Key Enabling Technologies in FP9

Call for strong support for EU Future Technology Competitiveness

Key Enabling Technologies[1] are technologies selected for their ability to: 1) address global challenges (e.g. low-carbon energy or resource efficiency), 2) support the development of new products, and 3) stimulate economic growth and provide jobs.

Sustainable chemistry is essential to the technological advancement of Key Enabling Technologies (KETs) such as advanced materials, advanced manufacturing technologies, industrial biotechnology, micro and nanoelectronics, nanotechnology, and photonics.

SusChem *KETs in FP9* Key Messages:

1. SusChem asks that the next innovation framework programme (FP9) firmly embraces KETs as drivers of technology development, ensures its overall policy alignment and assigns appropriate levels of funding to maintain the EU's KETs leadership and keep industry jobs in Europe.
2. Advanced Materials, Advanced Process Technologies and Industrial Biotechnology KETs are essential to address societal challenges and accelerate the development of a low-carbon economy, circular economy, and the energy transition.
3. Considering the current digital evolution and the enormous benefits that it offers, SusChem recognises the need to integrate digital technologies into processes technologies, materials development, and business model creation. Synergies between the current KETs and potential new 'digital' KETs will accelerate the creation of new markets, growth, and jobs.

KETs address societal needs, but have low visibility in Society

KETs contribute to strengthening and modernising Europe's industrial base, and the development of entirely new markets, opportunities and industries. KETs reduce CO_2 emissions, make cars lighter and safer, enable storage of energy, and make a range of products from medicines to mobile devices more effective and sustainable. They "drive" innovation and value creation in a range of industrial value chains such as automotive, food, chemicals, electronics, energy, pharmaceuticals, construction, and telecommunications.

SusChem embraces KETs as the main technology building blocks for advancing Europe.
In preparation for the next Research and Innovation (R&I) Framework Programme, SusChem outlines *what can be achieved by KETs* and details the major *technology developments and initiatives needed* to:

- *create* **Advanced Materials** for use in energy efficiency (e.g., light weight), renewable electricity production and energy storage (e.g., batteries elements), or smart functionalities responding to stimuli (e.g., self repair).
- *develop* **Advanced Process Technologies**, including Industrial Biotechnology, for more sustainable production including through utilisation of alternative carbon feedstock (waste, biomass, CO_2) and alternative energy sources.
- *leverage* **Digital Technologies** for use in advanced process control and materials modeling, to enable disruptive business models and to create new customer experiences.

[1] KETs are knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly-skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. KETs can assist technology leaders in other fields to capitalise on their research efforts.
Ref: EC Document 30 September 2009: *Preparing for our future: Developing a common strategy for key enabling technologies in the EU*

KETs fuel EU economy - Sustainable Chemistry IMPACT examples:

1. Technical improvements in **catalyst** and related processes could further reduce **energy intensity** for chemical production processes by **20% to 40%** as a whole by 2050.
2. **Lightweight materials** are key for fuel efficiency and **reduce CO_2 emissions** in the **transport sector.**
3. Process technologies enabling **recycling of carbon from CO_2** for more sustainable production of chemicals and polymers can effectively contribute to a more circular economy.
4. By applying **big data and supercomputer science** in catalyst research **time-to-market can be three times faster** than today.
5. **Industrial Biotech** enables **2.5 billion tonnes of potential CO_2 savings** per year, which is equivalent to the **CO_2** emissions of 490 million cars.
6. Materials for **rechargeable batteries** with higher energy and power density, reduced cost, and higher cycle life will enable **700 km of electrical driving range by 2025.**
7. **Process intensification** and **plant modularization** considerably decrease energy consumption, CAPEX, and time-to-market of processes
8. Eco-design of **composites materials** lead to potential **saving of 40,000 tonnes of deposits in EU landfill** annually.
9. **Real-time Monitoring** and optimization of **resource efficiency** in chemical processes will make process lines **more energy efficient** translating into **reductions in CO_2 emissions.**
10. Advanced **insulation foam materials** will help to enable **50-80% energy savings** in the building sector
11. **Digitalisation** has the potential to reduce CO_2 emissions by **60-100 million tonnes** over the next decade. Digitally enabled business models could **generate up-to 225,000 jobs**.
12. Process technologies for the **production of major chemical building blocks** from CO_2 and H_2 from **renewable electricity** can enable high potential **CO_2 emission reduction**.
13. Implementing **digital advanced technologies** into the chemical industry in Europe could likely **increase profit margins** thus improving competitiveness and **securing jobs.**
14. The use of **alternative energy sources** in chemical processes have the potential to **lower the global warming potential significantly** compared to the conventional pathways.

Create Advanced Materials

Of essential importance to a wide range of EU economic sectors now

The advanced materials KET creates tailored materials for many value chains, including Construction, Energy, Mobility, Industry, Food, Health, and Electronics. Once a process technology for producing a material has been applied, it can be further refined to obtain final smart properties defined for a specific application. This same material technology with new functionalities can often then be used in the development of other new applications.

The goals of the Circular Economy requires disruptive innovation with respect to materials that it uses.

What can be achieved?

- Increased energy efficiency through:
  - Improved internal and external insulation of buildings, working on properties like insulation values, moisture absorption, thermal capacity, reflectance (for outdoor coatings), long life sealing, and pipe insulation
  - An holistic approach to the use of material systems in construction via Building Information Modeling (BIM)
  - Weight reduction of materials
  - Use of efficient light-absorbing and emitting chromophores
  - Cleaning clothes at lower temperatures using 30% less electricity by using washing products including enzymes
- Increased energy storage through:
  - Development of energy storage with higher energy and power density at reduced cost
  - Increased safety and cycle life for current and new battery systems for both stationary applications and electrical mobility
- Increased renewable energy production through:
  - Longer and lighter blades for wind turbines
  - Improved conversion, space efficiency, and cost base improvement of photovoltaic (PV) cells
  - Development of combined piezo- and thermo- electric properties and vibration for PV integration in roads or buildings
  - The efficient capture of solar energy to produce solar fuels
- Increased Fuel Efficiency through:
  - Reduced emissions and contaminants in fuels for transport
  - Reduced vehicle structural mass (that should also be recyclable)
  - New exhaust catalysts with lower temperature activity and/ or higher resistance to deactivation
  - CO_2 or renewables based fuels
  - Blending of biobased fuels to achieve blends with 90% GHG reduction potential
  - Development of materials with resistance to high temperature for aerospace applications
  - More efficient processing of carbon fibres for cost reduction
- Reduced emissions, waste and footprints for industries through:
  - Moving to “zero waste/discharge” using new separation membranes for water and gaseous effluents treatment
  - Biological or chemical recycling of materials and recyclable materials by design
- Increased use of byproducts from the food processing industries to create valuable products, better biocompatibility and tolerance in the human body for materials in medical devices and regeneration and integration of tissues (e.g bones, tendons, joints) through:
  - Developing antibacterial devices and implants using nanostructuration
  - Integrating biomimicry and functionalisation

  - Providing personalised devices produced by 3D printing of biocompatible materials
- Flexible sustainable, active and intelligent packaging for food through:
  - Enhancing the shelf life, quality and safety of fresh food
  - Developing recyclability and renewability of materials
  - Reducing moisture and oxygen impact
- Innovative cosmetic products through:
  - Balancing the skin's biotope, long hydration, bioavailability
  - Use of animal free prediction of risk and functionality
  - Use of biomass as raw materials
- Innovative textiles through:
  - Integrated ability to measure pulse and breathing
  - Temperature control capability

The following are key examples of the technology developments required:

New generation lightweighting technologies;

- Development of high performance reinforcement fibres (glass, carbon, bio-based etc.) for composite materials
- Re-design of polymer matrices such as thermoplastic resins for advanced mechanical properties and cost effective manufacturing
- Cellular material developments including foamed nanostructuring and aerogel polymer blends
- Development of recyclable new materials, like thermoplastic resins, biobased resins and polymers (for example, PLA and sustainable composites)
- Upcycling of (in)organic waste streams
- Development of durable coatings (erosion, resistance)
- Additives mixing

Electrodes and electrolyte technologies and separators:

- Electrodes development for next generation Li-ion batteries, flow batteries and solid state energy storage
- Development of gel polymer and solid state electrolyte ingredients and formulations for higher performance and safety
- Development of electrolytes, additives and solvents for high voltage and high capacity

Materials for ICT (see Digital Technologies):

- Embedded sensors for the Internet of Things
- New materials for future computing (memristors for neural networks, quantum computers)
- Stretchable electronics for interaction with the human body
- New man/machine interfaces

New Catalysts: (see advanced process technologies)

Stimuli responsive materials:

- Development of polymers responsive to parameters like pH, temperature, electromagnetic radiation at various wavelengths, mechanical force (e.g. self healing properties or shape memory) and hydrophobic for self cleaning
- Development of biologically responsive materials, such as enzyme responsive, biosensor applications or controlled drug delivery systems

Nanostructuring of crystalline materials, polymers and surfaces:

- Self assembly of nanostructured building blocks
- Organic nanostructures, metal organic frameworks
- Chemical functionalisation of carbon nanotubes, graphene
- Metal halide perovskites, organic electronics for solar cells, LEDs, lasers, sensors, etc.
- Nanostructured photoelectrodes for production of solar fuels and CO_2 valorisation

Formulation:

- Use of biobased compounds
- Smart, functional and engineered additives (for example, substitution of BPA, Phtalates, flame retardants etc.)
- Use of high throughput technologies and modeling (multiscale digital design) to maximise results (for example, complex mixtures)
- Sustainable liquid to powder processes and small particle control

Medical devices:

- Use of biocompatible materials
- 3D printable materials for tissue engineering

Combining stimuli responsive polymers with biological systems and nanomaterials can potentially give access to a wide variety of new functions and properties.

In addition, the following technologies **support all advanced materials** KETs and are essential for the success of research and innovation in this area:

- Characterisation
- Modeling
- Nanoengineering
- Ecodesign

Develop Advanced Process Technologies

Our commitment to sustainable production

Process Technologies enable the transformation of raw materials into materials, which have a different chemical composition, structure, and properties than the input raw materials. Advanced process technologies are a specific type of KETs that enable the chemical industry to provide all industrial value chains (e.g. construction, automotive, medical, electronics, energy) with (solid, gas and/or, liquid) the materials required and novel properties to produce a vast range of end-user products.[2]

What can be achieved?

Further reduction of the footprint of the chemical industry and its wide portfolio of products can be achieved through:

- Better utilisation of alternative carbon sources:
    - Biomass including biogeneous waste streams
    - CO_2 (and CO) from industrial sources with and without H_2
    - Waste materials (mechanical and chemical recycling)
- Utilisation of renewable electricity, alternative energy sources, H_2 with low carbon footprint
- Improved energy management and higher conversion efficiency of chemical production processes
- Sustainable water management
- Materials created through advanced processes for high efficiency in value chain applications (higher quality, increased performance, advanced & lightweight materials)
- Retrofit of existing plants for fast technical adaption and higher quality target achievement with reduced risk (novel feedstocks or processes)

Technology developments needed:

In order to achieve the above goals, a portfolio of advanced process technologies and their combination needs to be developed.

- **Process design** and realisation for sustainable process intensification, utilisation of alternative feedstock (e.g. waste/recycled materials, biomass, CO_2) and energy sources (supported by advanced sustainability-based process modeling, see Digital Technologies section),
  Advanced recycling technologies for physical and chemical recycling of materials.
- **Process and plant redesign** for retrofit of exiting assets with the optimal combination of process technologies (supported by sustainability-based advanced process modeling, see Digitital Technologies).
- More **robust and tolerant production processes** enabling flexibility towards potential specification variations in feedstock (e.g. less purified CO_2 streams, integration of different/multiple sources of feedstock in biorefineries), energy and output.
- **Modular** concept for more sustainable continuous production systems for small and medium scale chemical processes, and a competitive approach in new and developing markets. Technical developments include design and realisation of “plug-and-produce” modules (including reaction, separation/workup, pumps and other utilities) equipped with advanced process control (see also Digital Technologies) to enable different plant set-ups and flexible adaptation of scale as well as stepwise modernisation or feedstock/process adaption of existing plants.
- New **catalyst** design and development (Incl. Materials development for asymmetric, organo catalysis, tandem-reactions, and support from Digital Technologies) for higher selectivity. and reduced energy consumption (including for depolymerisation, CO_2 valorisation, H_2 production).

[2] Differs from ‘Discrete Manufacturing Technologies’ that enable the production of distinct units (systems and end-user products) by shaping materials provided by the Process industry, and assembling element, part of ‘Advanced Manufacturing Systems’ defined by the HLG KETs.

Novel catalysts should be designed and produced to be less prone to poisoning and deactivation, be able to accommodate more complex and or variable feedstock quality, be less expensive to produce, and enable integration with separation technologies to reduce the number of process steps.

- **Biotech processes** including development of enzymes/catalysts, production strains, and processes enabling the efficient production of fuels, chemicals and polymers from new feedstock sources (e.g., biomass 1st and 2nd Generation). Development of improved fermentation protocols, improved bioreactors and improved downstream technologies (see separation technologies below) to improve cost competitiveness. Enable the use of modern molecular biology, biocatalysis and process options to make biotechnology more efficient, more versatile (feedstock) and more cost competitive. Enable the use of 2nd Generation sugars and CO_2/CO with biotechnological means.
- **Electrochemical** processes including development of new electrocatalysts electrodes (see Materials), compact electrolysis cells, and bioelectrocatalytic systems (incl. for CO_2 valorisation)
- Intensified processes with **alternative energy forms** such as plasma and microwave technologies, and pyrolysis technologies for better valorisation of current and alternative types of feedstock.
- Advanced **electro photocalatytic** systems for direct utilisation of sunlight in H_2 production and $CO_{2;}$ valorisation.
- Advanced **separation technologies** including advanced and flexible thermal technologies, alternatives to thermal separations (e.g., membranes, adsorption including specific Materials development), integrated and reactive separations technologies, separation technologies for recycling (of catalysts, polymers, composites), technologies for solvent management, technologies for water management including dilute solutions for bio-processes, and separation technologies for biomass pre-treatment (incl. lignocellulosic).
- **Advanced control technologies** for optimised production including advanced sensing technologies (see Digital Technologies).

Leverage Digital Technologies

We recognise the need to fully integrate digital technologies into processes, materials development, and business models

The chemical industries' contribution to the development of advanced materials is largely the enabler for other industries' continuous development of smarter and more sustainable electronic devices and equipment (see Materials Section).

However, at the same time, the chemical industry is itself being transformed and disrupted through digitalisation. From new forms of innovation and production - including modeling of processes and materials - to new business models the chemical industry is about to go through a revolution by taking full advantage of new innovative digital technologies. The fourth industrial revolution (Industry 4.0) is present in all aspects of the chemical industry, and will have impact throughout its value chains, from procurement, logistics, process- and materials design, planning, risk management, plant operations, process automatisation, manufacturing excellence, plant safety, monitoring and predictive maintenance of factory equipment to new roads to market.

Intensified continuous and batch processes using new types of real-time-sensors/process analytical technology (PAT) and model-predictive control are being further developed. Data science in a high-performance-computing (HPC) environment and artificial intelligence will enable the efficient management and optimisation of complex processes including the recognition of unusual situations, optimised recovery measures, equipment condition monitoring, monitoring of environmental targets, model maintanance, energy consumption and emissions, including aspects of retrofitting for 'brownfield' assets. Simulation capabilities (digital-twin) along the whole life cycle of a plant specifically in early design phases of processes and plants, and especially supporting flexible, modular, miniaturised and de-localisable plant and process intensification concepts.

Materials modeling including the use of high-performance-computing will revolutionise the development of new advanced materials and structures including, for example, *in-silico* development and testing of catalysts that allow more efficiency processes (see Process Technologies).

Precision farming resulting from digitalisation is also adding value to farms, forests and food producers by enabling more sustainable primary production, harvesting, transportation and storage of biomass. This, in turn, will result in the development of even more sustainable bio-based chemicals and other products.

What can be achieved?

Engagement in digital technologies is expected to have a particularly high impact in modernising Europe's production and R&D-capabilities and will support the European chemical industry's leading position for competitiveness, sustainability and safety.

Digital technologies are a major enabler of higher plant availability, flexibility and throughput, better predictability of manufacturing, reduced lead times, remote operations, less quality issues, higher resource and energy efficiency, less costs for laboratory experimentation, switch to continous manufacturing, reduced time to market for product and process developments, more efficient plant maintenance, more efficient allocation of staff, new and disruptive business models.

Larger and smaller companies including their innovation networks need to be fully supported to leverage new digital technologies in their operations and processes.

Technology developments needed:

Process Design Phase

- '**Digital Twins**' (virtual process and/or plant models) to predict the impact of (design) decisions and to anticipate bottlenecks as well allow efficient upfront operators traing for new processes. Such **Simulation capabilities** are specifically required in early design phases to systematically assess possible alternatives in terms of capital investment, quality levels, process sustainability, operational costs and flexibility, because in this phase fundamental decisions are taken that influence significantly the overall process efficiency
- Technologies to digitally **retrofit** existing plants

Production Phase

- New control strategies for **intensified** and **modular processes** and plants
- Safe **remote-control** of plants/processes
- New types of robust **online process sensors/PATdevices** with (wireless) communication abilities
- **Sensors** to measure online the **quality of water/wastewater**
- **Real-time architectures** – to provide accurate process information to operators in real-time
- **Feedback control** to detect deviations and automatically adjust process operations immediately
- More efficient **model-predictive control** methodologies
- Advanced **operator decision support** – new technologies like 'smart glasses' and augmented reality combined with smart hand-held devices and/or wearable-technologies to provide a hitherto unknown availability of information, visualisation and interaction possibilities
- Increase energy and raw material efficiency via **data-based optimisation**
- Asset performance management and **predictive maintenance** of equipment/plants
- Use of **autonomous systems** in production and logistics

Product Design Phase

- Advanced **materials modeling** (e.g., catalyst design)
- **Modeling of complex mixtures**, structure-property relationships to achieve prediction of formulation /final product properties

Supply Chain

- Marketing and **sales channel optimisation**
- Integration into 'digital platforms' to realise **new business models**
- Use of **blockchain technologies** for, for example, logistic solutions

Data Management

- Applied **'Big Data' science** for complete utilisation of information along the whole process, value chain and transfer between the industrial and sectorial interfaces (planning assistance along the whole plant lifecycle, material flow management etc.)
- **Information integration** across operations and enterprise technology layers
- Strategies to employ **decision analytics**
- Standardised **communication platforms** for the Internet of Things (IoT)
- Broad accessibility of data to enable big data approaches and **artificial intelligence**

Impact that can be achieved by KETs

Create Advanced Materials

Light weighting technologies

- A better fuel efficiency and CO_2 reduced emissions in transport using lightweight materials: Each 100 kg of mass reduction in a car reduces the CO_2 emissions by 8 g/km.

  Polymer composites for automotive sustainability

- Ability to downsize batteries on electrical vehicles, using lightweight materials for EVs.

- Higher wind energy efficiency using lightweight materials for longer blades: 13000 tonnes of composites / installed GW .30% production time reduction.

  Wind in power: 2016 European statistics
  windeurope.org

- A better recyclability of Composites materials (potential saving of 40,000 tonnes of deposits in EU landfill per year).

  Working paper Suschem Composites circularity

Insulation foams: 50-80% energy savings in buildings

- With electricity costing some 10-25 cents per kWh and gas ranging from 3 to 12 cents per kWh a typical gas heated 100 m^2 apartment would save 100 x 56 x €0,06 = €336 per year. In terms of energy this would be some 5600 kWh per apartment saved per year. If we can refurbish some 180.000 apartments per year under the Smart Cities program and build also some 20.000 new ones using the proposed solutions then this would bring a total saving of 1.120 million kWh.

- For commercial buildings, the possible target to refurbish some 10.000 office buildings of on average 5.000 m^2 per building, which would deliver at 40% energy reduction, could result in 3.9 billion kWh saved annually. This would provide an equivalent of 350 million euros of annual savings.

  Suschem brochure:
  Innovative Chemistry for energy efficiency in smart cities

Electrolyte / electrodes/separators technologies

- Increased energy storage through higher energy and power density, reduced cost, cycle life increase through materials for rechargeable batteries: 600 GWh by 2025 mainly in electrification. 700 km of electrical driving range to be expected by 2025.

  Fraunhofer Institute for System and Innovation Research ISI; BMW communication on new battery cell center

Impact that can be achieved by KETs

Develop Advanced Process Technologies

CO_2 as alternative feedstock and renewable electricity

Process technologies for the production of major chemical building blocks (e.g. methanol, olefins and BTX) from CO_2 and H_2 from renewable electricity can enable high potential CO_2 emission reduction in the chemical industry, as evaluated by DECHEMA in a recent study. As an example:

-1.13tCO_2/t olefin for alternative CO_2-based route vs 0.76tCO_2/t olefin for the fossil based route, i.e. 1.89t CO_2 avoided/t olefin, which in a theoretical maximum deployment scenario in 2050 would lead to 79.2 CO_2 mill. t per year CO_2 avoided vs fossil route, for an electricity demand of 3,270 TWh, and significant investments.

The same process technologies, can have an even higher absolute impact (evaluated on a well-to wheel basis) if used for the production synthetic fuels.

Low carbon energy and feedstock for the European chemical industry, Technology Study, DECHEMA, 2017

Alternative energy sources: Plasma

For the Nitrogen fixation process assisted by plasma technology and incorporating renewable energy: a reduction in the global warming potential of 19% as compared to the conventional production pathway has been reported from the Mapsyn project.

Life Cycle Assessment of the Nitrogen Fixation Process Assisted by Plasma Technology and Incorporating Renewable Energy
Ind. Eng. Chem. Res., 2016, 55 (29), pp 8141–8153

Catalyst & Process

Technical improvements in catalyst and related process could reduce energy intensity for the top 18 energy intensive large volume chemicals by 20% to 40% as a whole by 2050 combining all scenarios. In absolute terms, improvements could save as much as 13 EJ (exajoules) and 1 Gt of carbon dioxide equivalent (CO_2-eq) per year by 2050 versus a "business-as-usual" scenario. Catalysis is thus crucial to reduce this environmental burden

European Cluster on Catalysis, October 2016
Science and Technology roadmap on catalysis for Europe, A path to create a sustainable future

IEA-ICCA-DECHEMA, 2013
Technology Roadmap, Energy and GHG Reduction in the Chemical Industry via Catalytic Processes

Process intensification and plant modularization

Process intensification and plant modularization will decrease energy consumption of processes up to -30%, CAPEX by -40%, and time-to-market by -50% have been reported from the F^3 Factory project (2013).

F^3 Factory Project:
http://www.f3factory.com/scripts/pages/en/home.php

Industrial Biotechnology

- Industrial biotech (IB), one of the six technologies identified as a KET by the EU, is broadly accepted as one of the EU's core strengths, helping enable a more competitive and sustainable bioeconomy. When considering direct, upstream, and downstream employment, IB alone is predicted to contribute up to 1.5 million jobs adding almost €100 billion to the EU economy by 20301. Its potential to, quite literally, catalyse the transition towards a renewable future is being harnessed by an increasing number of sectors, creating new value chains. Therefore, IB is often considered the key to the development of the bioeconomy.
- Industrial biotech can also add value to industrial side streams such as CO_2, as well as biogenic waste streams, making valuable products from what might otherwise be considered either worthless or a cost burden. In this regard, IB can also make an important contribution to the Commission's objective to turn waste into a resource, a key pillar of the Commission's circular economy approach.
- Saving 31 million tonnes of CO_2 as a result of industrial biotechnology[2]. Using 30% less energy with biological washing powders enabling clothes to be cleaned at 30°C rather than 40°C[3]. This will result in 2.5 billion tonnes of potential CO_2 savings per year from Industrial Biotech[4], which is equivalent to the CO_2 emissions of 490 million cars.
- Improving crop production and preserving soil quality through the use of biodegradable agricultural mulch films. Reducing the use of water and chemicals by using enzymes for leather and textile production.
- Making lightweight and durable bio-based plastics and tyres for the automotive industry. Improving the efficiency of pulp and paper production. Producing bio-based molecules with new and novel functionalities such as durable and shatterproof smart phone and tablet screens.
- Making 100% recyclable and bio-based plastics for consumer products and packaging. Enabling investment of €3.7 billion in bio-based research and innovation in Europe over 7 years (2014-2021). Contributing up to 1.5 million jobs adding almost €100 billion to the EU economy by 2030[1]

EuropaBio - The European Association for Bioindustries

1. https://www.europabio.org/industrial-biotech/publications/jobs-and-growth-generated-industrial-biotechnology-europe
2. Annual global impact: WWF Denmark 2009
3. Life cycle assessment supporting cold wash enzymes: International Journal of Applied Sciences 2005
4. Annual global impact: WWF Denmark 2009

Impact that can be achieved by KETs

Leverage Digital Technologies

Advanced Digital Technologies:

As result of further developing and implementing digital advanced technologies, the chemical industry in Europe could likely increase profit margins by 10 - 15% thus improving competitiveness and securing industrial jobs in Europe.

Deloitte study 2017: *Digital Transformation: Are chemical companies ready?*

Catalyst & Process Simulation/Modeling:

"BASF applies 'big data' in catalyst research we reached a factor of 3 reduction in cycle times from customer request to the first promising product"

Public statement Frithjof Netzer, Senior Vice President BASF 4.0

Real-time Monitoring and Optimization of Resource Efficiency:

Extrapolating from our results, we believe that visualizing resource indicators in real-time will make process lines 2-3% more energy efficient. This improvement in efficiency translates directly into energy savings and reductions in CO_2 emissions.

FP7 project MORE,
interview Stefan Krämer of INEOS
http://ec.europa.eu/research/infocentre/article_en.cfm?&artid=42677&caller=SuccessStories

Social and Economic Benefits of Digitalisation within the Chemical Industry – Value-at-Stake:

Digitalisation has the potential to save 20 to 30 lives, to avoid 2000 to 3000 injuries and to reduce CO_2 emissions by 60-100 million tonnes over the next decade. Digitally enabled business models and offerings could generate 100,000 to 225,000 jobs. Across value migration and value addition to the chemical industry, the estimated cumulative economic value for the period 2016 to 2025 ranges from approximately €250 billion to €500 billion.

World Economic Forum, Digital Transformation Initiative, Chemistry and Advanced Materials Industry, 2017