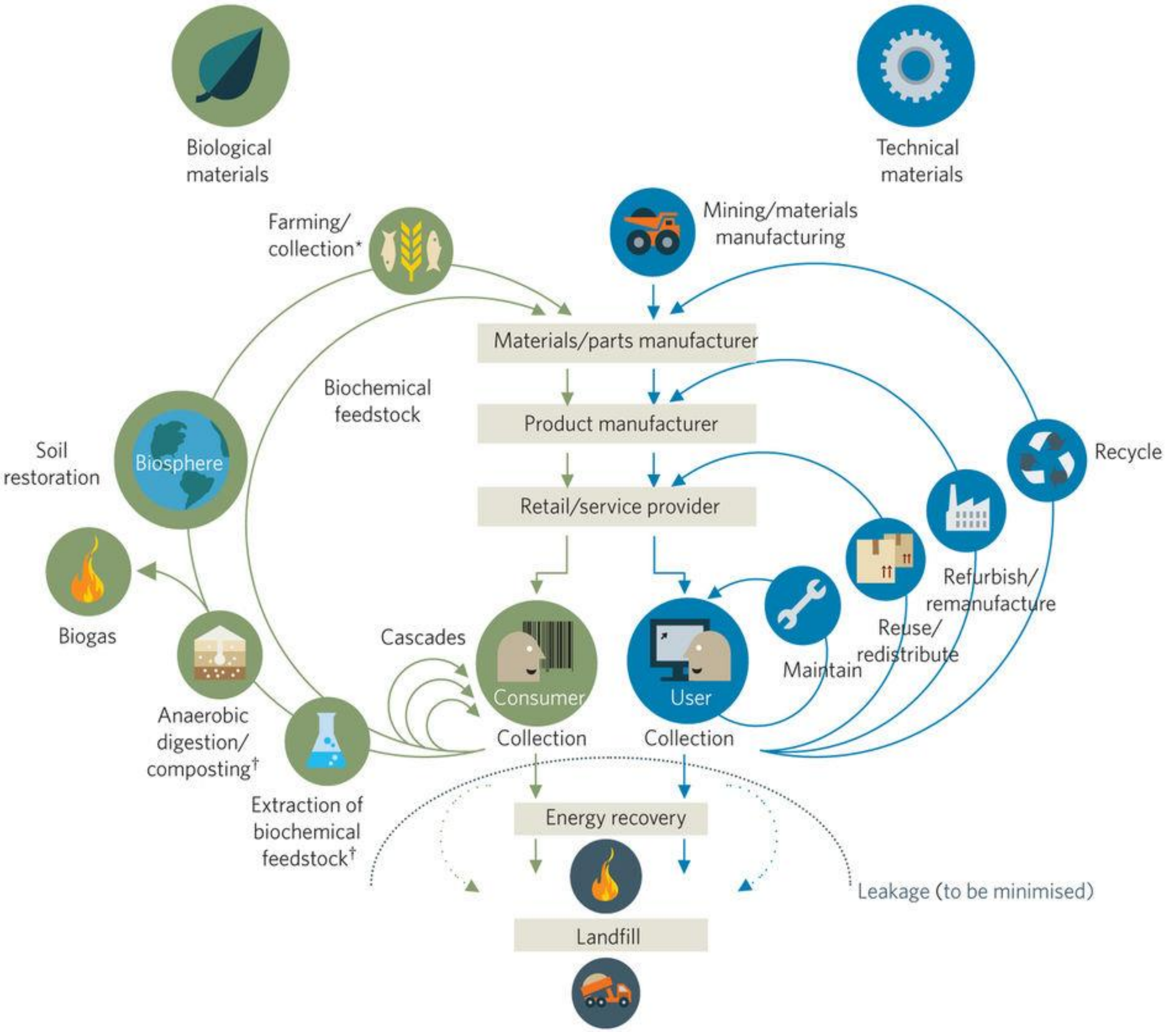
Optimize resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles.

This means designing for remanufacturing, refurbishing, and recycling to keep components and materials circulating in and contributing to the economy.

Principle 3: Foster system effectiveness

Foster system effectiveness by discovering and designing out negative externalities.

This includes reducing damage to human utility, such as food, mobility, shelter, education, health, and entertainment, and managing externalities, such as land use, air, water and noise pollution, release of toxic substances, and climate change.



Source: Ellen MacArthur Foundation; McKinsey Center for Business and Environment; Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN); Drawing from Braungart & McDonough, Cradle to Cradle (C2C)

Circular economy: business actions

The **Ellen MacArthur Foundation** has broadly identified a set of **six actions** that businesses and governments can take in order to foster the transition towards a circular economy: Regenerate, Share, Optimise, Loop, Virtualize, and Exchange – together, the ReSOLVE framework. The ReSOLVE framework offers businesses and governments a tool for generating circular strategies and growth initiatives.

REGENERATE

- Shift to renewable energy and materials.
- Reclaim, retain, and restore health of ecosystems.
- Return recovered biological resources to the biosphere.

LOOP

- Remanufacture products or components.
- Recycle materials.
- Digest anaerobically.
- Extract biochemicals from organic waste.

SHARE

- Share assets (e.g., cars, rooms, appliances)
- Reuse/second hand
- Prolong life through maintenance, design for durability, upgradability, etc.

VIRTUALISE

- Dematerialize directly (e.g., books, CDs, DVDs, travel)
- Dematerialize indirectly (e.g., online shopping)

OPTIMISE

- Increase product performance/efficiency.
- Remove waste in production and supply chain.
- Leverage big data, automation, remote sensing and steering.

EXCHANGE

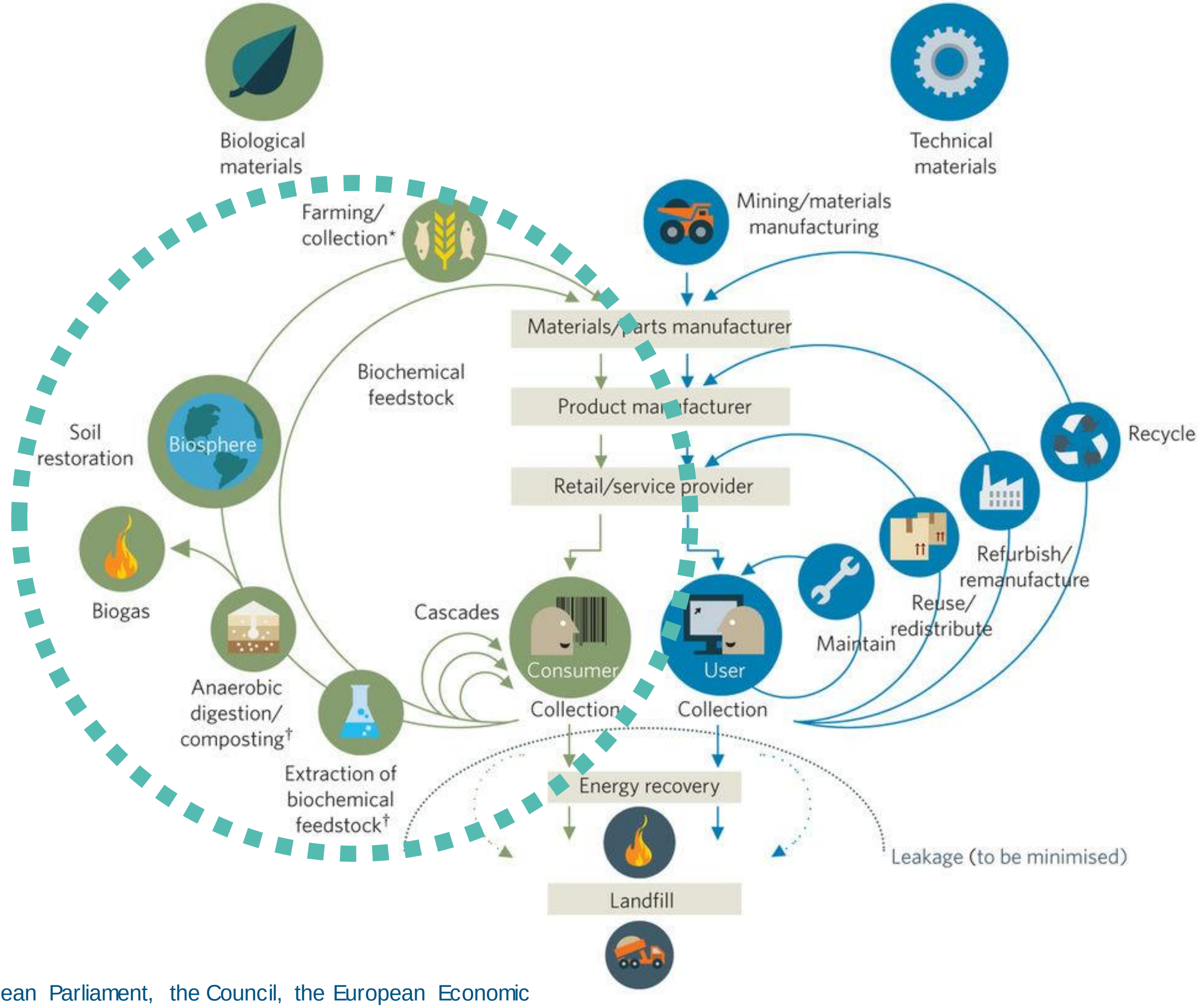
- Replace old with advanced non-renewable materials.
- Apply new technologies (e.g., 3D printing).
- Choose new products/services (e.g., multimodal transport).

Source: Growth Within: a circular economy vision for a competitive Europe", Ellen MacArthur Foundation, SUN, McKinsey & Co. (June 2015)

Bioeconomy

‘The bioeconomy […] encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products and bioenergy’.

The bioeconomy is the biological motor of the circular economy as it brings the renewability aspect into the cycle, puts carbon ‘back in the loop’, and brings additional dimensions to the circular economy discussion, moving beyond waste.



Source: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Bioeconomy for Europe, COM(2012) 60.

Bioeconomy: Europe's strategy

The threat: The global food crises of 2008 and 2011 were striking reminders of the importance of innovation in agriculture to address global challenges such as population growth as well as the consequences of climate change such as droughts.

The opportunity: A transition to the use of renewable resources, including the sustainable use of biomass, can contribute to reducing emissions and circumventing resource scarcity. A healthy bioeconomy is crucial for a successful and sustainable transition.

The role of the chemical sector: The chemical industry is exploring ways to create products -traditionally produced from fossil fuels- using biomass through novel value chains such as fermentation and biocatalysis. However, biomass availability is limited, which leads to potential competition for biomass between different biomass-consuming sectors.

The action plan: In order to support bioeconomy and bioeconomy-related policies, the European Commission's Bioeconomy Observatory collects and analyses data and information about bioeconomy.

Source: Innovating for sustainable growth, a bioeconomy for Europe (2012), European Commission.

Bioeconomy: European public & private initiatives

European Bioeconomy Strategy

The recently reviewed ‘Innovating for sustainable growth: a bioeconomy strategy for Europe’, launched and adopted on 13 February 2012, addresses the production of renewable biological resources and their conversion into vital products and bio-energy.

European Bioeconomy Alliance (EUBA)

The EUBA, a cross-sectoral alliance that aims to mainstream and release the potential of the bioeconomy in Europe, highlighted that bio-based feedstocks and materials can be used to produce a wide range of products. The EUBA emphasizes the importance of biorefineries, where biomass from a range of sources such as crops, wood, forest and agricultural residues is converted into everyday products and materials.

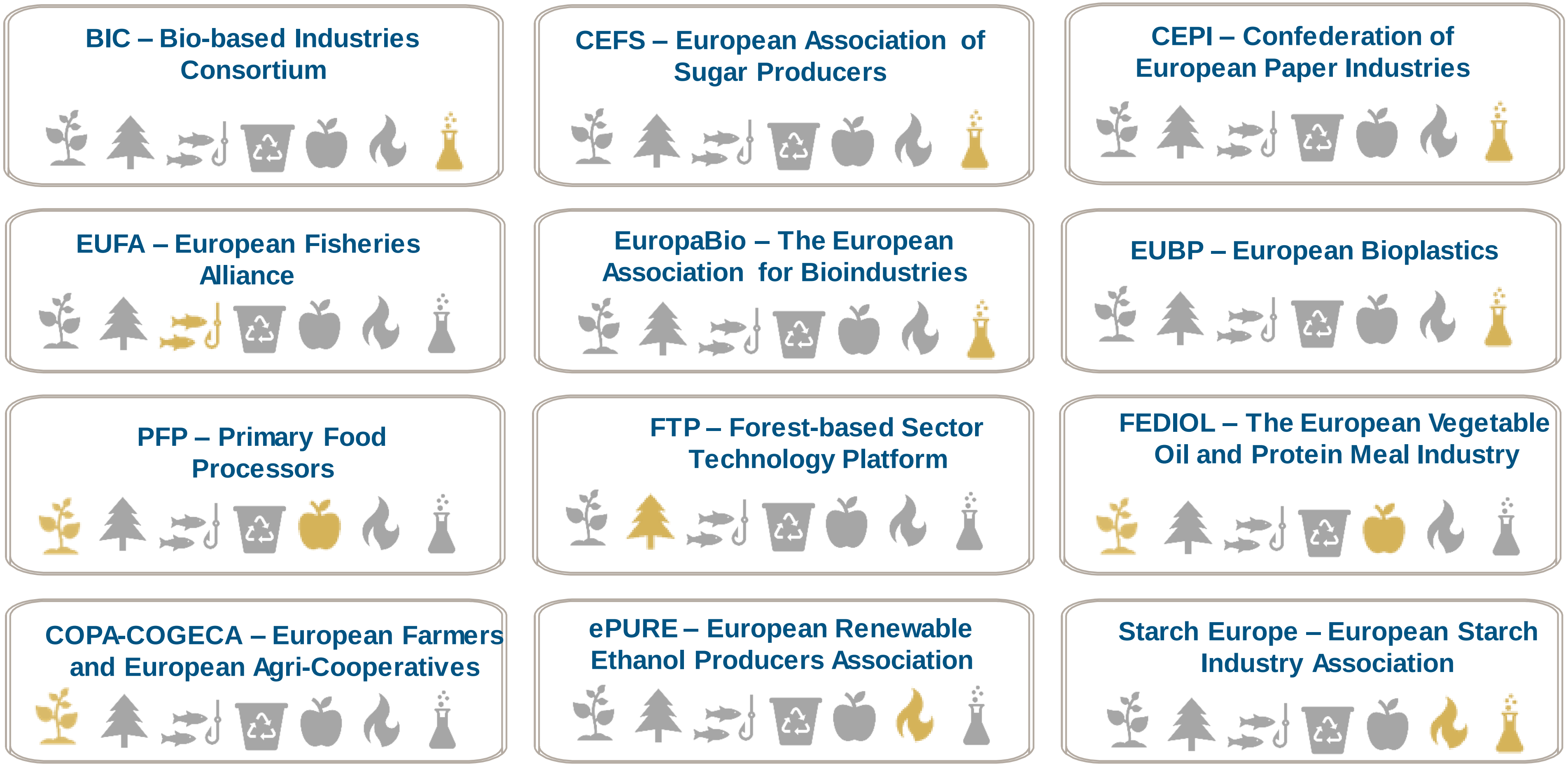
RoadToBio Project

The RoadToBio project focused on how globally competitive bio-based chemicals will help shape the future of the Europe’s chemical industry and help to secure jobs in Europe’s rural and less developed regions.

Bio-Based Industries Consortium

The Bio-Based Industries Joint Undertaking is a €3.7 billion Public-Private Partnership between the EU and the Bio-based Industries Consortium. Operating under Horizon 2020, it is driven by the Vision and Strategic Innovation and Research Agenda (SIRA) developed by the industry.

Bioeconomy: agents related to *RoadToBio* project



BIC – Bio-based Industries Consortium

CEFS – European Association of Sugar Producers

CEPI – Confederation of European Paper Industries

EUFA – European Fisheries Alliance

EuropaBio – The European Association for Bioindustries

EUBP – European Bioplastics

PFP – Primary Food Processors

FTP – Forest-based Sector Technology Platform

FEDIOL – The European Vegetable Oil and Protein Meal Industry

COPA-COGECA – European Farmers and European Agri-Cooperatives

ePURE – European Renewable Ethanol Producers Association

Starch Europe – European Starch Industry Association

Source:Roadmap for the Chemical Industry in Europe towards a Bioeconomy, RoadToBio.

Bioeconomy: EU policy strategies

The European Bioeconomy Strategy is supported by others actions and policies such as: Food 2030, Blue Growth, Bio-based products and processing policies, the Bioeconomy Knowledge Centre and the Bioeconomy Panel, an advisory body to give policy guidance. **The strategy actions are directed at sectors that supply Biomass** (agriculture, forestry, fisheries, waste, aquaculture and algae) **and sectors that use it** (food security, bioenergy and bio-based industries).

Sectors supplying biomass	EU policy strategies	Implications
Agriculture	○ 'The CAP towards 2020: meeting the food, natural resources and territorial challenges of the future' (EC 2010)	'**The agriculture, forestry, fisheries, aquaculture and algae sectors are the main suppliers of biomass.** The goals of these three sectors are very similar and all include sustainable and inclusive growth, stimulating innovation, the sustainable exploitation of resources, resource efficiency, rural development and climate change mitigation and adaptation.
Forestry	○ 'A new EU forest strategy: for forests and the forest-based sector' (EC 2013). ○ 'Multiannual implementation plan of the new EU forest strategy' (EC 2015).	
Fisheries, aquaculture and algae	○ 'Reform of the common fisheries policy' (EC 2011) ○ 'Blue growth: opportunities for marine and maritime growth' (EC 2012). ○ 'Strategic guidelines for the sustainable development of EU aquaculture' (EC 2013)	
Waste	○ 'Towards a circular economy: a zero waste programme for Europe' (EC 2014) ○ 'Closing the loop – An EU action plan for the circular economy' (EC 2015) ○ 'The role of waste-to-energy in the circular economy' (EC 2017)	A **further, increasingly important source of biomass is waste** coming from the agricultural, forestry and fisheries sectors, but also from other sources such as households or manufacturing.

Bioeconomy: EU policy strategies

Sectors using biomass	EU policy strategies	Implications
Food and feed	○ 'An EU policy framework to assist developing countries in addressing food security challenges' (EC 2010). ○ 'The EU approach to resilience: learning from food security crises' (EC 2012).	The bioeconomy strategy stresses the **need to reconcile the competition of different sectors** (food, feed and industrial uses) **for biomass.**
Bioenergy	○ 'Energy 2020 – A strategy for competitive, sustainable and secure energy' (EC 2010). ○ 'Energy roadmap 2050' (EC 2011). ○ 'A policy framework for climate and energy in the period from 2020 to 2030' (EC 2014). ○ 'Accelerating Europe's transition to a low-carbon economy' (EC 2016). ○ 'The role of waste-to-energy in the circular economy', (EC 2017).	**Bioenergy is expected to play an important role in achieving GHG emissions reduction goals.** To do so, investments in new renewable technologies are needed, such as ocean energy, concentrated solar power and second and third generation biofuels.
Bio-based industries (e.g Chemical Industry)	○ 'A stronger European industry for growth and economic recovery' (EC 2012). ○ 'For a European industrial renaissance' (EC 2014) ○ Future strategy on plastics use, reuse and recycling (EC 2016).	Priority should be given to granting access to sustainable raw materials for the production of bio-based products. This will require the application of the **cascade principle in the use of biomass.**

Bioeconomy: the link with the Chemical Sector

Bio-based industries

The bioeconomy offers an opportunity for the chemical industry to diversify its raw material base. The chemical industry's contribution is also critical for the success of bioeconomy as many bioeconomy-enabling products and solutions are based on chemicals.

The European chemical industry is gradually increasing its production, **integrating bio-based processes and the conversion of renewable biological resources and associated waste streams**. This marks a transition towards a more sustainable chemical industry.

Chemistry enables Bioeconomy

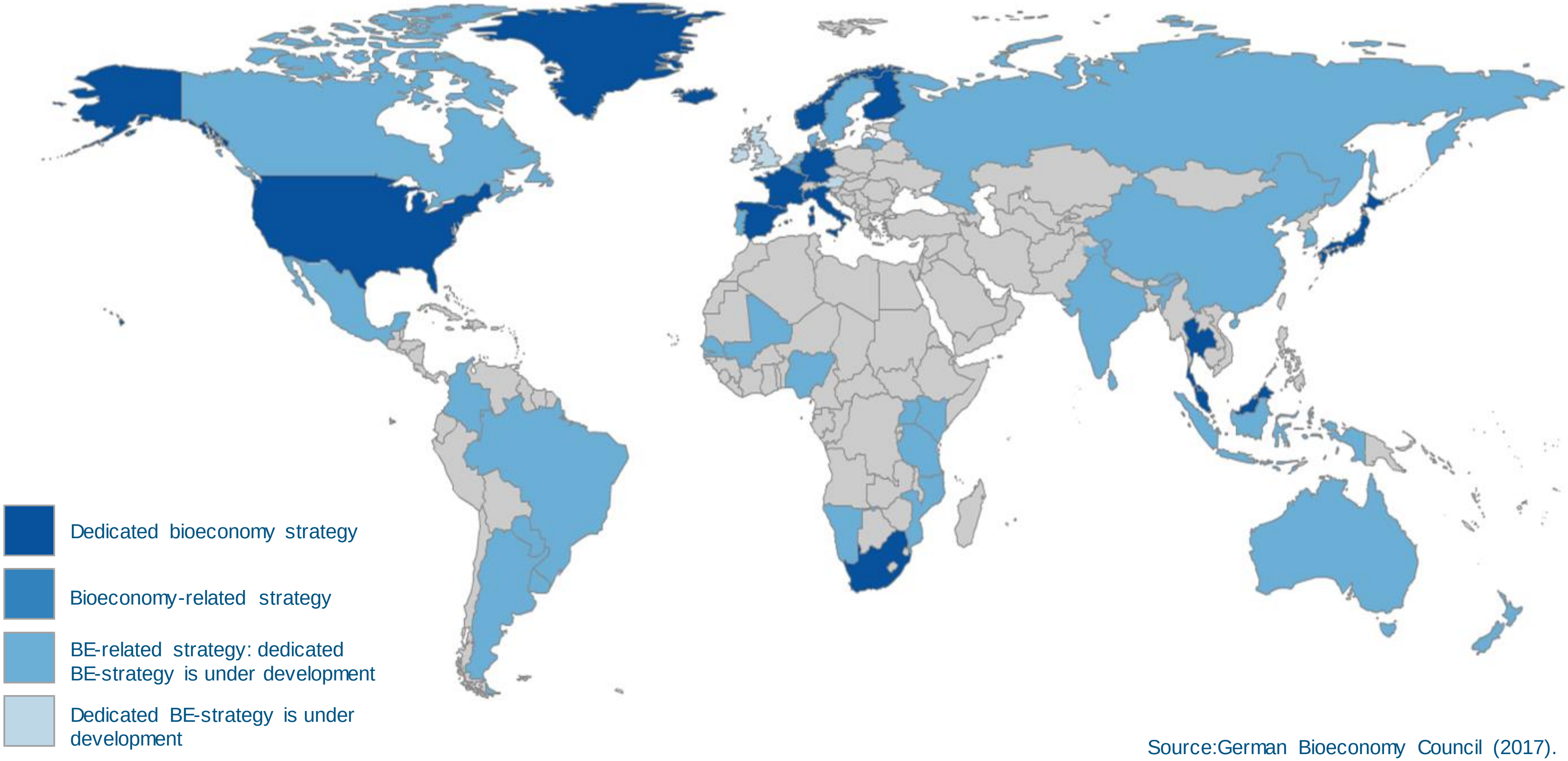
Utilization of bio-based raw materials	▪ Medicines, cosmetics, packings, paints, adhesives, chemicals, detergents, rubber products, ...
Processing of biofractions	▪ Tall oil products ▪ Bioethanol, renewable diesel, biogas, ...
Fracturation of biomasses	▪ Separation resins ▪ Chemicals and enzymes ▪ Micro-organisms
Cultivation of biomasses	▪ Fertilizers and nutrients ▪ Plant protecting agents
Recycling of bioproducts	▪ Bioreactors ▪ Composting

Source:RoadToBio.

3. Worldwide data

Worldwide data: bioeconomy

Bioeconomy policies around the world



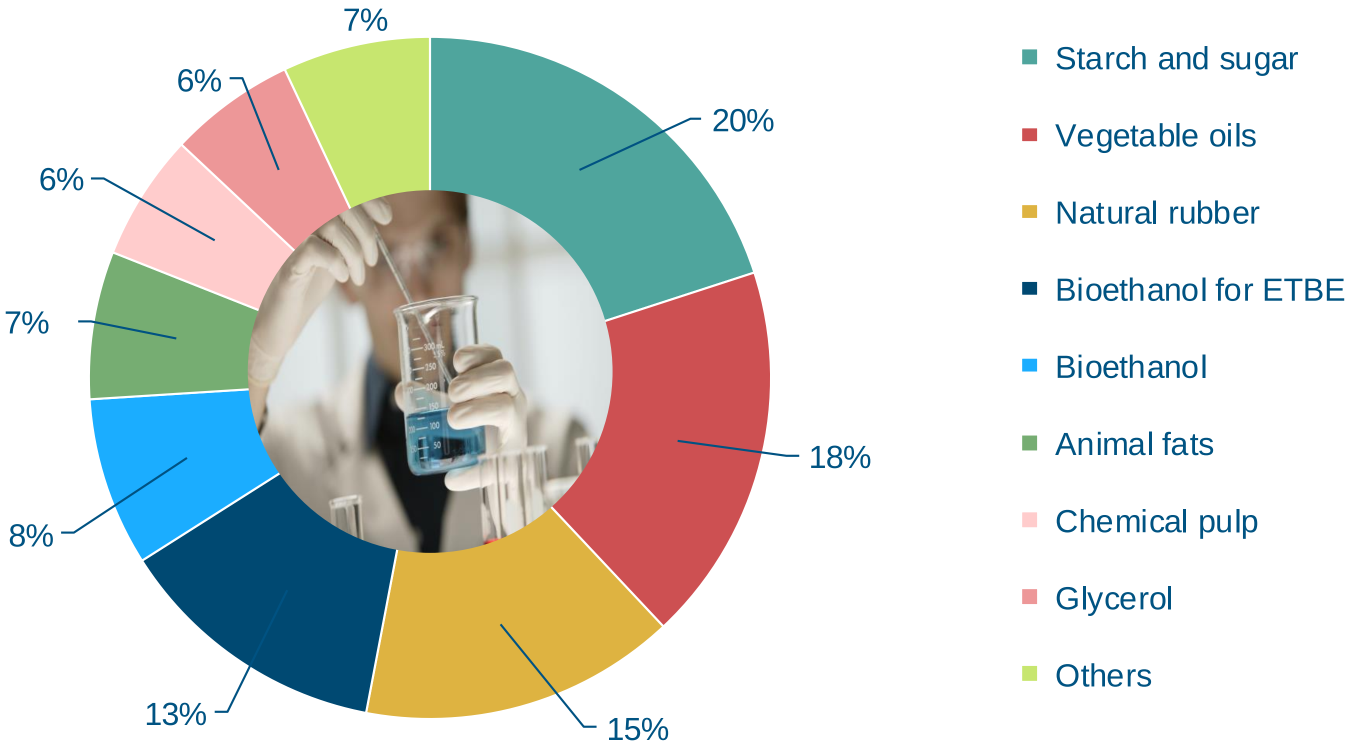
Source:German Bioeconomy Council (2017).

Worldwide data: bioeconomy

Bio-based raw materials use in the chemical industry

Bio-based chemical raw materials distribution in the EU

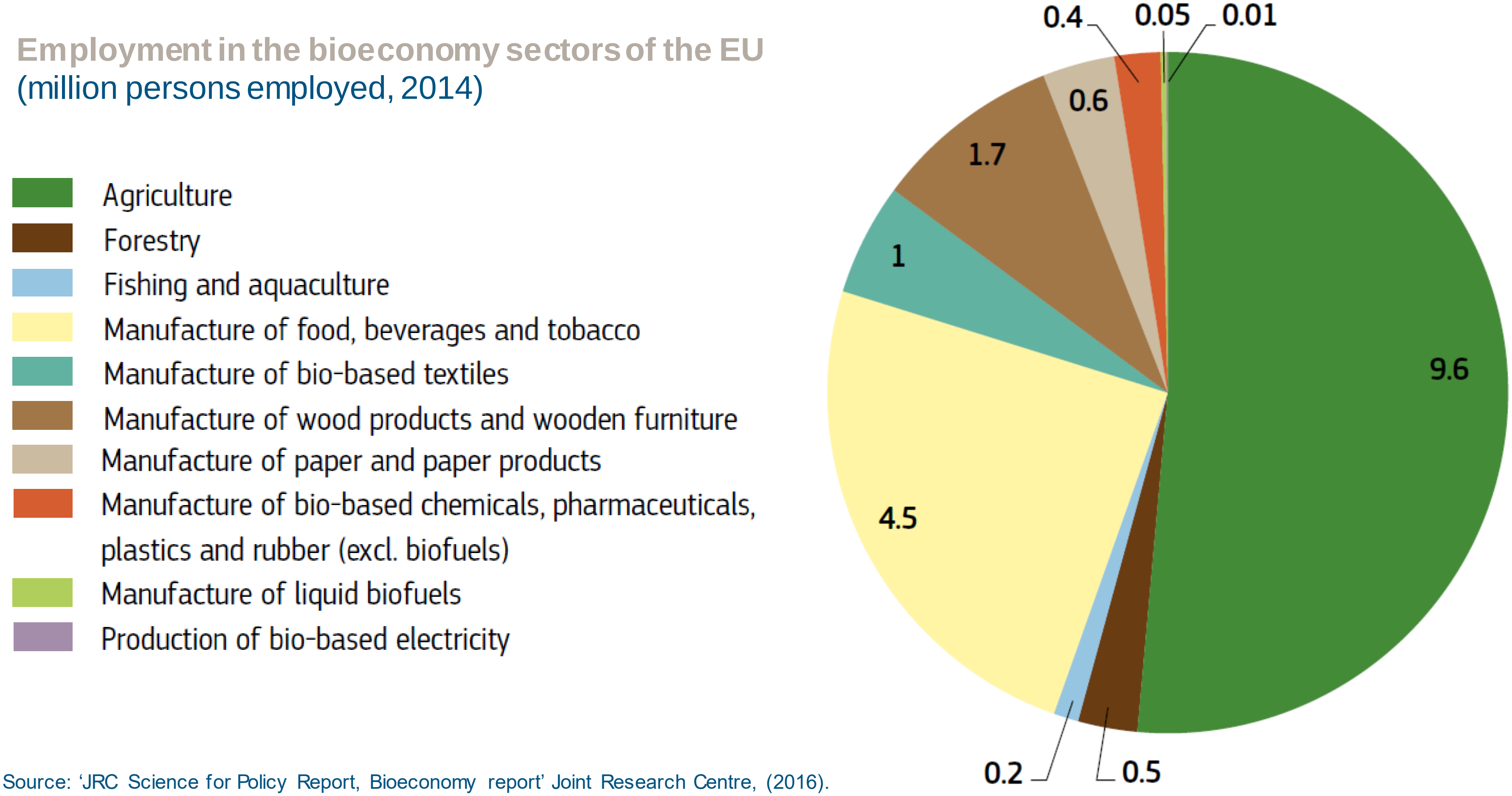
(As a percentage of total 7.8 million tonnes, 2016)



Source: Cefic Chemdata International, 2017.

Worldwide data: bioeconomy

Bioeconomy employment in Europe



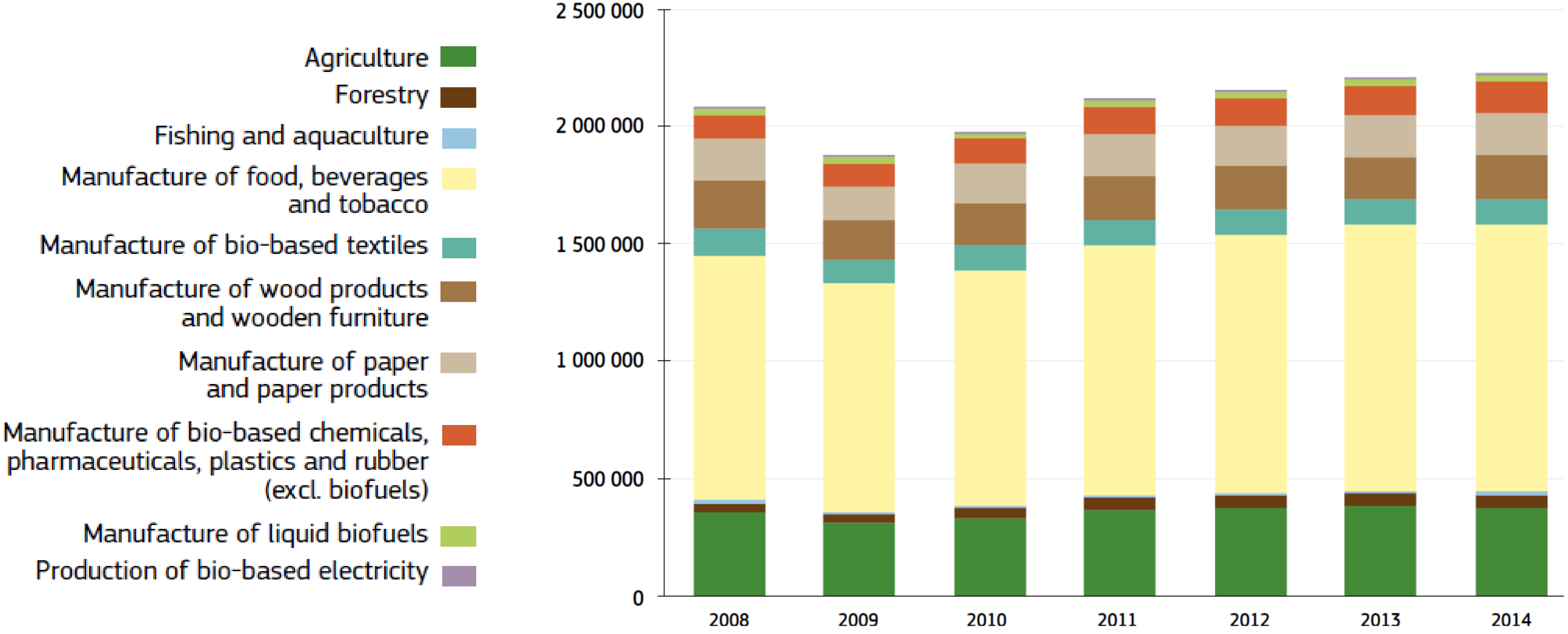
Employment in the bioeconomy sectors of the EU
(million persons employed, 2014)

Source: 'JRC Science for Policy Report, Bioeconomy report' Joint Research Centre, (2016).

Worldwide data: bioeconomy

Bioeconomy turnover in Europe

Development of sectorial turnovers in the EU bioeconomy
(in million EUR, 2008-2014)



Source: 'JRC Science for Policy Report, Bioeconomy report' Joint Research Centre, (2016).

Worldwide data: bioeconomy related demo-cases

(Waste) gas into value: Turning C1 gas streams (from biogas production, biomass gasification or industrial emissions) into chemicals or fuels. Ghent Bio-energy Valley (Belgium)

Bio Aviation Fuel: Promoting larger scale aviation biofuel production. Värmland – Paper Province (Sweden)

Biobased Aromatics: Interregional value chains and joint demonstration on biomass valorization to aromatics. Flanders – VITO (Belgium)

Production of bulk and fine chemicals and fuels from lignocellulose biomass: Set-up of a European value chain from lignocellulose to end products using biotechnology (refinery) Biobased Delta (Netherlands)

Food & Feed from Agrofood Waste: Extracting functional foods and feed from different waste streams, such as fish, domesticated animals and cereals. Scottish Enterprise (UK)

Lignocellulose Refinery - Biogas Beyond Energy: Advancing the state of the art of biogas production towards more and higher value added outputs. Lombardy – Green Chemistry Association (Italy)

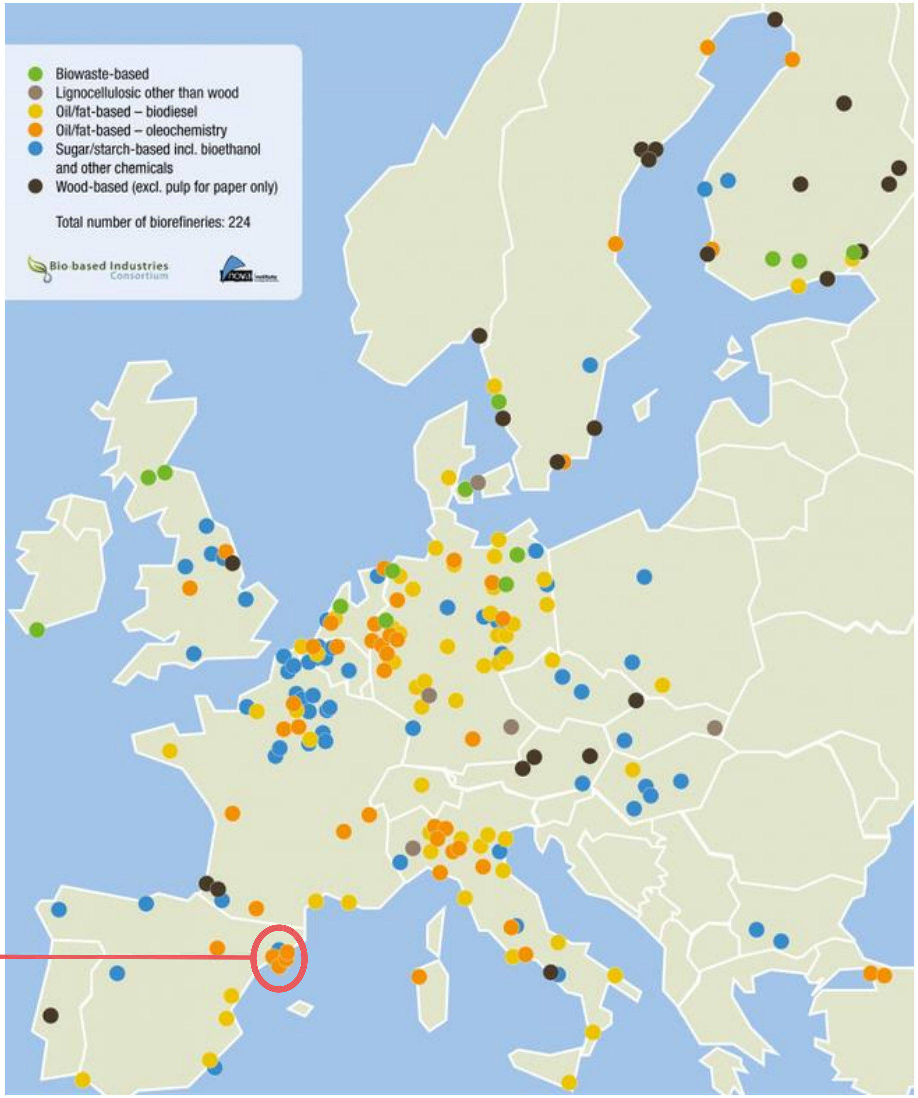
Food and Feed ingredients from Algae: Extraction of high value products from microalgae for the food & feed sector. Asturias (Spain)

Source: Vanguard Initiative (2016).

Worldwide data: chemical industry

Biorefineries in Europe

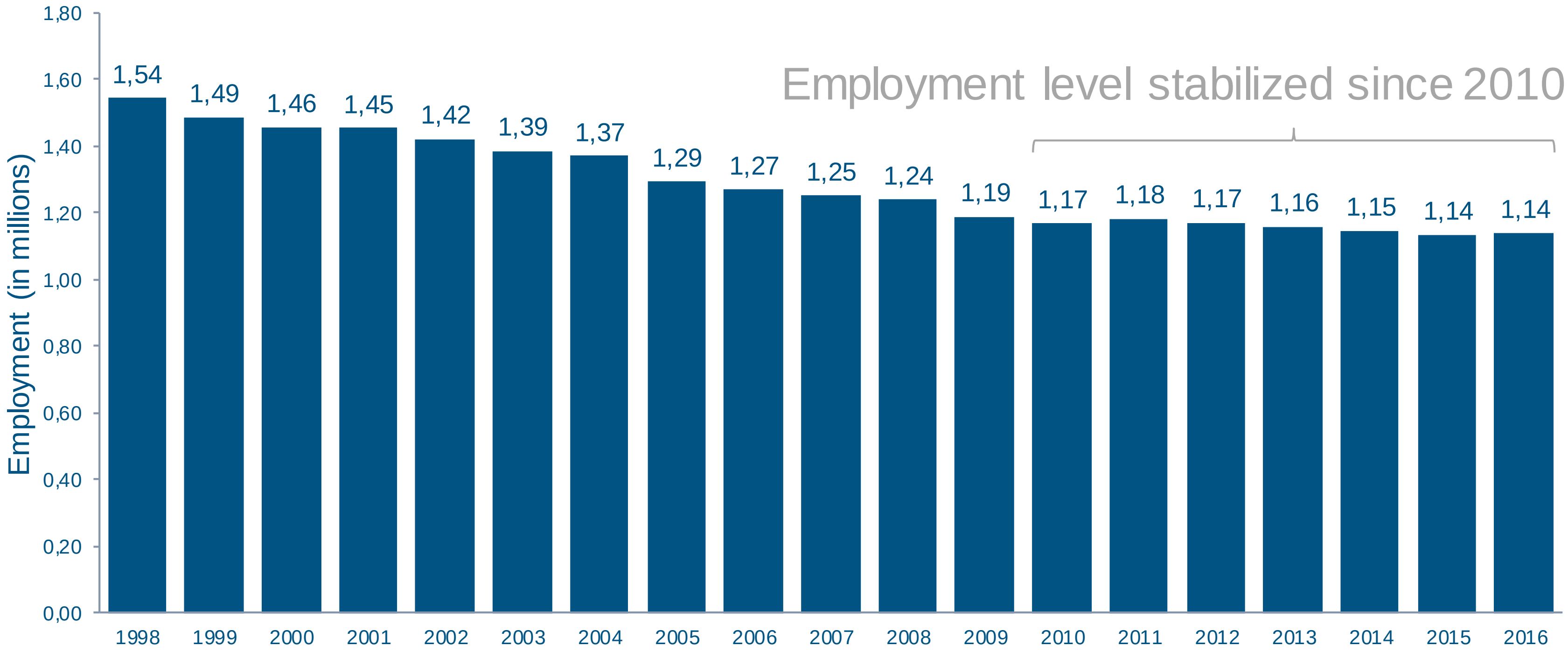
- The **chemical sector related to Bioeconomy depends on the existence of Biorefineries**.
- Biorefineries are processing facilities that convert biomass into food, food ingredients, feed, chemicals, materials, fuels and energy using a wide variety of conversion technologies in an integrated manner. **A common goal for biorefineries is to use all parts of the biomass raw material as efficiently as possible**.
- Therefore, the existence of Biorefineries is key for ensuring a **robust bio-based chemical industry in the region**.
- **Catalonia has a strong industrial oleochemistry and bioethanol network.**



Source: Bio Based Industries consortium (2017).

Worldwide data: chemical industry

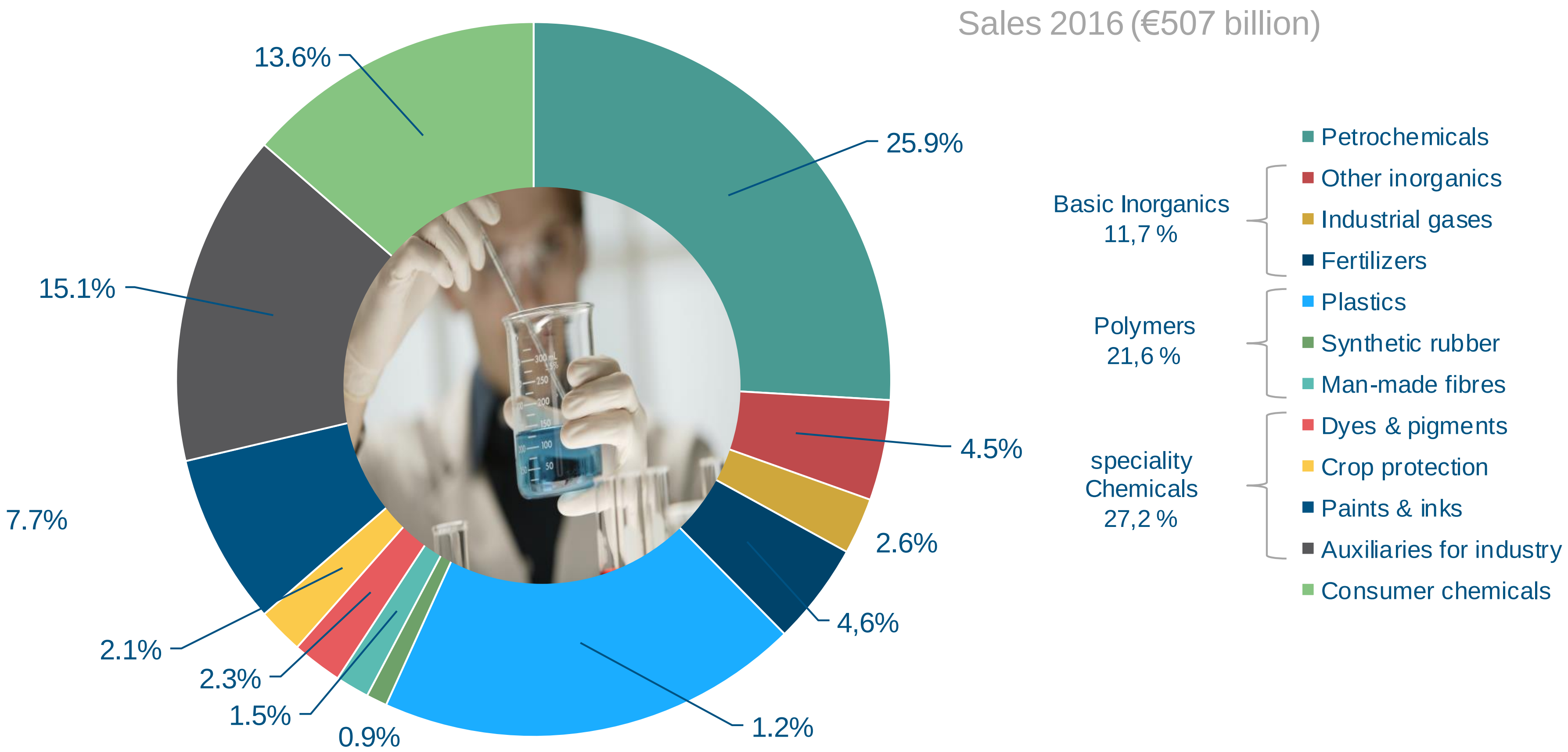
Employment in the EU chemical industry



Source: Cefic Chemdata International 2017.

Worldwide data: chemical industry

Petrochemicals and speciality chemicals account for half of the EU chemical sales

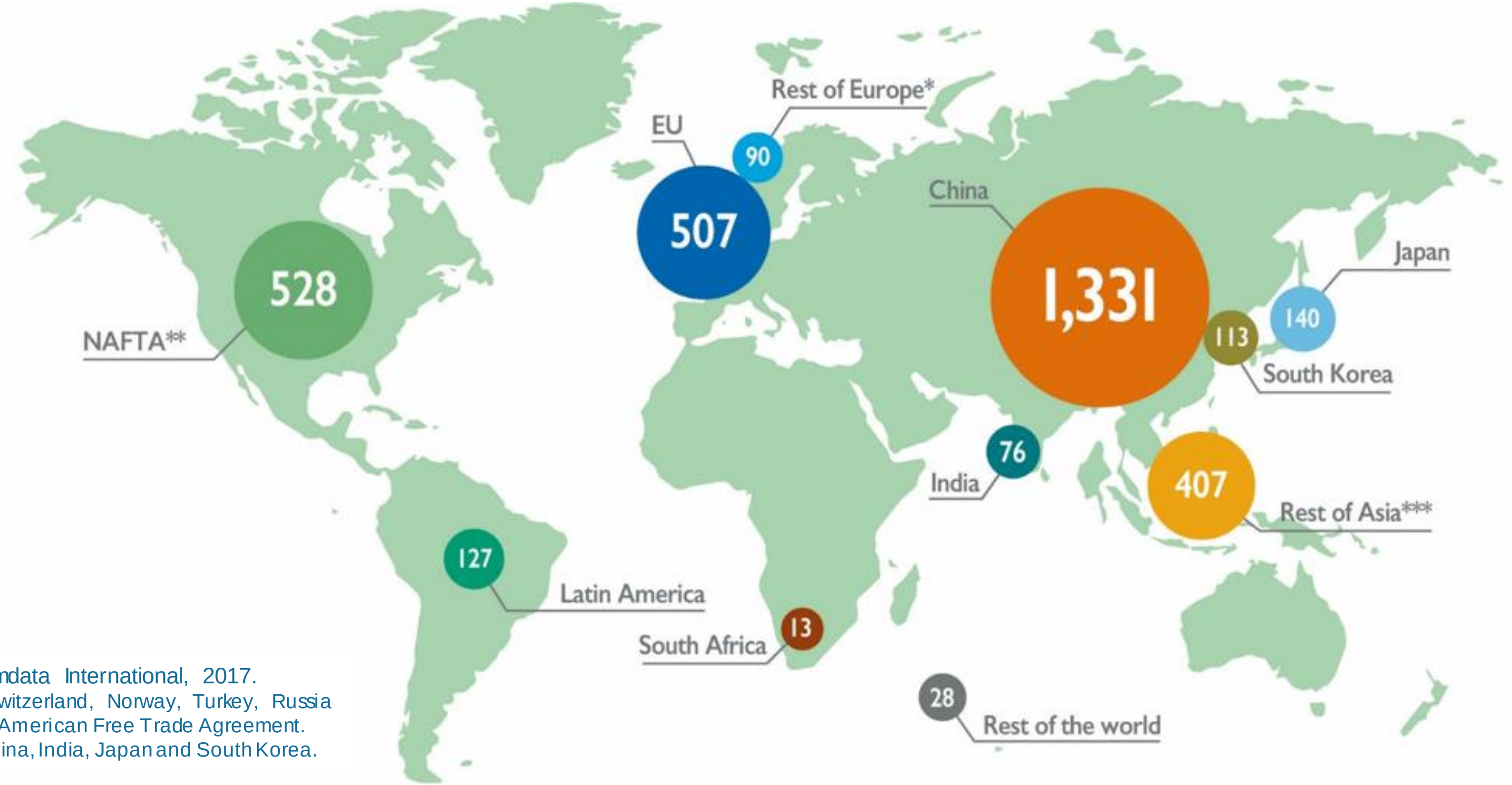


Source: Cefic Chemdata International, 2017.

Worldwide data: chemical industry

Asian Chemical production outpaces other regions

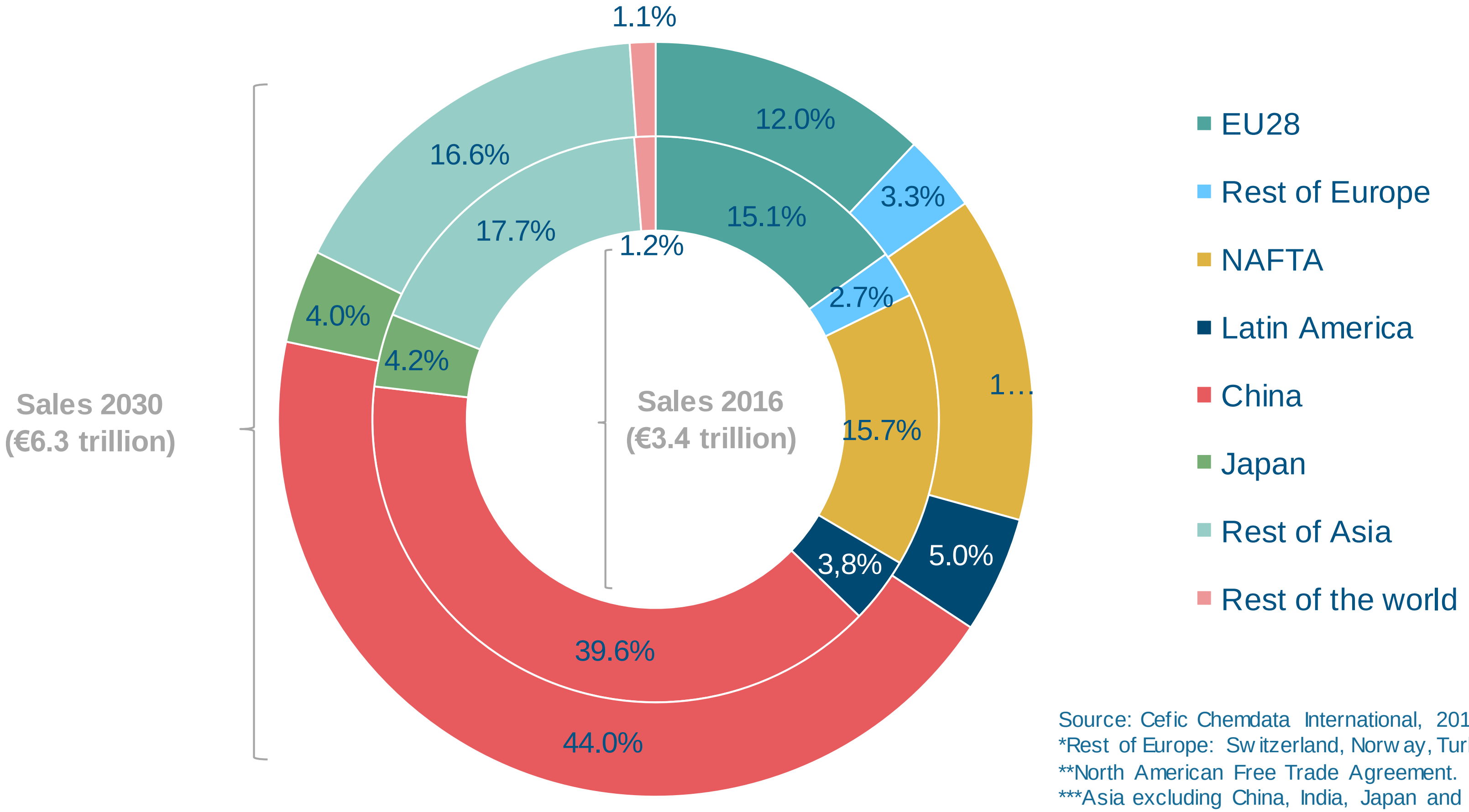
World total Chemical sales in 2016 (€3,360 billion)



Source: Cefic Chemdata International, 2017.
*Rest of Europe: Switzerland, Norway, Turkey, Russia and Ukraine.**North American Free Trade Agreement.
***Asia excluding China, India, Japan and South Korea.

Worldwide data: chemical industry

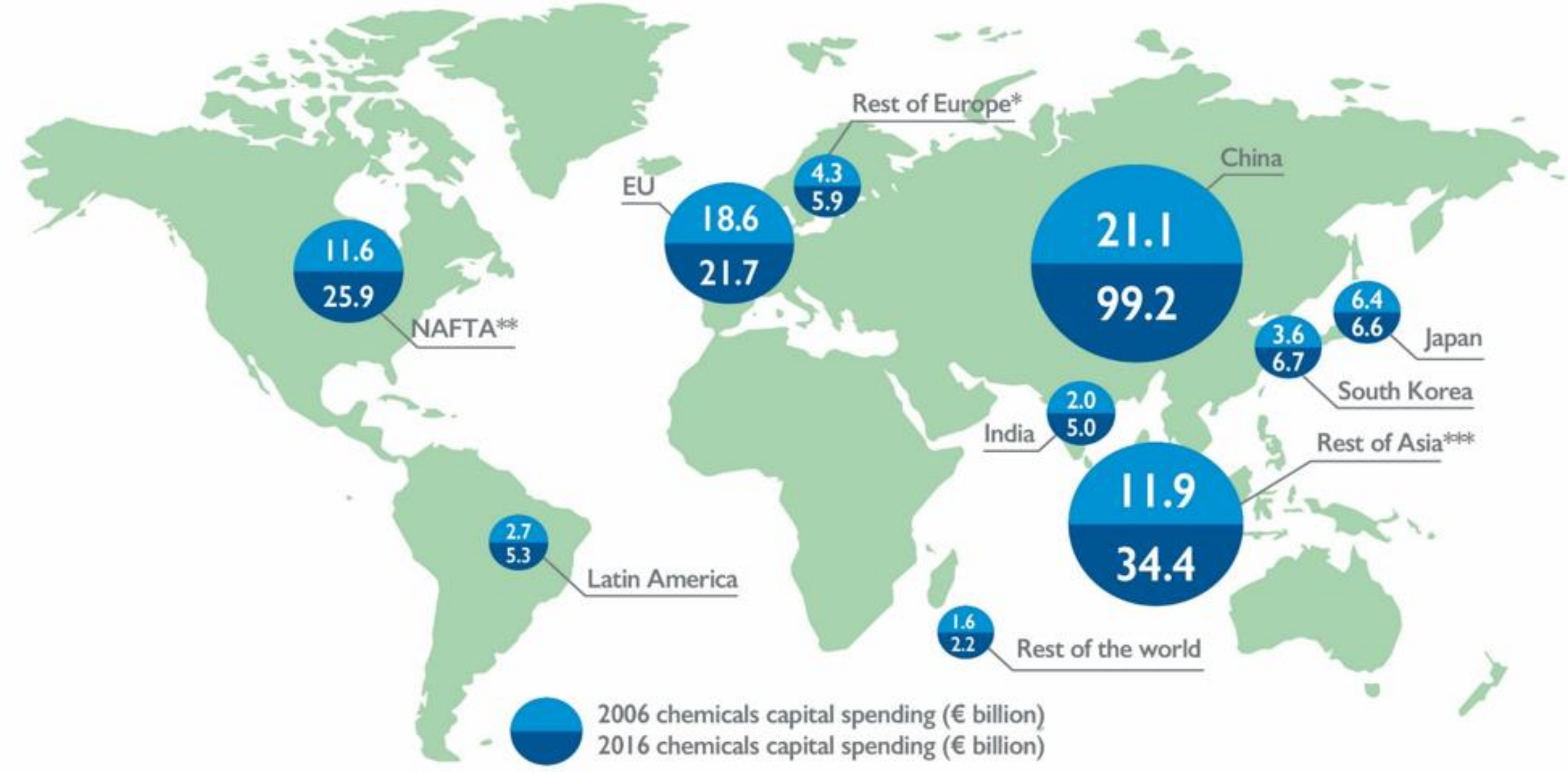
Asian Chemical production dominance is expected to continue



Source: Cefic Chemdata International, 2017.
*Rest of Europe: Switzerland, Norway, Turkey, Russia and Ukraine.
**North American Free Trade Agreement.
***Asia excluding China, India, Japan and South Korea.

Worldwide data: chemical industry

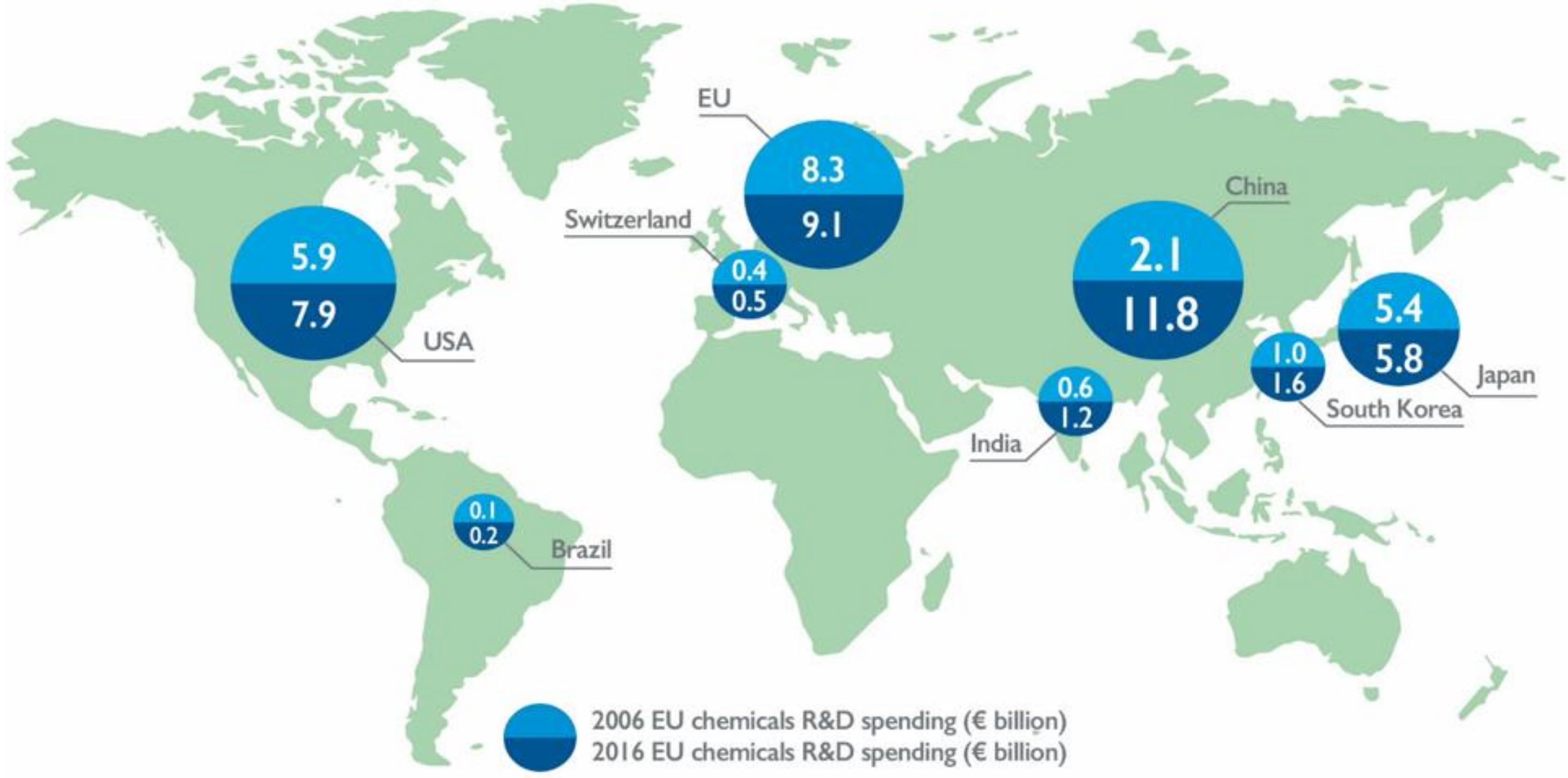
China dominates world chemicals investment, US spending surges ahead



Source: Cefic Chemdata International, 2017.

Worldwide data: chemical industry

China outspends industrial and emerging countries in chemicals R&D



Source: Cefic Chemdata International, 2017.

Worldwide data: chemical industry

26% growth potential for chemical products

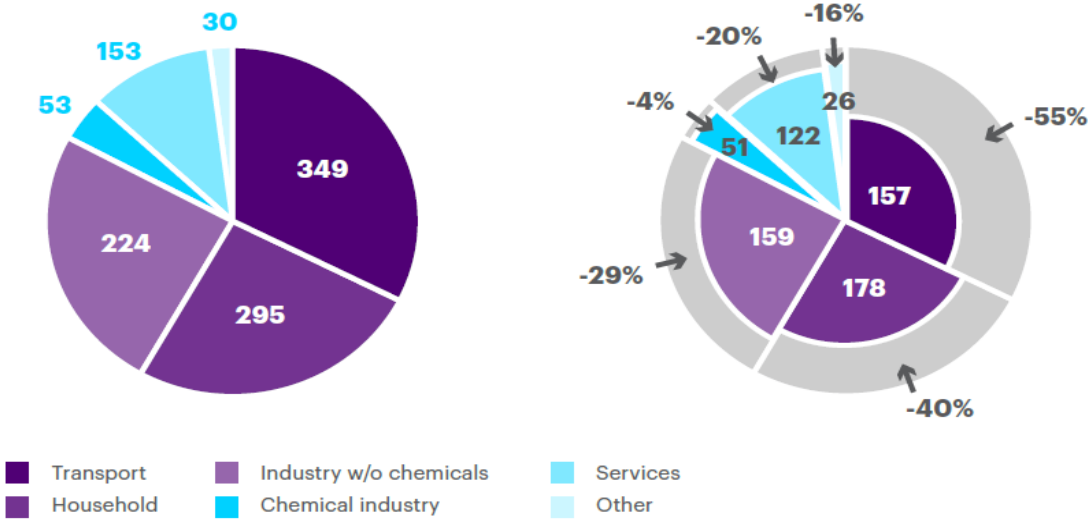
In spite of the reduced demand for some products that would result from the increased circulation of molecules, **overall demand for chemical products is likely to grow** -driven by the need for products that enable circularity downstream in the value chain.

The chemical industry is a supplier to almost every industry.

- It is in a position to enable circular economy models for its **downstream customers**.
- The chemical industry itself accounts for only approximately **5 percent of Europe's energy consumption,** but with its extended impact across industries, **chemicals could help reduce overall European energy consumption by up to 37 percent.**

Energy consumption in a 2030 circularity scenario (in Mtoe)

As-is: 1,104 Mtoe energy consumption | **37%** | **Circular scenario 2030: 693 Mtoe energy consumption**



Source: Accenture, 2017.

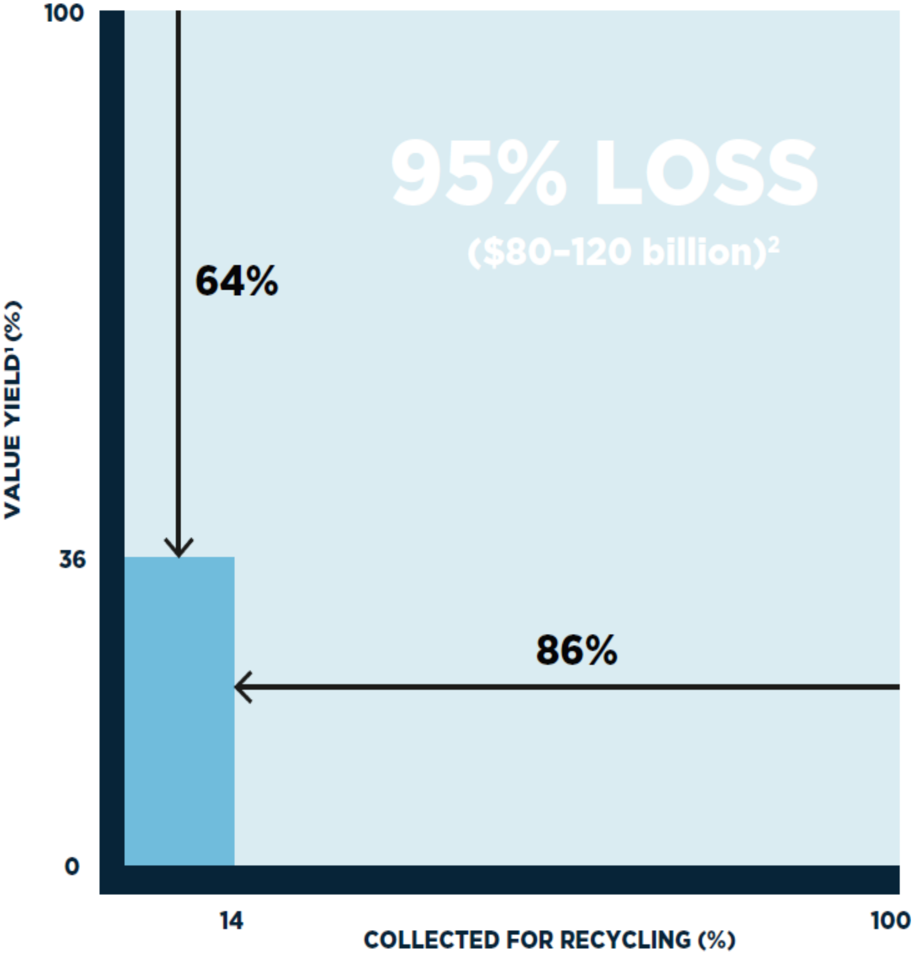
Worldwide data: chemical industry

Hazardous waste generated

- Hazardous waste is waste that can cause substantial threats to our health and the environment.
- More than 400 million tonnes are produced each year.
- 15% of all hazardous waste in the US is generated by the Chemical Industry. Extrapolating that percentage to the whole world, **the chemical industry's worldwide waste generation reaches 60 million tonnes every year.**

Polymers

- Today, 95% of plastic packaging material value or **$80–120 billion annually is lost** to the economy after a short first use.



[1] Value yield = volume yield * price yield, where volume yield = output volumes/input volumes.

Price yield = USD per tone of reprocessed material/USD per tone of virgin material.

[2] Current situation based on 14% recycling rate, 72% volume yield and 50% price yield. Total volume of plastic packaging of 78 Mt, given a weighted average price of 1,100–1,600 USD/t.

Source: World Economic Forum, 2016.

4. Trends

Trends | Potential shifts in the industry fundamentals

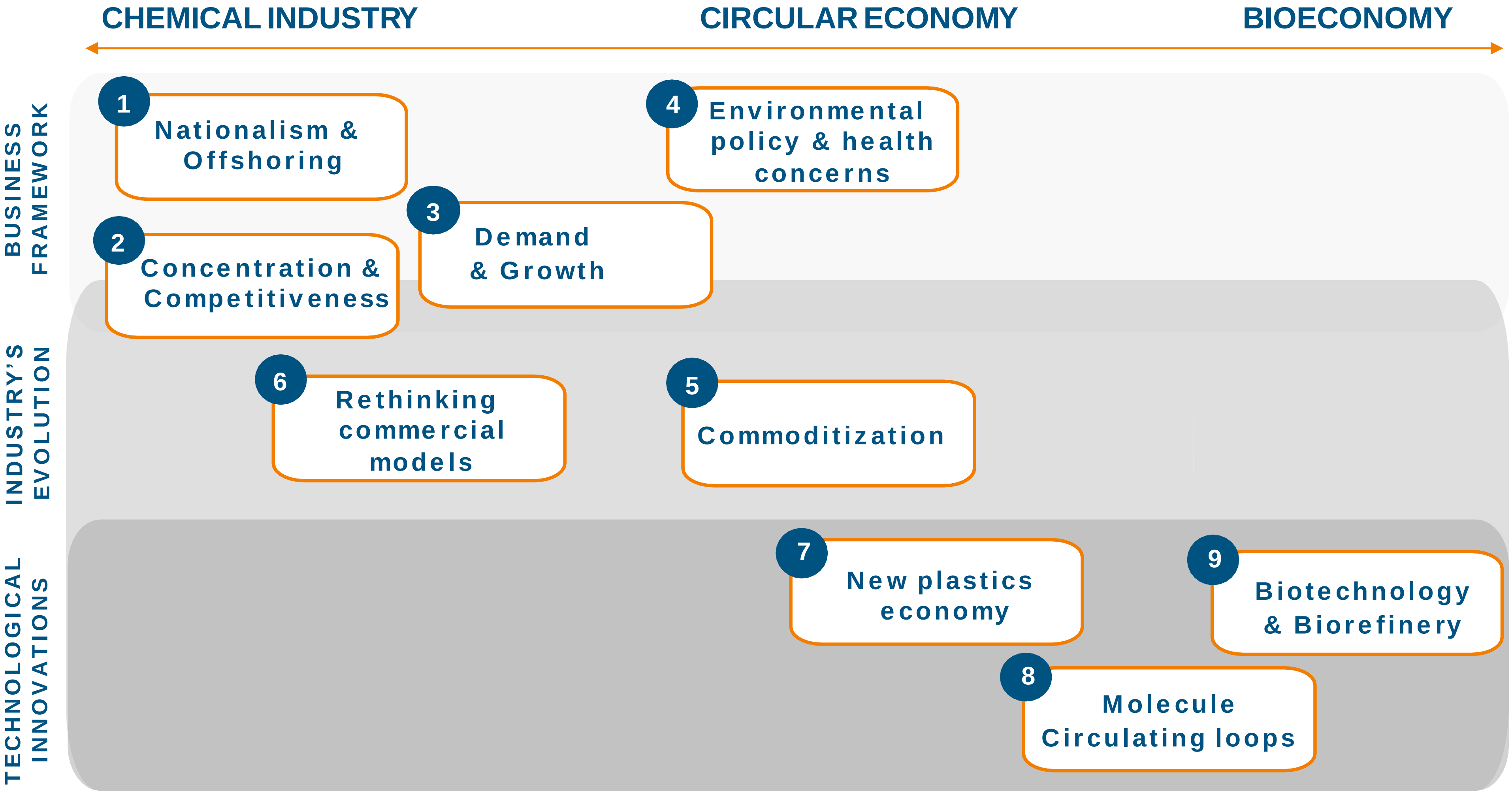
The chemical industry's strong performance during recent decades is closely linked to the following factors:

- Although the sector may look fragmented, two decades of portfolio restructuring have created a **highly concentrated industry structure** in many segments. This has put chemical companies in a **strong bargaining position relative to customers and suppliers**.
- Although their home markets were stagnated, **Western European and North American chemical companies have grown during the last two decades due to China's economic growth**. Since China's capacity could not be built fast enough to meet domestic demand, **chemicals had to be imported**.
- The chemical industry has a wide range of links with other industries, from manufacturing to healthcare. Thus, **the chemical sector is well positioned to benefit from many different trends** (e.g., sustainability, e-mobility, major changes in consumer behaviour, …)
- There are also some **events that have had a positive effect on the industry, such as the availability of stranded gas in the Middle East and shale gas in North America**, and the upward trend in many agricultural-commodity prices from 2000 to 2013.

How have these factors changed and how are they shaping the future of the industry?

Source: According to McKinsey & Company, 2017.

Trends



CHEMICAL INDUSTRY

CIRCULAR ECONOMY

BIOECONOMY

BUSINESS FRAMEWORK

1 Nationalism & Offshoring

2 Concentration & Competitiveness

3 Demand & Growth

4 Environmental policy & health concerns

INDUSTRY'S EVOLUTION

6 Rethinking commercial models

5 Commoditization

TECHNOLOGICAL INNOVATIONS

7 New plastics economy

9 Biotechnology & Biorefinery

8 Molecule Circulating loops

Trends | Business framework

1 Nationalism & Offshoring

CHEMCHINA
中国化工集团公司
China National Chemical Corporation

Nationalist markets: **Not only have the trade and investment policies of a number of emerging-market countries always been somewhat protective** (and may have become even more so recently**), but the US administration and Brexit appear to embrace a similar attitude**. In parallel with this resurgence of nationalism, state-owned enterprises (SOEs) are taking an increasing share in the chemical industry. **Private and listed companies may find it difficult to compete with SOEs, specially when it comes to the development of new technologies.**

Offshoring: **The imbalances in raw-material prices** (the cost of stranded and shale gas versus oil), **labour costs** (China versus developed economies), **or just regional mismatches in supply and demand** (China's growth) **resulted in a significant internationalization of the chemical industry in the past**, but given the context of oil prices moving to lower levels since 2014 and Chinese labour costs rising, it is fair to speculate that **this development might go into reverse in the coming years.**

Trends | Business framework

2 Concentration & Competitiveness

On the basis of total returns to shareholders (TRS), in the long term the chemical sector has outperformed not only the overall market but also most of its customer industries and raw-material suppliers. This strong performance is likely to change:

- **While the industry's 15-year performance still looks good**, a closer look at the past five years is less favourable: not only have chemicals lagged the total stock market since 2011 in TRS performance but the **industry's return on invested capital (ROIC) performance has flattened**, and for some chemical subsectors, decreased.

- **The industry is finding it increasingly difficult to hold onto the benefits of its productivity-improvement efforts**, despite of the fact that the implementation of digital approaches and modern analytics are creating new opportunities to increase productivity. Thus, the **decrease in productivity** might be a consequence of increasing competitiveness.

- **The industry's structure is increasingly concentrated:** During the last decade many segments of the industry have been increasingly competitive due to the **large number of new entrants**, mostly Chinese. Besides, **overcapacity** in some product areas is hampering productivity improvements. In the last year, the industry seems to be leaning towards new waves of M&A in order to gain market dominance and greater economies of scale.

Source: According to McKinsey & Company, 2015 and 2017.

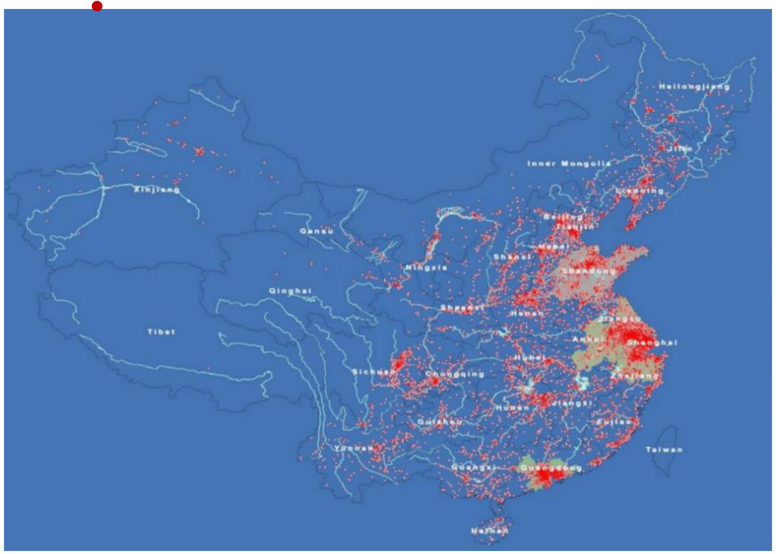
Trends | Business framework

3 Demand & Growth

Decrease in Chinese demand: Both global demand (led by China) and the Chinese GDP growth rate are declining and the trend seems to be downward. **China has moved from its investment stage -**built up infrastructure across the country while much of its population has equipped itself with new homes, consumer durables, automobiles, and other possessions- **to an economy characterized rather by services and "upgrades," which provide far less demand for chemicals.**

Less growth: McKinsey & Company (2017) estimates that the last decade's 3.6 percent **growth rate for petrochemicals may decrease** by between 0.5 and 2.0 percentage points over the next ten years, depending on assumptions for regional GDP growth. **Other sectors are likely to see similar reductions in growth rates - although the growth in overall chemical demand will continue to outpace GDP**. In agrochemicals, for example, changes in diet as well as the potential to tap enormous productivity reserves in the existing food chain could suppress overall chemical demand. In terms of growth, experts from McKinsey argue that Chinese supply needs broad and drastic consolidation.

Chemical companies stablished in China



Source: Greenpeace, 2016

Trends | Business framework

4 Environmental policy & health concerns

- **Environmental and health concerns:** Governments and corporations are being pushed both from within and without by activists and consumers to pay more attention to the maintenance of our natural resources and the impact of chemicals on our health.
- **Innovation constraints:** Public awareness is exerting pressure on many of the day-to-day actions routinely undertaken by corporations, government and non-profit agencies. The uncertainty of the impact of chemicals on the environment and our **health might hamper the most ambitious and innovative investments in the industry**.
- **Towards a non-toxic environment strategy:** The 7th Environment Action Programme (7th EAP), mandated the **European Commission to develop by 2018 "a Union strategy for a non-toxic environment** that is conducive to innovation and the development of sustainable substitutes including non-chemical solutions."
- **Plastics:** Since plastics consume the majority of petrochemical products, there is potentially an industry-wide impact. Future environmental policies consider reducing the use of plastics in many aspects and there is no consensus concerning how plastics affect public health. Given the sector's rather low forecast growth rates, **such regulation could potentially result in a scenario in which the need for plastic would not only stop growing but might even** (though not in the short term) **shrink**.
- **"No data, no market":** REACH (EC 1907/2006) aims to improve the protection of human health and the environment through **better and earlier identification of the intrinsic properties of chemical substances**. This is carried out by the four processes of REACH, namely the registration, evaluation, authorization and restriction of chemicals. The Regulation also calls for the **progressive substitution of the most dangerous chemicals** (referred to as "substances of very high concern") **when suitable alternatives have been identified**. The REACH Regulation **places responsibility on industry to manage the risks from chemicals** and to provide safety information on the substances.

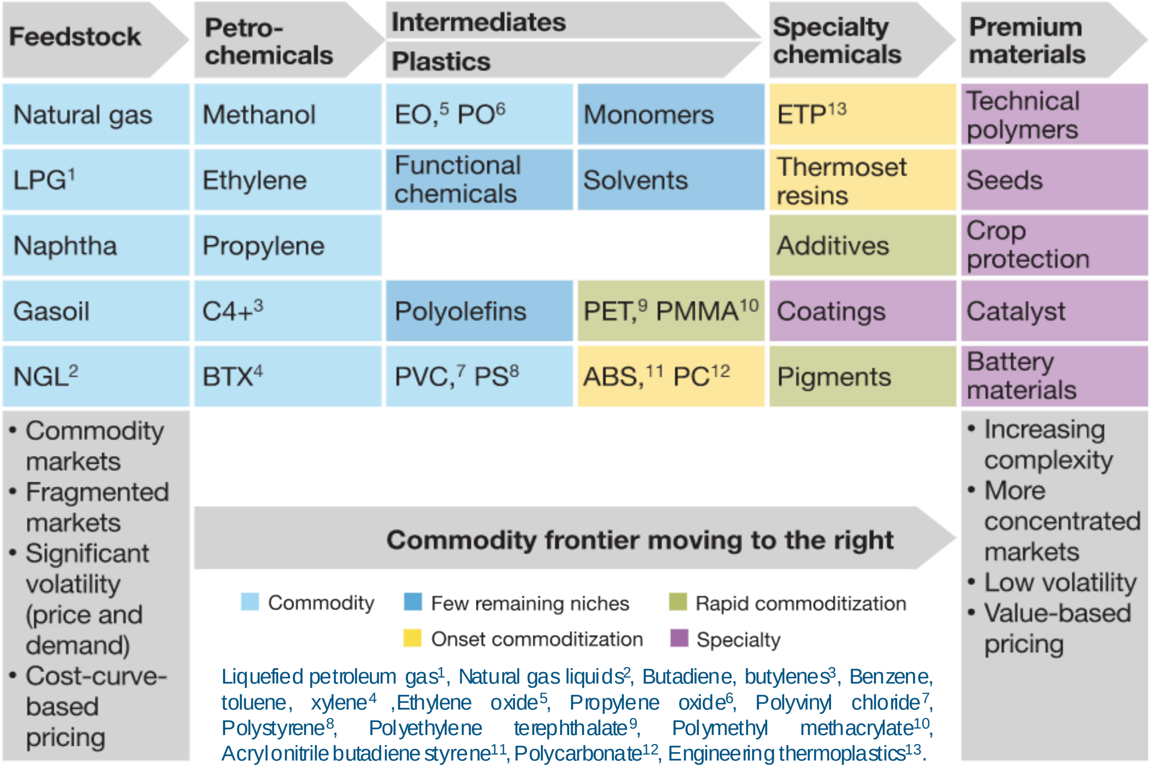
Trends | Industry evolution

5 Commoditization

Chemical companies are facing a progressively harsher environment as **growing segments of the industry are becoming increasingly commoditized**.

According to McKinsey (2017), **production technology for chemicals has become more broadly available, and there has been a rapid build-up of capacity, particularly in emerging markets**.

The commodity frontier continues to move to the right



Feedstock	Petro-chemicals	Intermediates Plastics		Specialty chemicals	Premium materials
Natural gas	Methanol	EO,[5] PO[6]	Monomers	ETP[13]	Technical polymers
LPG[1]	Ethylene	Functional chemicals	Solvents	Thermoset resins	Seeds
Naphtha	Propylene			Additives	Crop protection
Gasoil	C4+[3]	Polyolefins	PET,[9] PMMA[10]	Coatings	Catalyst
NGL[2]	BTX[4]	PVC,[7] PS[8]	ABS,[11] PC[12]	Pigments	Battery materials

- Commodity markets
- Fragmented markets
- Significant volatility (price and demand)
- Cost-curve-based pricing

Commodity frontier moving to the right

- Increasing complexity
- More concentrated markets
- Low volatility
- Value-based pricing

Commodity · Few remaining niches · Rapid commoditization · Onset commoditization · Specialty

Liquefied petroleum gas[1], Natural gas liquids[2], Butadiene, butylenes[3], Benzene, toluene, xylene[4] ,Ethylene oxide[5], Propylene oxide[6], Polyvinyl chloride[7], Polystyrene[8], Polyethylene terephthalate[9], Polymethyl methacrylate[10], Acrylonitrile butadiene styrene[11], Polycarbonate[12], Engineering thermoplastics[13].

Source: McKinsey & Company, 2017.

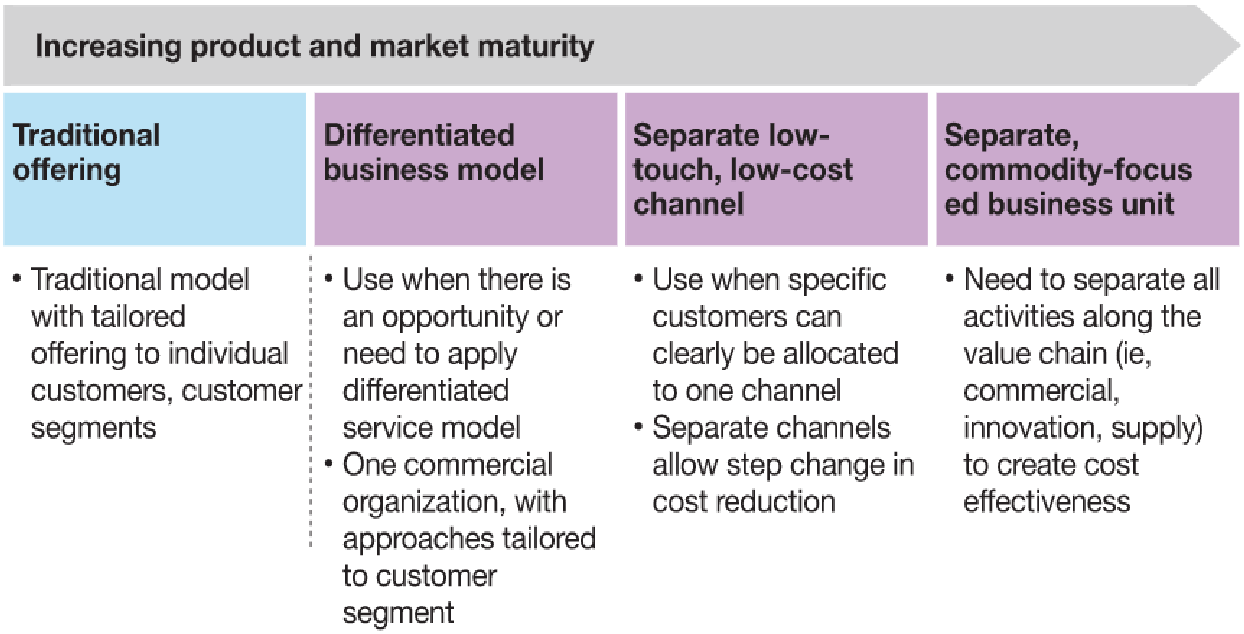
Trends | Industry evolution

6 Rethinking commercial models

Nowadays **the type of engagement with customers is different** from that of a traditional chemical producer, which would have originally developed a chemical to meet its customer's need: **Now products are simply sold on price due to commoditization.**

The new market reality requires an overhaul of models for marketing and sales. **Companies that are able to align their commercial business models with the market environment can harness a substantial payback**. Apart from the traditional commercial structure, others have been proved to be not only appropriate, but necessary.

Different approaches are available to serve different commercial requirements



Increasing product and market maturity

Traditional offering	**Differentiated business model**	**Separate low-touch, low-cost channel**	**Separate, commodity-focused business unit**
• Traditional model with tailored offering to individual customers, customer segments	• Use when there is an opportunity or need to apply differentiated service model • One commercial organization, with approaches tailored to customer segment	• Use when specific customers can clearly be allocated to one channel • Separate channels allow step change in cost reduction	• Need to separate all activities along the value chain (ie, commercial, innovation, supply) to create cost effectiveness

Source: McKinsey & Company, 2017.

Trends | Technological innovations

7 New plastics and textiles economy

Examples of Promising Enabling Technologies for the New Plastics Economy and their Level of Maturity

Source: World Economic Forum, (2016) The New Plastics Economy: Rethinking the future of plastics

Innovation	Description	Current state
Removing additives	Separating additives from recovered polymers to increase recyclate purity	Lab stage: Some technologies exist but with limited application.
Reversible adhesives	Recycling multi-material packaging by designing “reversible” adhesives that allow for triggered separation of different material layers.	Conceptual stage: Innovation needed to develop cost-competitive adhesive.
Super-polymer	Finding a super-polymer that combines functionality and cost with superior after-use properties.	Conceptual stage: Innovation needed to develop cost-competitive polymer with desired functional and after-use properties.
Depolymerization	Recycling plastics to monomer feedstock (building blocks) for virgin-quality polymers.	Lab stage: Proven technically possible for polyolefins. Limited adoption: Large scale adoption of depolymerization for PET hindered by processing costs.
Chemical markers	Sorting plastics by using dye, ink or other additive markers detectable by automated sorting technology.	Pilot stage: Food-grade markers available but unproven under commercial operating conditions.

Trends | Technological innovations

7 New plastics and textiles economy

Examples of Promising Enabling Technologies for the New Plastics Economy and Their Level of Maturity

Source: World Economic Forum, (2016) The New Plastics Economy: Rethinking the future of plastics

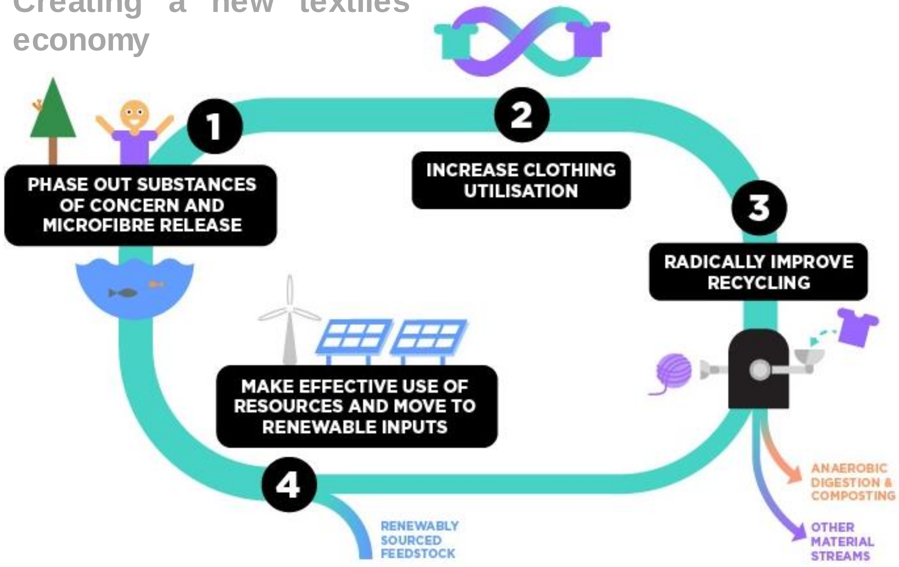
Innovation	Description	Current state
Near infrared	Sorting plastics by using automated optical sorting technology to distinguish polymer types.	Fragmented adoption: Large scale adoption limited by capex demands.
Benign in marine environments	Design plastics that are less harmful to marine environments in case of spill.	Lab stage: First grades of marine degradable plastics (one avenue towards benign materials) already certified as marine degradable - impact of large scale adoption to be proved.
Benign in fresh water	Design plastics that are less harmful to fresh water environments in case of spill.	Lab stage: Marine degradable plastics theoretically fresh water degradable. One certified product - impact of large scale adoption to be proved.
GHG-based	Sourcing plastics from carbon in greenhouse gases released by industrial or waste management processes.	Pilot stage: CO_2-based proved cost competitive in pilots; methane-based being scaled up to commercial volumes.
Bio-based	Sourcing plastics from carbon in biomass.	Limited adoption: Large scale adoption hindered by limited economies of scale and sophistication of global supply chains.

Trends | Technological innovations

7 New plastics and textiles economy

It is estimated that more than **half of fast fashion production is disposed of in under a year**, and one refuse lorry full of textiles is landfilled or burnt every second. This factor combined with a very low rate of recycling - less than 1% of material used - leads to ever-expanding pressure on resources. The vision of the report **'A new textiles economy'** drafted by the Ellen Macarthur Foundation, hinges around four ambitions that would harness opportunities missed by the current linear textiles system:

Creating a new textiles economy



- **Phase out substances of concern and microfibre release**, by aligning industry efforts and coordinate innovation to create safe material cycles.
- **Transform the way clothes are designed**, sold and used to break free from their increasingly disposable nature, by scaling up clothing rental schemes; making durability more attractive; and increasing clothing utilization through brand commitments and policy.
- **Radically improve recycling** by transforming clothing design, collection and reprocessing; pursuing innovation to improve the economics and quality of recycling;
- **Make effective use of resources and move to renewable inputs.**

Source: Ellen Macarthur Foundation, (2017) A New Textiles Economy: Redesigning fashion's future

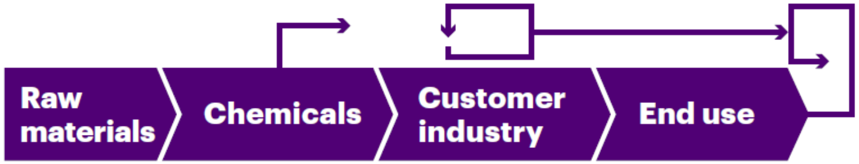
Trends | Technological innovations

8 Molecule circulating loops

According to Accenture (2017), to understand the impact that the circular economy could have on the chemical industry, it is useful to look at the issue **from two perspectives: circulating molecules and enabling the circular economy in downstream industries.**

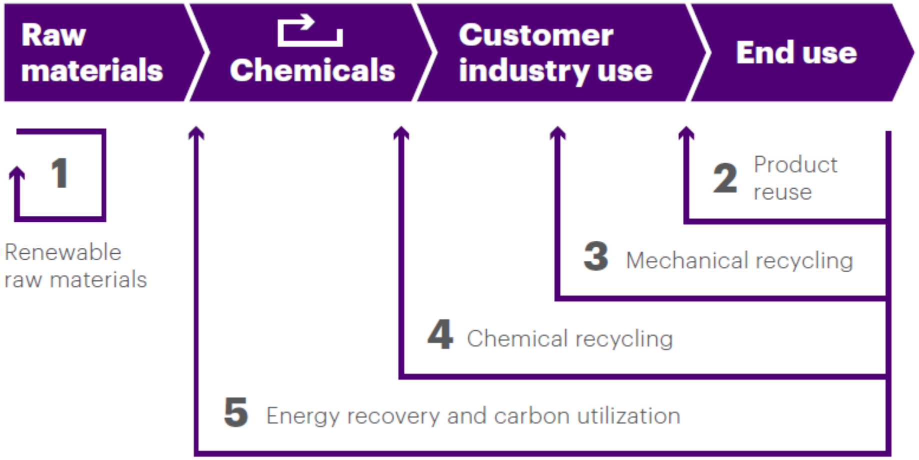
Circularity in chemicals has two aspects:

1) Enabling circularity



Enabling maximum utility in end usage
(e.g., higher durability of goods, making products suitable for sharing and increasing energy efficiency)

2) Circulating molecules



Maximizing utility of existing molecules
(e.g., reusing/recycling molecules such as through the reuse of PET bottles)

Source: Accenture, 2017.

Trends | Technological innovations

8 Molecule circulating loops

How would the circulation of molecules be accomplished?

There are five fundamental molecule-circulating loops in the chemical industry. Each of the five loops has its own requirements and each could have a significant impact on the consumption of carbon-based raw materials:

- **Substituting raw materials**: **The industry could substitute some portion of fossil feedstocks with renewable feedstocks** such as biomass material (e.g., bioethanol, lactic acid, bio C2/C4). Re-thinking the raw materials loop would require investment in new feedstock infrastructure and conversion assets.
- **Increased reuse of end-user products**: The industry could focus on **developing full suites of new products and solutions that can essentially be reused "as is,"** such as durable PET bottles. To do so, the industry might consider establishing "**design to reuse**" partnerships involving suppliers, original equipment manufacturers (OEMs), and companies that have close relationships with end-customers.
- **Mechanical recycling**: This involves **reusing existing materials without modifying their chemical bonds**. In essence, end-use materials could be collected, processed and reinserted into the upstream value chain for use in similar or downgraded applications.
- **Chemical recycling**: When molecules cannot be reused in their intact structure, chemical companies could **modify the material's molecular bonds to recover hydrocarbons**. This would involve **breaking up long-chain hydrocarbons into precursors** via processes such as catalytic cracking or plasma gasification. For this loop, the industry would need to invest in further research and development in cracking and gasification processes, as well as invest in required large scale assets.
- **Energy recovery and carbon utilization**: This involves **recovering the energy** contained in molecules by oxidizing hydrocarbons to CO_2, harnessing it and then **building new chemical feedstocks** via a catalytic reaction.

Source: According to Accenture, 2017.

Trends | Technological innovations

9 Biotechnology & Biorefinery

Biorefinery is a biotechnological process which aims to produce renewable feedstock in a bid to provide alternative solutions for petroleum-based products that are used rampantly in the world. If the biotechnological route is used and the biorefinery concept implemented, **chemicals will be produced with glucose as the starting material obtained, of course, from cheaper natural raw materials**.

The economics of chemical manufacture from petroleum refineries is threatened with the increasing shortage and rising prices of petroleum, and biorefineries can repair the economic situation:

- **Incremental use of agricultural produce for chemical manufacture** will also provide alternative domestic markets for agricultural produce when exports are declining in developed countries.
- **Companies that have been building up their biotech capabilities will have advantages** while those who are slow to adopt biotech capabilities may miss out on some long-term opportunities.
- **Value will be derived through the creation of new business opportunities**, such as **developing synthetic compounds** that were previously inaccessible through classic chemistry, adding value to processes by **shortening time to market, reducing process costs** by cutting out steps in synthesis or vastly increasing yields, and through the use of **cheaper raw materials**, for example, making the transition from oil to corn and, ultimately, corn stover.

Source: According to Chemical Weekly, 2016.

Trends | Technological innovations

9

Biotechnology & Biorefinery

Advantages of Biotechnology in Chemical Production:

- **Cleaner production** since fewer waste will be generated. It can eliminate environmental concerns over the disposal of chemical processing waste.
  Increased product yield.
- **Reaction steps will be reduced**, usually compressed into one synthesis and one isolation step in a biotech process. The outcome is a 75% saving in capital equipment costs and a 50% cut in operating costs.
- **Cost-effective routes and new chemical entities** possible.
- **Low-cost raw materials**. Use of cellulose and biomass will reduce the cost. We will see the first biorefineries in a few years.
- **No by-products generated** which have undesirable colour or odour.
- **High regio- and stereoselectivity of biocatalytic reactions**.
- **Using plant biomass** as feedstock means feedstock grows, and **it consumes CO_2** — one of the greenhouse gases.
- **Use of plant biomass, if done successfully, will provide primary feedstock as well as energy**. Today at least 5 billion kilograms of commodity chemicals are produced annually only in the United States using plant biomass as the primary feedstock.
- Unlike many chemical reactions that require very high temperatures and pressures, reactions using biological molecules work best at ambient temperatures under 100°F, atmospheric pressure and in water-based solutions. Therefore, **manufacturing processes that use biological molecules can lower the amount of energy needed to generate reactions**.

Source: According to Chemical Weekly, 2016.

5. The Catalan chemical sector

The Catalan chemical sector

The following facts sum up the main characteristics of the industry in the region:

Catalonia's turnover amounts to 42.6% of the total of Spain's chemical business volume. Tarragona has one of southern Europe's biggest petrochemical clusters and generates 23% of this volume. The sector provides direct employment to 32,679 people in the region (2014).

Easy market access to high growth regions in Northern and Western Africa, Mediterranean Countries and Latin America. Catalonia is a gateway to the EU chemicals market.

Flexible labour market and competitive labour costs. There are strong links between universities, business schools, research centres, chemical engineers and professional associations.

High national chemical consumption. Catalonia has the largest gas infrastructure in Europe and has great potential for shale gas. Besides, the sector has a National Competitiveness Plan for the Chemical Industry.

It is the **largest chemical cluster in the Mediterranean**. There are **ongoing rail investments** to introduce the UIC standard gauge and develop the Mediterranean, Central and North corridors to **connect the region with the European market**.

Close collaboration between authorities, universities and businesses in the development of national R&D&I strategies and programmes.

Source: UIC 'International Union of Railways'. Informe anual sobre la indústria a Catalunya (2016), Generalitat de Catalunya

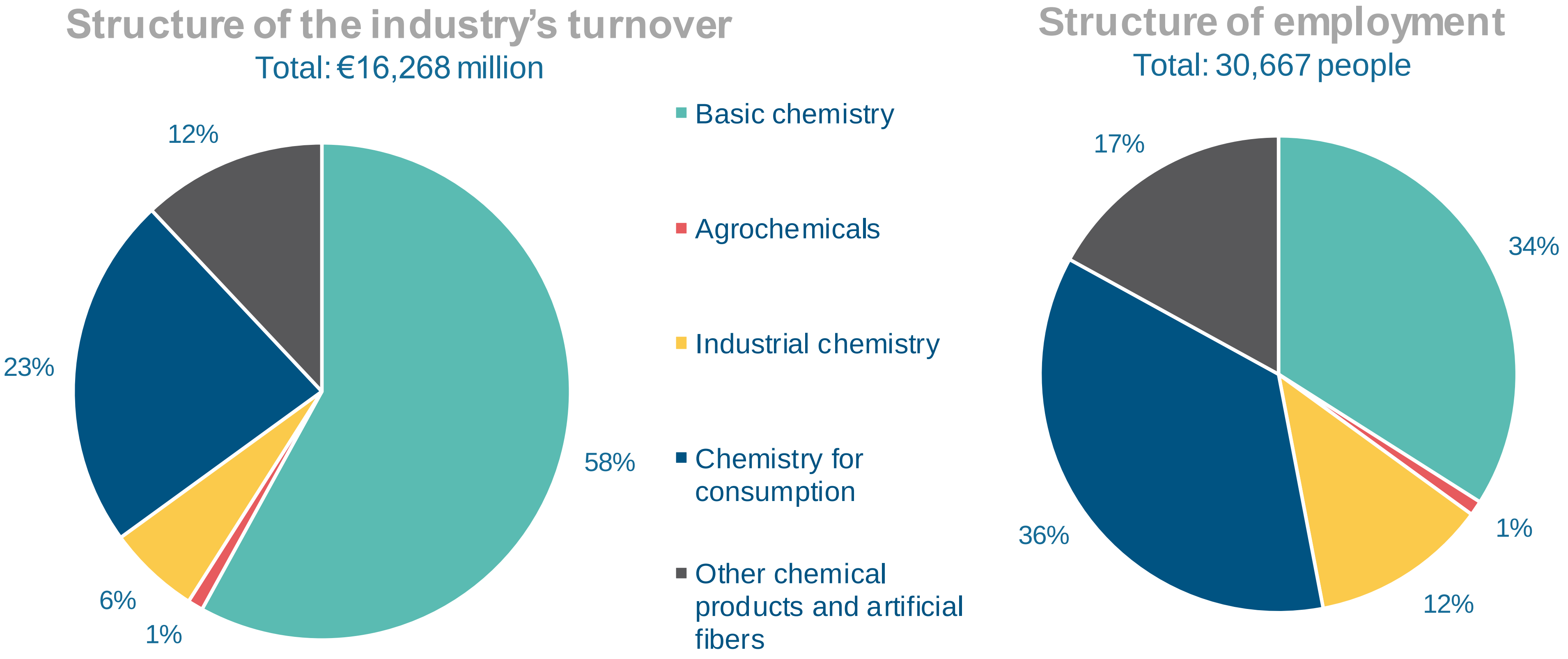
The Catalan chemical sector

Industry subsectors

- **Basic chemistry:** Activities for the manufacture of basic chemical products, nitrogen compounds, fertilizers, plastics, synthetic rubber in primary forms, industrial gases, dyes and pigments, other basic inorganic chemistry products and other basic organic chemistry products.
- **Chemistry for agriculture or agrochemicals:** Fertilizers of all kinds, as well as insecticides and pesticides -fumigants, fungicides, seed disinfectants, herbicides, molluscicides, etc.
- **Industrial chemistry:** Compressed gases -hydrogen, nitrogen, oxygen, liquid air, etc.-, dyes and pigments, paints, varnishes and lacquers, printing dyes, oils and greases for industrial use, auxiliary products for the textile, leather and rubber industries, and various other products.
- **Chemistry for consumption:** Soaps, detergents and dyes, articles of perfumery and cosmetics, waxes and paraffin, sensitive photographic material, pyrotechnic articles, etc.
- **Other chemical products:** Explosives, aromatic substances, etc.
- **Artificial and synthetic fibres:** Manufacture of fabrics, papermaking, plastics, structural products designed to resist stress, insulators, filters, cosmetics, etc.

The Catalan chemical sector

Industry subsectors



Structure of the industry's turnover

Total: €16,268 million

Structure of employment

Total: 30,667 people

Source: Informe anual sobre la indústria a Catalunya (2016), Generalitat de Catalunya

The Catalan and state-level chemical sector

The domestic chemical industry, in numbers:

12.8 %

OF CATALAN GDP

comes from the chemical sector (2014), which contributes about 1.7% of the Catalan total gross added value and 10.3% of industrial gross added value in 2014.

4.5%

SECTOR GROWTH

is expected annually until 2030, According to the VCI Prognos Study. The chemical sector is the second largest exporter of the Spanish economy and it exports more than a half of its production.

5th

PLACE IN EUROPE

and 12th place worldwide in the classification of the chemical sector. This position, however, is highly vulnerable to changes in oil prices and depends heavily on the automotive industry, its biggest client.

€38,174 m

TURNOVER IN SPAIN (2014)

The sector's turnover is expected to grow at a slow but steady pace (1.7%) in the coming years.

€16,268 m

TURNOVER IN CATALONIA (2014)

Catalonia had the largest share of the Spanish turnover by region (42.6%) in 2016.

4.6%

PRODUCTION GROWTH

Consolidated in Catalonia during 2016. This growth was supported by the recovery of domestic consumption and industrial activity. The sector grew more in Catalonia than in Spain.

Source: Informe anual sobre la indústria a Catalunya (2016), Generalitat de Catalunya

Regional impact

Potential benefits for the Catalan economy

€3.7 billion will be injected into the European economy between 2014 and 2024 - €975 million from the European Commission and €2.7 billion from the Bio-based Industries Consortium (BIC)

…to develop an emerging bioeconomy sector. Through the financing of research and innovation projects, the BBI (Bio Based Industries) **will create new and novel partnerships across sectors, such as agriculture, agro-food, technology providers, forestry/pulp and paper, chemicals and energy.**

The aim of the BBI is to **use Europe's untapped biomass and waste as feedstock to make fossil-free and greener everyday products**. At the heart of it are advanced biorefineries and innovative technologies that will **convert renewable resources into sustainable bio-based chemicals, materials and fuels**.

The chemical industry could generate additional wealth for Catalonia worth €270 million by 2020 if a bioeconomy approach is adopted.

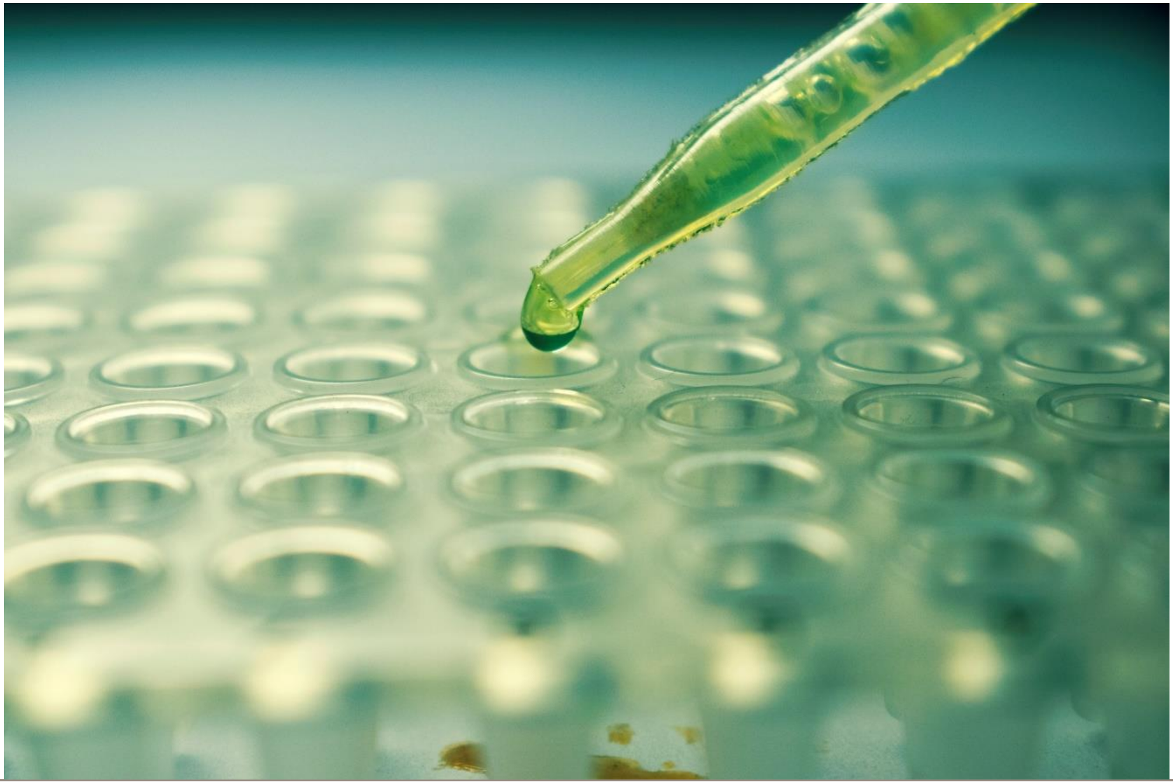
Both upstream and downstream bio-based chemical production have been found to generate significant wealth effects:

- €190 million for the industry's suppliers.
- €80 million for the Catalan chemical industry's clients.

The bio-based share of all chemical sales in Catalonia could rise to 15% by 2020.

***Estimation:** As a basis for quantitatively assessing the macroeconomic contribution of the bio-based industries, a common feature of these studies is the usage of economy-wide supply and use tables (SUT) or social accounting matrix (SAM) national accounts data (United Nations, 1999). **This study provides multiplayers for the EU countries and bioeconomy sectors in the form of backward- (2.23) and forward-looking (0.91) linkages**. This means that for each million euro of additional demand, the regional economy generates €2.23 million for upstream supply industries and €0.91 million for downstream sectors and retailers.

6. Opportunities for the Catalan chemical industry related to bioeconomy



The Catalan chemical Industry

Multiple development paths for the local bio-based industries

Bio-health

- Biopharmaceuticals
- Medical devices
- Natural compound bioactives
- Bio molecules

...

Bio-energy

- Bioediesel
- Ethanol
- Methane
- Bio-oil

...

Bio-Industrial

- Biocatalysts
- Biosolvents
- Bioplastics (Packaging)
- Bioadhesives

...

Agri-biotech

- Food chain
- Food waste
- Food safety
- Nutrition and dietary
- Livestock production

...

In order to unleash the full potential of Bioeconomy in the region, the **chemical industry's capacity-building initiatives should prioritize** the following opportunities:

Develop new value chains

Bioeconomy oriented R&D

Focus on opportunities

Develop new value chains

The analysis carried out in the EC's ***Bioeconomy development in EU regions report*** (2017) shows a wide variety of drivers of bioeconomy sectors and subsectors, of regional capacities and maturity and of approaches to deploy the bioeconomy. This **diversity in thematic orientation and value chain approach towards the bioeconomy** makes the understanding of regional realities and the definition of support schemes more complex.

Type 5

Industrial Biotech focus

Bioeconomy drivers:
- Strong industrial sectors that focus on bio-based products (e.g., chemical)
- Innovative companies

Bioeconomy capacities:
- Medium-high maturity
- R&D in biochemistry, advanced manufacturing, …

Approach to value generation:
- Technological conversion
- Integrate fossil-based and bio-based technologies
- Develop new value chains

According to the EC report, **the characterization of Catalonia** would be the following:

New value chains

BIOREFINERIES

'Biorefining processes and applications seem to **be key for the regions in defining new and modified value chains** in many different areas' EC (2017).

7/10

Maturity Index

The maturity index is a combination of regional innovation variables on bioeconomy. Despite having a high maturity level (7/10), **Catalonia's value chain approach focuses on Biomass processing and conversion**, which is a characteristic of regions of low level bioeconomy maturity. Therefore, **the regional bioeconomy maturity level enables creating and sustaining a new value chain approach**.

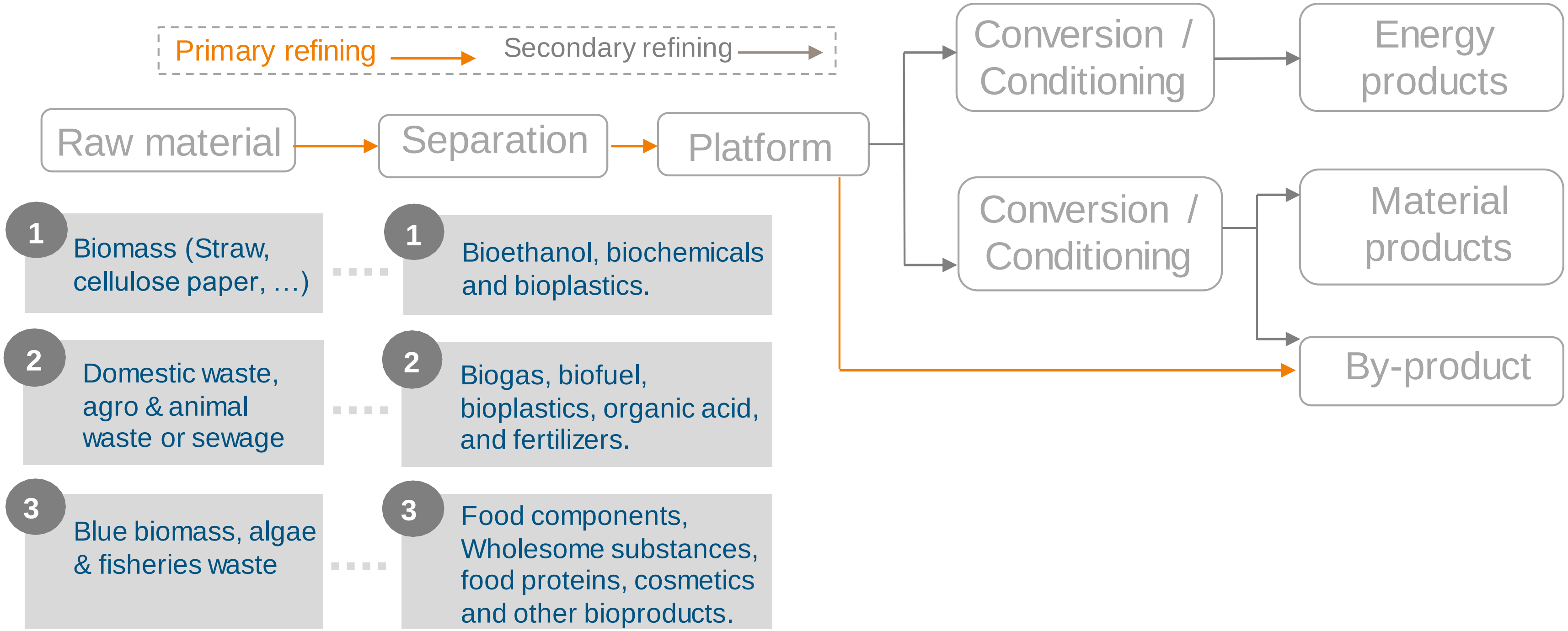
Focus on opportunities

Develop new value chains

Tonnes of **underutilized biomass and around 60% of the organic waste generated in the region is available for conversion into new products, chemicals or energy** through biorefining processes. According to the Secretary of State for Research, Development and Innovation, the three current possibilities are:

The different components within the Biorefinery Concept

(Based on the German Agency of Renewable Resources, and the Secretary of State for Research, Development and Innovation)



Primary refining → Secondary refining →

Raw material → Separation → Platform

Conversion / Conditioning → Energy products

Conversion / Conditioning → Material products

By-product

1	Biomass (Straw, cellulose paper, …)	1	Bioethanol, biochemicals and bioplastics.
2	Domestic waste, agro & animal waste or sewage	2	Biogas, biofuel, bioplastics, organic acid, and fertilizers.
3	Blue biomass, algae & fisheries waste	3	Food components, Wholesome substances, food proteins, cosmetics and other bioproducts.

Focus on opportunities

Develop new value chains

Does Catalonia have a strategic position for the development of biorefineries?

1 **Availability of Biomass**

Underutilized wealth of biomass of a diverse nature in the region waiting to be exploited.

2 **Involvement of key sectors**

Both primary (agriculture, forestry) and secondary sector (chemicals, …) are seeking to increase competitiveness and penetrate new markets.

3 **Scientific and technological capabilities**

World class resources associated with biomass, chemistry and bioenergy.

4 **Environmental issues**

Exploitation of biomass contributes to converting problematic waste into resources and reducing GHG emissions.

5 **Employment creation**

Jobs associated with innovative productive models capable of generating high added value using local resources.

6 **Rural industrialization**

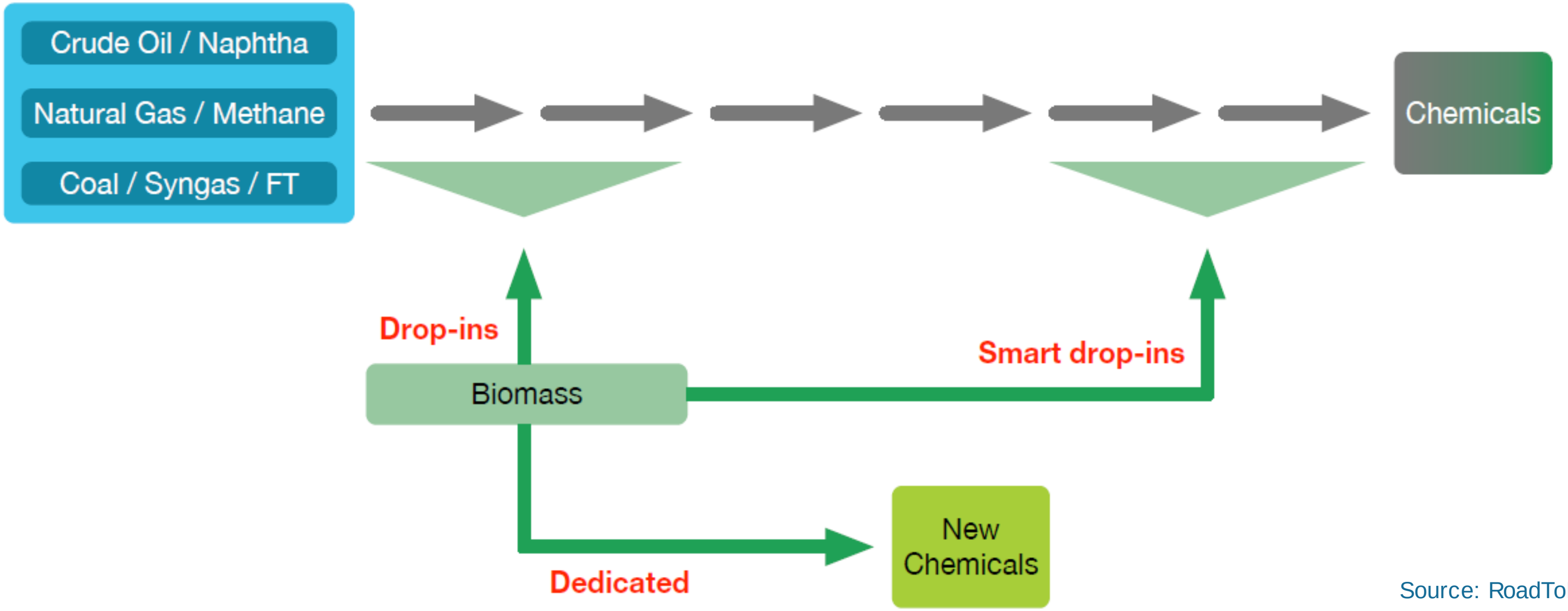
Biorefineries promote rural development and create opportunities that involve territorial articulation.

Focus on opportunities

Investment and research oriented

The European RoadToBio project designed specifically for the chemical industry could pave the way for the **Catalan chemical industry towards a larger bio-based portfolio and competitive success**. The roadmap developed in RoadToBio will specify the benefits for the chemical industry along the path from a fossil-based industry towards a bioeconomy to meet the societal needs in 2030. The first paper published by RoadToBio aimed to differentiate three kinds of bio-based chemicals in order to encourage further research:

Schematic differentiation of pathways of drop-in, smart drop-in and dedicated bio-based chemicals



Source: RoadToBio, 2017.

Focus on opportunities

Investment- and research-oriented

Advances in industrial biotechnology allow the **selective production of added-value small molecules** used as **building blocks for several applications** of fine chemicals and pharmaceuticals.

The utilization of Bio-based drop-in chemicals, but especially the development Bio-based smart drop-in chemicals, may imply a quantum leap for the industry in terms of **fighting the commoditization of chemicals and shifting the industry focus towards bioeconomy** and green chemistry.

Catalan chemical industry's bioeconomy R&D opportunities

- **Bio-based drop-in chemicals** are bio-based versions of existing petrochemicals which have established markets. They are chemically identical to existing fossil-based chemicals (BIO-TIC 2014).
- **Smart drop-in chemicals** are a special sub-group of drop-in chemicals. They are also chemically identical to existing chemicals based on fossil hydrocarbons, but their bio-based pathways provide advantages compared to the conventional pathways (less toxic, shorter time-to-product is shorter, …).
- **Dedicated bio-based chemicals** are chemicals produced via a dedicated pathway and do not have an identical fossil-based counterpart. As such, they can be used to produce products that cannot be obtained through traditional chemical reactions and products that may offer unique and superior properties that are unattainable with fossil-based alternatives.

7. Success stories

Success stories

BBCAT Comunitat de Bioindústries per a la Bioeconomia RIS3CAT

EIG eco intelligent growth

Lean2Cradle Beyond Lean Construction

grupo construcía

ICIQ Institut Català d'Investigació Química

NOVELL

CLARIANT

ERTFLOW Efficient Reaction Technologies

inKemia IUCT group

residuorecurso bolsa de subproductos y materias primas

CROMOGENIA UNITS YOUR SPECIALIST FOR SPECIALTIES

Indulleida,s.a.

dbA

ACCIÓ Generalitat de Catalunya

ferrer

medichem

ZICLA®

CTQC química sostenible

eurecat Centre Tecnològic de Catalunya

UNIVERSITAT ROVIRA i VIRGILI

GICOM Grup d'Investigació en Compostatge Universitat Autònoma de Barcelona

NATURDEV

I. Creation of a community of bioindustries

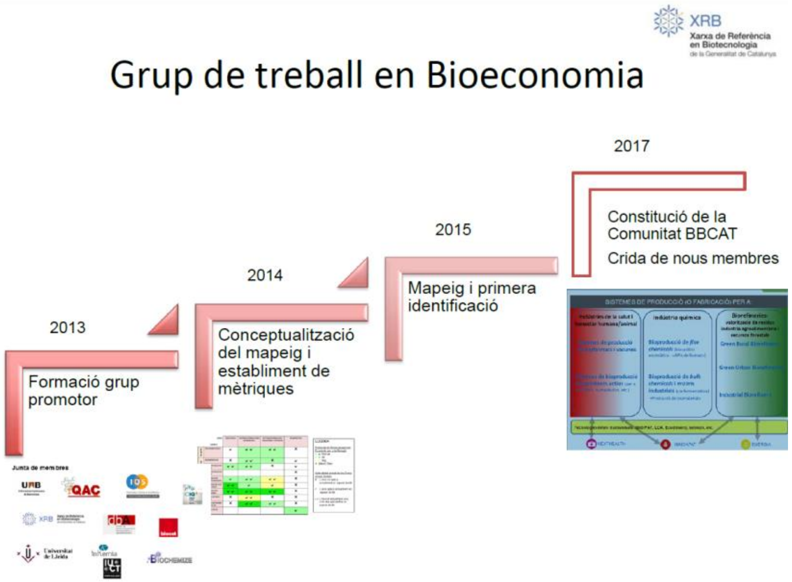
The goal is to create a group of companies and agents of the Catalan R&D system that develop projects to enhance the efficient management of biological resources, and with special emphasis, generate bioprocesses and bioproducts on an industrial scale.

TARGETS

- Increase the efficiency, competitiveness, profitability and sustainability of bioproductive processes based on promoting the application of key enabling technologies (advanced biomanufacturing).
- Promote the maximum efficiency management of biological resources.
- Reduce the environmental impact of production processes.
- Promote lines of innovation focused on real needs of the sector.
- Establish a joint action plan to promote synergies among partners with other communities in the leading sectoral areas (energy, food, health).
- Facilitate coordinated access to initiatives from other European regions/funds.
- Create new qualified jobs.
- Educate skilled specialists in bioindustries.
- Promote the development of biorefineries as models of circular economies.

BBCAT Comunitat de Bioindústries per a la Bioeconomia RIS3CAT

“Promote the industrial biotechnology and bioeconomy sector to become one of the main economic motors of Catalonia”



Grup de treball en Bioeconomia

2013
Formació grup promotor

2014
Conceptualització del mapeig i establiment de mètriques

2015
Mapeig i primera identificació

2017
Constitució de la Comunitat BBCAT
Crida de nous membres

II. Ferrous chloride as a coagulant

Waste generated from stripping wire during the treatment process of metal surfaces. In a chemical decanter, a solution of hydrochloric acid is used to eliminate the oxide layer. This process generates an acidic solution of ferrous chloride.

Clariant, a waste-receiving company, is dedicated to the manufacture of dyes and pigments for the paper, textile and leather sectors. The wastewater produced in Clariant contains dyes and organic material, and for this reason they require treatment based on two processes: physical and/or chemical process and biological treatment.

Physicochemical treatment. Elimination of colloidal particles carried out in three operations:

1. Coagulation
2. Flocculation
3. Precipitation

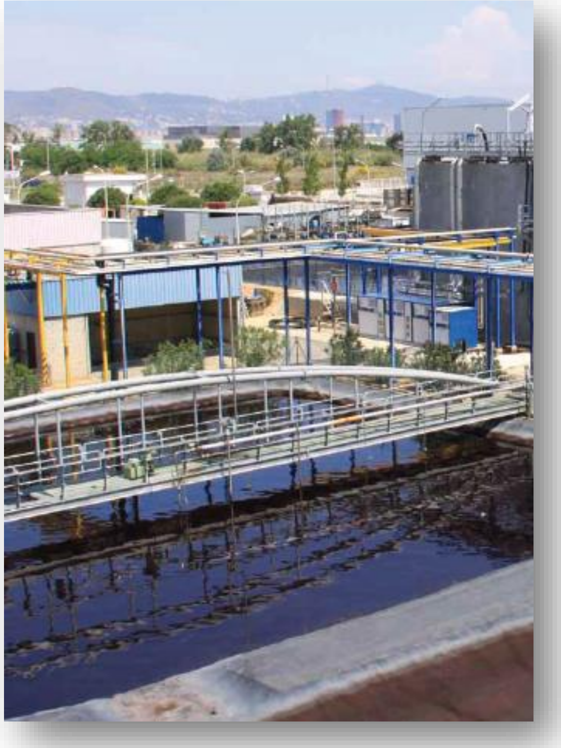
Coagulation consists of destabilizing a colloid to neutralize its loads and thus favour the formation of the flocculum. The factors to take into account are the time necessary for destabilization, the pH and the energy necessary to guarantee the mixture between the colloids and reagents. Clariant performs coagulation with organic compounds and ferrous chloride (by-product).

The advantages:

- Save waste treatment costs
- Reduce the cost of raw materials (coagulants)
- Reduce document management (acceptance form, track record and authorized carrier)

residuorecurso
bolsa de subproductos y materias primas

CLARIANT



III. ALDEFRUIT: Aldehydes from fruit waste for application in the tanning industry.

RETOS COLABORACION: RTC-2015-3652-5

The main goal of this project is to develop new chemical and biotechnological processes to transform fruit waste into dialdehyde compounds for use in the tanning process as alternative to the current products.

This project has been funded by the Ministerio de Economía y Competitividad and by the European Regional Development Fund (ERDF) and is being developed by a consortium including two companies: Cromogenia Units S.A. and Indulleida S.A. and the University of Lleida through the DBA Centre.

This project should provide a new tanning product with similar properties to those currently being used but cheaper and with a lower environmental impact

"Una manera de hacer Europa"

IV. Inspired by Nature: membranes for artificial photosynthesis

During the last decade, society has demanded from energy providers solutions for the production and storage of alternative/green fuels. The market calls for new upstream technological innovations to respond sustainably, efficiently and safely to current and future energy needs. For this reason, most companies have decided to dedicate their R&D departments to finding achievable solutions to these societal demands.

Artificial photosynthesis interests scientists from all backgrounds, providing the possibilities to mimic nature on the premise of the precise design and functionality of materials. This approach appears as a source of sustainable fuels, for instance hydrogen and methanol. When combined with a fuel cell (FC) converting the energy of chemical bonds into electricity, it presents practical access to power locked into solar radiation.

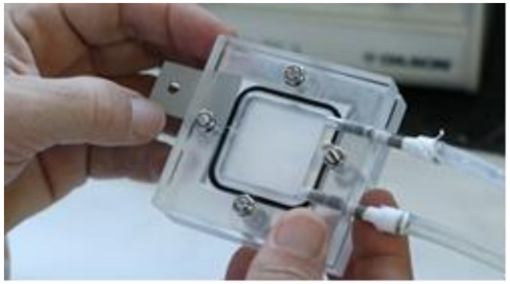
An essential element of artificial synthesis systems is CO_2 absorption. Our group has been working with a polysulphone membrane contactor and the preliminary data show good absorption rates by playing with the internal morphology of the membrane. The absorbing solution and the active CO_2 components fixed to the external face of the membrane show that they can act as artificial leaves and stomatas. Very recently we filed a patent application in which we protect a breakthrough CO_2 membrane which achieves capturing rates of 70-90 g atmospheric CO_2·m2/h at pH 8-10 which can be transformed into methanol and then energy.

Ricard Garcia-Valls
Adrianna Nogalska
Bartosz Tylkowski

CTQC química sostenible

eurecat Centre Tecnològic de Catalunya

UNIVERSITAT ROVIRA i VIRGILI



V. Application of the Lean2Cradle® methodology in the execution of the BMW Barcelona Premium Building, in Hospitalet de Llobregat.

EIG worked with Construcía Group to apply the L2C® methodology, created by EIG in order to enable Construcía's intention to adapt its business model to the circular economy.

On this occasion, the design of the building was led by another team, so EIG was only involved in some solutions and in the selection of materials and work management.

The main goal was to preserve the value of materials by enabling their recovery through the following strategies:

- ***Modular constructive solutions:*** we proposed and applied easily detachable solutions, such as the façade system.
- ***Use of C2C Certified TM products:*** preference for certified products and financial support to companies that wanted to certify their products.
- ***Training and work team,*** in order to preserve the value of the materials ensuring their correct installation.
- ***Material Passport:*** preparation of the Material Passport linked to the BIM model, including circularity parameters.
- ***Deconstruction Manual:*** preparation of a document that shows how to recover valuable materials at the end of its life cycle, with the consequent economic and environmental benefit.

The construction of the building was finished in November 2017 and currently the latest adjustments to the BIM model and Material Passport are being made.

Benefits:

- 0% over cost compared to the initial project
- More than 80% of the materials used are recyclable at the end of their life cycle
- Incorporation of more than 10 Smart Solutions
- Transformation engine: training 50% of the suppliers in L2C® and CIRCULAR ECONOMY concepts
- Fewer 0mistakes and greater customer and supplier satisfaction

VI. Flow chemistry: from batch to continuous flow production for a safer and more efficient pharma & fine chemicals industry

ERTFLOW, a technology development unit of the Institute of Chemical Research of Catalonia (ICIQ) provides R&D services and supports pharmaceutical and fine chemical companies in the paradigm shift from batch to (continuous) flow production.

Working with flow processes implies high process intensification as well as faster mixing and increased heat and mass transfer, resulting in:

- **Improved safety and fewer runaway reactions**
- **Waste reduction:** better purity profiles and higher yields; no minimum batch size needed
- **Industry 4.0:** online analysis, amenable for the automation and on-demand production of chemicals

ERTFLOW's expertise, in addition to **flow technology** knowledge and development, includes the **design, development and use of easily recyclable immobilized (asymmetric) catalysts applied in flow,** combining the improved selectivity, purity, lower energy consumption, etc. of catalytic processes with the advantages of flow processes.

www.ertflow.com

VII. Ecodesign of the packaging of Repavar and Atopic Piel ranges

Within Ferrer's sustainability strategy, the Ecodesign of packaging takes priority, led by the Repavar and Atopic Piel ranges. With this project, they have reduced the environmental impact of packaging at each stage of its life:

- **Materials:**
  - use of mono-material
  - 38% reduction in weight
  - Packaging is labelled rather than printed
  - No box and no packaging insert
- **Transport:** they work with material suppliers who are less than 50 km away from the production factory, thereby reducing CO_2 emissions.
- **Production:** as the packaging does not have to be boxed, energy use is reduced, as well as costs and time. The same packaging can also be used for several products (only the label is different), which means that there is no packaging surplus and no obsolete packaging.
- **Distribution:** for certain products, they have managed to distribute up to twice as many products in the same number of packing boxes.
- **Product:** the new packaging designs make it easier to get all the product out, so it can be used fully with no waste.
- **Recycling:** when it comes to the end of its useful life, the ecodesigned packaging is easier and more convenient to recycle: 100% RECYCLABLE!

ferrer

repavar®

> *"Ecodesign introduces environmental criteria into the packaging design process with the aim of reducing the environmental impact during the life span of the packaging, thereby protecting the planet."*

VIII. Tanning industry: closure of the material cycle in the process of depilation

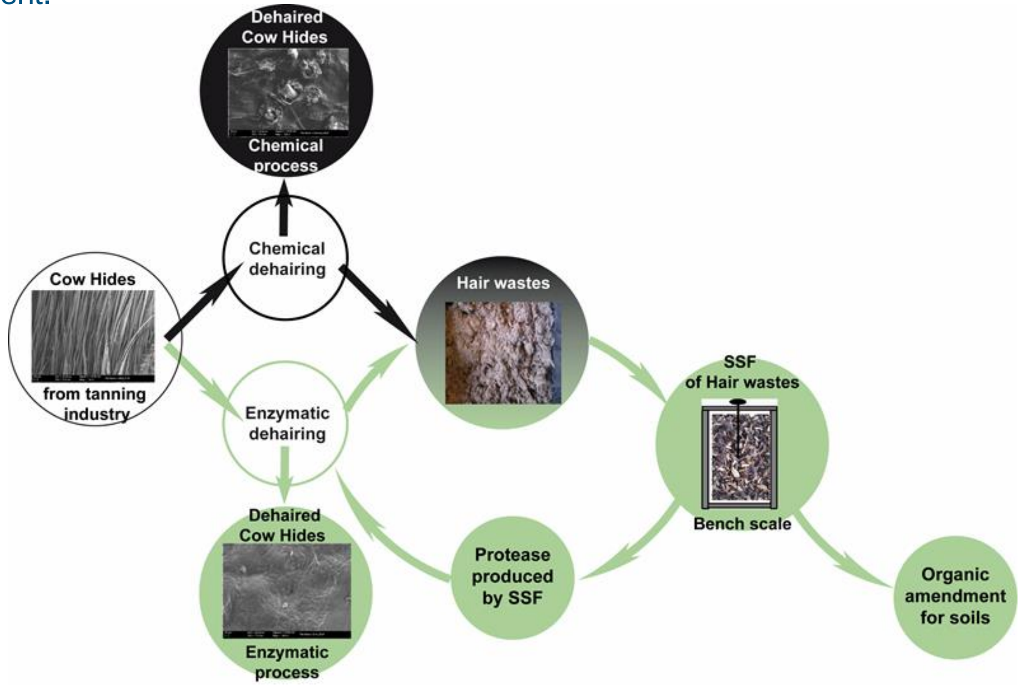
GICOM
Grup d'Investigació en Compostatge
Universitat Autònoma de Barcelona

Use of waste from industry to produce enzymes for the process of depilation (proteases), eliminating the need for chemical products.

The Composting Research Group of the UAB (www.gicom.cat) has sound experience in **organic waste treatment through biological systems**, both in terms of urban and industrial waste. In recent years, GICOM has focused its research on obtaining bioproducts from waste in order to replace existing materials based on non-renewable sources, often little biodegradable and persistent in the environment.

This paradigm shift in waste management (waste-to-product) is based on a biological process called Solid State Fermentation, that produces some significant products such as biosurfactants, biopesticides, different types of enzymes or aromas.

More specifically, in the project presented, waste from depilation (mainly hair) was used in tannery to produce proteases through SSF. These proteases were successfully used in the depilation process, so made it more sustainable (since it neither uses chemical reagents nor produces waste) and based on the circular economy,



IX. Polymers incorporating bio-based monomers and/or CO_2

ICIQ
Institut
Català
d'Investigació
Química

ICIQ has developed a bio-based polymer platform using Prof. Arjan Kleij's expertise in catalysis.

This technology allows generating a wide range of polymers, including polycarbonates and polyesters, where traditional monomers coming from oil are partially or fully replaced by monomers from biomass. Moreover, the polycarbonates also incorporate CO_2, which allows further reducing the carbon footprint of the resulting products.

The most advanced example of this bio-based polymer platform is a polycarbonate containing limonene (a compound that is extracted from orange and lemon peels).

ICIQ is currently working both internally and in collaboration with industrial partners to develop this bio-based polymer platform, scale up and optimize its production, characterize the polymers obtained, and explore their potential applications in commercial products.

X. Taking biofuels to the second generation

- During the past decade, InKemia IUCT group has been developing technology to produce "**o-bio**“ bio-fuels, as well as other high-value chemicals.
- InKemia Advanced BF Ltd. (IABF) is a spin-off of the Spanish technological group InKemia, born to commercially develop technology of new advanced biofuels and introduce its "**o-bio**" product to the diesel market.
- “**o-bio**" gets a good score in all the key parameters to obtain a successful advanced biofuel::

- **Air quality**: 30% reduction in small particles without increasing NOx

- **Sustainability**: uses glycerine in crude oil and other raw materials not competing with food or with the exploitation of land

- **Climatic change**: Greater GHG reduction than within conventional diesel

- **Economy**: better than biodiesel, since glycerine is incorporated into the fuel (100% atomic economy)

XI. Pharmaceutical active principles

Medichem SA, dedicated to the development of processes and the manufacture of Pharmaceutical Active Principles (PAP), manages 3 types of waste as by-products.

By-product 1: Non-halogenated organic solvent
It is generated when mixing the active principle with the solvent and distilling it later to eliminate the solvent. The residue contains 90% organic solvent and 10% water. It is managed as a by-product by a company producing rectified alcohols and derivatives, which introduces this organic solvent rather than hydroalcoholic mixtures.

By-product 2: Ammoniac waters
They are generated in the process of regeneration of ion exchange columns through ammonia, to make an antiepileptic agent. This water has a nitrogen content of 1%. The by-product is sent to a company dedicated to the production of fertilizers and nitrogen fertilizer compounds to replace totally the water needed and partially the contribution of nitrogen in the manufacture of fertilizers

By-product 3: Aqueous solution of ammonium sulphate
It is generated by decanting it with ammonia to neutralize sulphuric acid, obtaining a pharmaceutical active used for treatment. The solution contains 40% ammonium sulphate and 60% water. The by-product replaces part of the raw material needed in the manufacture of polyelectrolytes for wastewater treatment (dispersion flocculants)

There are several related advantages such as:

- For Medichem SA this means an important saving in waste treatment costs and a reduction in waste document management
- For the recipient companies this means a reduction in raw materials purchased.

XII. NATURDEV: development of a competitive strategy to improve the sustainability of the agro-food chain and the efficient use of natural resources.

*‘Programa Estratégico de Consorcios de Investigación Empresarial Nacional (CIEN)***:** *IDI-20150587’*

The main goal of this project is to improve the sustainability of the food industry by proposing several new technologies to minimize waste and provide products with added value. Starting from various waste generated by the participating companies, different processes will be proposed to obtain new products using green technologies with a low environmental impact.

Waste from vegetable transformation or from fruit juice industries is to be transformed into other products to be applied in the food, aroma, feed and agricultural sectors.

This project has been funded by the ‘*Programa Estratégico de Consorcios de Investigación Empresarial Nacional (CIEN)’* and by the European Regional Development Fund (ERDF) and is being developed by a consortium including several industries assisted by different research centres.

XIII. Development of the first compostable Nespresso-compatible coffee pod on the market

Cafès Novell has developed the first compostable Nespresso-compatible coffee pod on the market, manufactured and marketed in Spain. It provides a sustainable solution to the growing number of coffee pods that become waste due to being manufactured out of non-biodegradable plastic or aluminium.

The pod is made from a polymer called Ecovio®, obtained from corn, which means it can be deposited in the container for the organic fraction of municipal waste, taking between 4 and 12 weeks to biodegrade. Both the adhesive and the paper lid are also compostable. It has been certified with the following seals: OK Compost, which guarantees that the packaging is biodegradable and compostable (according to European standard EN 13432), and OK Biobased, which accredits the use of renewable raw materials in the manufacture of the product.

It contains certified organic coffee cultivated without the use of artificial chemical substances (additives, pesticides and herbicides).

The project, that received the '*Catalunya Ecodesign 2017'* Award in the Product Category, is sold both through the *Cafès Novell* e-shop and in specialized shops.

"Conventional pods generate between 1.5 and 2 g of waste per unit on average and cannot be processed as packaging due to their legal classification and size"

XIV. Raw materials and by-products exchange

residuorecurso
bolsa de subproductos y materias primas

How it works

- A company willing to buy and sell by-products, waste and secondary raw materials can sign in to become a user
- Users can publish and search as many offers and requests as they wish
- *Residuorecurso* (wasteresource) provides a secure and efficient environment to negotiate with other users and transform waste into resources

XV. Closing the loop: the transformation of the waste generated by cities into innovative products which give an answer to cities' needs.

Every day, cities and their associated activities generate thousands of tonnes of waste which ends up in landfills due to the lack of recycling. This wastes valuable resources while virgin materials – many of them non-renewable – are extracted from our planet. But things are changing and gradually the way towards what is known as the circular economy is being opened up.

At Zicla, we are committed to the circular economy and we work so the recoverable waste generated by cities and their associated activities – waste which, although it has interesting potential for recovery, goes to landfill because of the lack of recycling – can be transformed into new materials.

Together with industry, we design the transformation processes needed to turn waste into new materials of acceptable quality and price. We work with industry both to design the new materials based on the waste and to adapt the industry's processes using innovation so these new secondary raw materials are acceptable.

One of our success stories in this field has been to develop a family of new materials using PVC waste coming from different sources, especially from the copper recovery process from out-of-use cables. At Zicla, we use these new PVC materials in the production of different products for cities. One of them is our **VECTORIAL System**, which allows building up bus boarder **platforms.** These platforms were designed to provide public road safety, better accessibility, and comfort for citizens at bus stops.

ZICLA® Vectorial

Main characteristics:

- Vectorial system allows improving the use of space, accessibility, and mobility in cities in an economic way and in the short term.
- It has a competitive price compared to other prefabricated systems as well as the permanent work on the public road.
- Flexible to urban and mobility changes in the area where it is installed. It can be installed and removed quickly and easily. Its modularity allows it to easily adapt to the available space.
- The whole system is designed to minimize its environmental impact and it is made with recycled materials and is fully recyclable. An Eco-label warranties its high environmental quality.

8. Conclusions & policy recommendations

Conclusions

These key elements will set the bases for the deployment of bioeconomy in Catalonia

- A **circular economy** is a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops.
- The **bioeconomy** is the biological motor of the circular economy. It encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products and bioenergy.

Bioeconomy & Circularity Concepts

Worldwide Data & Trends

- **Asian** chemical production outpaces other regions and its **production dominance** is expected to continue. By 2030, the **Chinese market share** in global chemical sales (worth €6.3 trillion) will reach **44%.**
- Growing segments of the chemical industry are becoming increasingly **commoditized** and competitive.
- New plastics economy, **molecule circulating loops** and biotechnology are **enabling new bioeconomy-related innovation** in the chemical industry.

- **The chemical sector's revenue in Catalonia accounts for 42.6%** of Spanish chemicals with a turnover of €16,268min 2016 (Growth around 4%)
- High national chemical consumption.
- **Largest chemical cluster in the Mediterranean.**
- **Close collaboration** with authorities, universities and businesses and **flexible labour market.**
- The chemical industry could **generate additional wealth for Catalonia worth €270 million by 2020** if a bioeconomy approach is adopted**.**

Catalan Chemical Industry

Opportunities & Challenges

- **The chemical industry's capacity-building** initiatives in Catalonia should prioritize the **development of new value chains** and **bioeconomy-oriented R&D**.
- There is a lack of confidence in the **long-term predictable political support** for the bioeconomy which **damages potential for investment** by industry in the EU. Apart from improved policy coherence and the need for stakeholder awareness, major **market stimulation measures** for bio-based products such as public procurement, harmonization and labelling are necessary.

Policy recommendations

Instruments to build a supportive framework

The recommendations regard the following domains:

Bioeconomy strategic planning and governance

- **The development of a common regional vision** and alignment of regional strategies to EU and national targets could prevent unnecessary duplication/conflicts.
- **Cross policy approach.**
- **Connect elements and platforms** between traditional (agro-food, fisheries) sectors and industry.
- **Support schemes** to increase the technology readiness level.
- **Green procurement**

Value chain/cycle development

- **Non-repayable grants** for pilot/facility plants to support upscaling activities are needed for new/niche value chains. Investments will lower operational cost and generate benefits.
- **Standardization** of primary feedstock for biorefineries.
- **Support living labs** and demonstration facilities/scaling up.
- **Support SMEs** through open access of demo infrastructure.

R&I knowledge transfer

- **Shorten learning curve** for new value chains through knowledge diffusion.
- **Promote partnerships and initiatives** (e.g., ERA-NETs, Vanguard, S3 platforms, macro-regional initiatives,…) bioeconomy should be better promoted in order to further stimulate learning and knowledge transfer.
- **Integrated research** and multidisciplinary education (closed loops)

Coordinated funding

- **Establish long-term frameworks to provide security** for the economic actors who invest in innovative projects.
- **Support regional consortia** along bio-based value chains in finding partners and secure suitable national and EU funding.
- **Set up regional R&D&I programmes which provide funding** for projects based on bio-economy approaches.

Public awareness

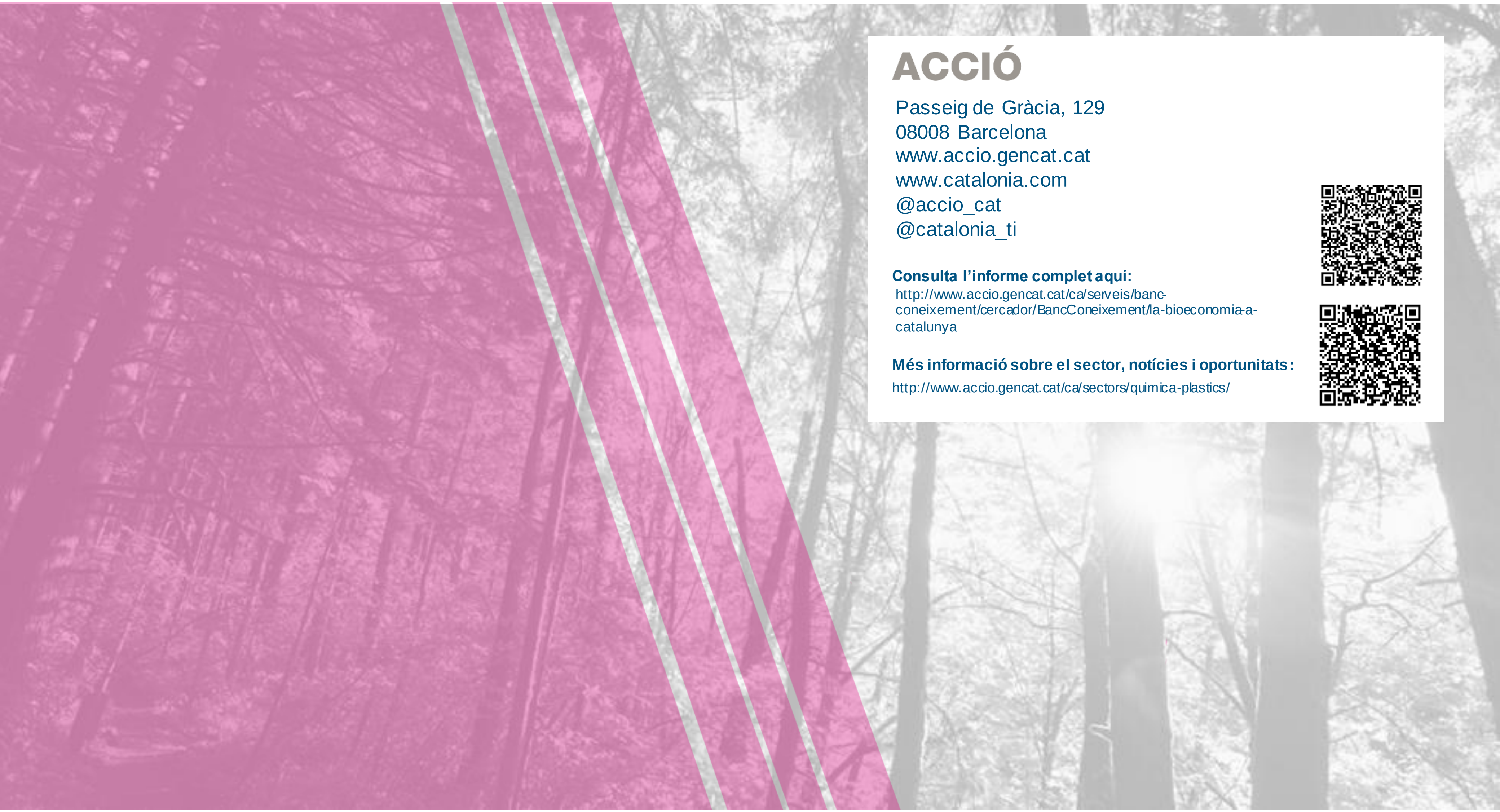
- **Raise awareness** on potential benefits of new/modified value chains in industrial/agricultural sectors.
- **Green tax** on urban and industrial waste to incentivize more efficient biological loops.
- **Bio standards** and labels should be developed to give an overview on positive and negative features of bio-based and recycled products.

Source: Authors' own based on primary information and Bioeconomy development in EU regions report (2017).

9. Annex I - Interviews & visits

	Type	Name
	Research Centre	IQS
	Cluster	Biomass Cluster
	Research Centre	GICOM Universitat Autònoma de Barcelona
	Company	REPSOL
	Company	INKEMIA
	Cluster	Packaging
	Research Centre	LEITAT
	Research Centre	UAB
	Company	SUEZ – Ecotermia
	Company	Ecogrowth
	Company	CORBION
	Cluster	Beauty
	Research Centre	ICIQ

Type	Name
Cluster	FEDEQUIM
Authority	Catalan Waste Agency
Company	FERRER
Authority	ECRN
Authority	Europa Bio
Authority	Raw material and by-product Exchange
Research Centre	Lleida University
Research Centre	URV
Company	BioChemize
Company	ZICLA
Cluster	BioBase Community
Research Centre	CTQC
Authority	Holland Chemistry



ACCIÓ

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Consulta l’informe complet aquí:
http://www.accio.gencat.cat/ca/serveis/banc-coneixement/cercador/BancConeixement/la-bioeconomia-a-catalunya

Més informació sobre el sector, notícies i oportunitats:
http://www.accio.gencat.cat/ca/sectors/quimica-plastics/

Amb la col·laboració de: S3Chem Interreg Europe
European Union
European Regional Development Fund

Strategy and Competitive Intelligence Unit