Coordinating European Strategies on Sustainable Materials,

Processes and Emerging Technologies Development in Chemical Process

and Water Industry across Technology Platforms

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Joint Research and Development Roadmap (JR&DR) on Water in Chemical Process Industries Across ETPs

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SUMMARY:

This roadmap is based on the strategic documents of the ETPs (European Technology Platforms) SusChem (European Technology Platform for Sustainable Chemistry) and WssTP (European Water Platform) and on the three ChemWater Vision 2050 workshops entitled: "Vision and Challenges", "Tools and Methodologies" as well as "Processes, Materials and Technologies for Water Sustainable Process Industry", held during 2012.

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ChemWater

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Introduction

The European Chemical Industry and aligned sectors has a pivotal role to play in the transition towards a sustainable, competitive and knowledge-based European society. In combination with its own downstream and supplier sectors, the chemical sector can provide an environmentally sensitive source of innovation that can contribute to improved economic and social welfare.

The authors of this report, comprising the European Technology Platforms SusChem and WssTP, seek to boost the competitiveness of European Industry by strengthening chemistry, biotechnology and chemical engineering research and development in Europe. We envision the future of the European chemical and associated industries as driving enhanced global competitiveness and minimal environmental impact, powered by world-leading technological innovation.. These industries will maintain a substantial contribution to EU employment and will enjoy widespread societal appreciation. This is an important prerequisite to fulfill Europe's vision of a sustainable and competitive knowledge-based economy. This vision is deliberately positive in the sense that it sets out how we think the European chemical industry can act as a catalyst for a more resource efficient economy, one which has successfully decoupled economic growth from resource consumption and pollution.

This document constitutes an important reference point for all stakeholders in Europe who wish to work with the chemical and associated sectors to co-ordinate future research funding policies at European level. Such collaboration will help secure the innovation base of the chemical industry in Europe and strengthen its role as an innovation engine for many allied and downstream businesses.

The ChemWater project has developed a vision for the chemical and allied industries through to the year 2050 and identified the actions needed now and in the future to realize the vision. These actions include both technical and non-technical advancements that need to be made in order to achieve the sector's ambitions. As such, the contents of this document inform the design and establishment of research and innovation programmes for the coming decades.

The ChemWater vision for the European Chemical Industry and aligned sectors in 2050 envisages that:

1. The European Chemical Industry and aligned sectors will be a benchmark sector for sustainable water management
2. The European chemical and associated process industries, as well as consumers along the value chain, will act to minimize water footprint.
3. The growth of current and new industrial sectors e.g. industrial biotechnology will be decoupled from higher resource consumption.
4. The European chemical and associated process industries as well as consumers along the value chain will make zero contribution to water stress.
5. New water and waste water treatment technologies will deliver water of appropriate quality for the type of use / discharge environment.
6. Sustainable and efficient water management will be based on efficient and reduced energy use.
7. Energy sources will be diversified and mainly based on the use of onsite energy production and the utilisation of renewables, leading to zero or minimum contribution to carbon footprint.
8. A symbiotic approach for ecological and economical efficient use of water and other resources, integrating industrial, urban and rural/agricultural resource flows will be widely implemented.
9. The European chemical industry will fully exploit their position as an enabler for the entire economy to provide opportunities for other sectors to deliver innovative solutions to water resource management challenges.
10. Stakeholders will have reliable, innovative and sustainable industrial water management solutions available.

WATER QUANTITY

WATER QUANTITY

WATER-ENERGY

NON TECHNOLOGICAL

Joint research and development needs to address the ChemWater vision to 2050

A desire to achieve industrial leadership and the need to address a range of societal challenges are the main drivers for innovation in Europe. With respect to water, the key enabling technologies to strengthen European industrial leadership are split into three categories: Ensuring that there is enough water to meet industrial, municipal, agricultural, and environmental demand; Ensuring that water of sufficient quality is available to match the demand; Ensuring that water services are delivered in an energy and carbon efficient manner.

The following sections list requirements in the form of technologies, initiatives, and other goals which need to be delivered in order for the vision illustrated above to be realised. Many of the suggestions made have been taken from reports by other initiatives (see footer for coding used to reference these).

CHAPTER 1: Industrial Leadership - Key enabling technologies

WATER QUANTITY

ICT:

A number of types of activity will target ICT industrial and technological leadership challenges and cover generic ICT research and innovation agendas.

General issues

- Systems and tools (including real time monitoring) to control water quality (including specific micro pollutants, microorganisms in complex matrices) and quantity (Sp)
- Systems and tools to continuously assess the availability and reliability of alternative sources;
- Methodologies, simulation tools, scenario analyses

Internal recycling and reuse, focusing on sustainable/advanced reuse and water loop closure.

- Online monitoring of water quality (monitoring of impurities accumulated due to water reuse) (S) (W).

Nanotechnologies:

Alternative water sources: purified wastewater (usually brackish water)

- Desalination technologies, e.g. for treatment of cooling tower blow down water, to increase re-use potential.

Alternative sources: water symbiosis

- Wastewater treatment technologies designed for reuse of waste water collected and transported from one production site/industrial park/areas to another (S)
- Reliable treatment adapted to cope with high variability of influents (load, composition and quantity) for each industrial sector, urban area (Aq)
- Selective removal of pathogens

CHEMWATER VISION 2050 FOR WATER QUANTITY:

1. THE EUROPEAN CHEMICAL INDUSTRY AND ALIGNED SECTORS WILL BE A BENCHMARK SECTOR FOR SUSTAINABLE WATER MANAGEMENT

2. THE EUROPEAN CHEMICAL AND ASSOCIATED PROCESS INDUSTRIES, AS WELL AS CONSUMERS ALONG THE VALUE CHAIN, WILL ACT TO MINIMIZE WATER FOOTPRINT.

3. THE GROWTH OF CURRENT AND NEW INDUSTRIAL SECTORS E.G. INDUSTRIAL BIOTECHNOLOGY WILL BE DECOUPLED FROM HIGHER RESOURCE CONSUMPTION.

4. THE EUROPEAN CHEMICAL AND ASSOCIATED PROCESS INDUSTRIES AS WELL AS CONSUMERS ALONG THE VALUE CHAIN WILL MAKE ZERO CONTRIBUTION TO WATER STRESS.

8. A SYMBIOTIC APPROACH FOR ECOLOGICAL AND ECONOMICAL EFFICIENT USE OF WATER AND OTHER RESOURCES, INTEGRATING INDUSTRIAL, URBAN AND RURAL/AGRICULTURAL RESOURCE FLOWS WILL BE WIDELY IMPLEMENTED.

It is important for the European chemical industry to be less dependent on external fresh water sources in the future. This can be achieved through a range of interventions such as increasing recycling including recycled urban wastewater, closing water circuits, employing new, less water intensive or waterless technologies, using rainwater harvesting and storage where appropriate and using water qualities tailored to product and process

- Selective removal of valuable resources from wastewaters (e.g. N,P,K for agriculture)

Internal recycling and reuse, focusing on Sustainable/Advanced reuse and water loop closure.

- Improved Design of the water system (Reaction and Process Design).
  - Selective separation processes aiming at an optimal 'designed' water (S).
  - Reduce bio-fouling in industrial water systems, so that less cleaning activities are needed (S) (W).
- Water treatment technologies.
  - Highly selective separation technologies (ion exchange systems, renewable and non-renewable sorbents, membranes) (Sp).
  - Salt separation treatment integrated into industrial re-use strategies in order to limit corrosion (Chloride) and scaling (Aq).
  - Further development and proliferation of small and compact water desalination devices (W).

Surface treatment (e.g. self-cleaning surfaces).

Advanced Materials:

Alternative water sources: purified wastewater (usually brackish water)

- Desalination technologies, e.g. for treatment of cooling tower blow down water, to increase re-use potential.

Alternative sources: water symbiosis

- Wastewater treatment technologies designed for reuse of waste water collected and transported from one production site/industrial park/areas to another (S)
- Reliable treatment adapted to cope with high variability of influents (load, composition and quantity) for each industrial sector, urban area (Aq)
- Selective removal of pathogens
- Selective removal of valuable resources from wastewaters (e.g. N,P,K for agriculture)

New design of processes: Processes using less water - Sustainable use of water in process.

- Advanced/multifunctional materials contributing to process intensification; examples cited:
  - Catalysts improving energy efficiency and process efficiency in water treatment. (S)
  - Improved efficiency of photocatalysts, e.g. improved efficiency at natural light wave length
  - Catalytic combined processes for adsorption and/or oxidation (nano-materials) (W).
  - Ceramic membranes with catalytic properties
  - Materials with increased separation performance (S).
  - Nanostructured membranes (S).
  - Increase of membrane capacity by nanotechnologies (Aq).

Internal recycling and reuse, focusing on sustainable/advanced reuse and water loop closure.

- Improved Design of the water system (Reaction and Process Design).

- Selective separation processes aiming at an optimal 'designed' water (S).
- Reduce bio-fouling in industrial water systems, so that less cleaning activities are needed (S) (W).

- Water treatment technologies.
    - Highly selective separation technologies (ion exchange systems, renewable and non-renewable sorbents, membranes) (Sp).
    - Salt separation treatment integrated into industrial re-use strategies in order to limit corrosion (Chloride) and scaling (Aq).
    - Further development and proliferation of small and compact water desalination devices (W).

Surface treatment (e.g. self-cleaning surfaces).

Product for leakage reduction: coating/ sealants that repair and renew water distribution systems to reduce water loss; new materials for pipes.

Biotechnology:

Alternative sources: water symbiosis

- Wastewater treatment technologies designed for reuse of waste water collected and transported from one production site/industrial park/areas to another (S)
- Reliable treatment adapted to cope with high variability of influents (load, composition and quantity) for each industrial sector, urban area (Aq)
- Selective removal of pathogens
- Selective removal of valuable resources from wastewaters (e.g. N,P,K for agriculture)

New design of processes: Processes using less water - Sustainable use of water in process.

- Implementation and improvement of Industrial Biotechnology processes, examples cited:
    - Replace 'classic' processes by biotechnological processes (W)(S).
    - Optimization and integration of processes for water and energy efficient production of bio-based platform chemicals (bio-refineries) (S).
    - Integration of downstream processing and bioprocess (e.g. development of water based chemo-enzymatic routes: biocatalytic process design/integration of biocatalysts into industrial processes) (S).
    - Industrial biotech application of membrane technology for water removal (S).
    - Optimize current processes or rethink/redesign processes e.g. moving from Industrial Biotechnology batch to continuous Industrial Biotechnology processes to reduce water use for cleaning activities (S) (W).
    - Enable bioconversions in more concentrated solutions (S) (Sp)

Advanced Manufacturing and Processing:

New design of processes: Processes using less water - Sustainable use of water in process.

- RPD (Reaction and Process Design): described as optimisation or rethink/redesign of processes resulting directly or indirectly in water saving; this includes technology development towards process intensification (S) (W) (Sp); examples cited.
    - Optimization of membrane separation for innovative downstream processes.
    - Dry technologies.

Internal recycling and reuse, focusing on Sustainable/Advanced reuse and water loop closure.

- Improved Design of the water system (Reaction and Process Design).
    - Selective separation processes aiming at an optimal 'designed' water (S).
    - Reduce bio-fouling in industrial water systems, so that less cleaning activities are needed (S) (W).
- Water treatment technologies.
    - Highly selective separation technologies (ion exchange systems, renewable and non-renewable sorbents, membranes) (Sp).
    - Salt separation treatment integrated into industrial re-use strategies in order to limit corrosion (Chloride) and scaling (Aq).
    - Further development and proliferation of small and compact water desalination devices (W).

WATER QUALITY

Nanotechnologies:

Alternative sources: water symbiosis

- Selective removal of pathogens
- Selective removal of valuable resources from wastewaters (e.g. N,P,K for agriculture)

Internal recycling and reuse, focusing on Sustainable/Advanced reuse and water loop closure.

- Water Treatment technologies.
    - Highly selective separation technologies (ion exchange systems, renewable and non-renewable sorbents, membranes) (Sp).
    - Salt separation treatment integrated into an industrial re-use strategy in order to limit corrosion (Chloride) and scaling (Aq).

Towards more innovative treatment and process solutions.

- Catalyst for water remediation (S).
- Catalytic combined processes for adsorption and/or oxidation (nano-materials) (W).
- Optimization of membranes for integrated reactive and hybrid separations.

Sustainable treatment of brines

- Energy saving membrane for concentrate treatment (Aq)
- Low fouling selective membrane for electro-dialysis treatment (Aq).

Development and efficient use of sustainable chemicals and technologies for water and wastewater treatment.

- Product design of chemical and biotech solutions/products for water and wastewater treatment (flocculation, coagulation, etc.) (with reduced environmental impact, optimised dosing, more selective reaction and energy optimisation) (S).
- Products and materials for filtration, separation technologies (membranes, adsorbents, etc.)

Waste stream valorisation: valuables recovery, selective separation of pollutants aiming at an improved quality of the remaining waste water stream:

- Selective separation of inorganic compounds with functionalized membrane (Aq).
- Selective separation of organic compounds through:
    - Functionalized membrane (Aq).
    - Membranes and PI integration.
- Selective separation of bio nutrients (e.g. phosphates and nitrates):
    - Coupled to water recovery: Valorisation of nutrient rich streams for biomass production and biomass valorisation; Valorisation of fermentation residue streams

Design of products to ensure sustainable wastewater treatment during the use and disposal phases of products.

- Self-cleaning materials and coatings, so that less water is used and polluted (S).

CHEMWATER VISION 2050 FOR WATER QUALITY:

4. THE EUROPEAN CHEMICAL AND ASSOCIATED PROCESS INDUSTRIES AS WELL AS CONSUMERS ALONG THE VALUE CHAIN WILL MAKE ZERO CONTRIBUTION TO WATER STRESS.

5. NEW WATER AND WASTE WATER TREATMENT TECHNOLOGIES WILL DELIVER WATER OF APPROPRIATE QUALITY FOR THE TYPE OF USE / DISCHARGE ENVIRONMENT.

New technologies helping to utilize waste and wastewater as a source of energy more efficiently will have to be adopted, including primary anaerobic wastewater treatment leading to more biogas production and the use of dry dewatered sludge as a fuel. New energy efficient solutions for inorganic contaminants will also have to be employed. To substantially reduce the pollution associated with chemical products, a treatment solution for all industrial products will be required and this should become a standard.

Advanced Materials:

In-process optimisation in material and product usage, maintenance, etc.

- Reduce bio-fouling and scaling in industrial water systems (S) (W).
    - Material surface properties/ treatment.
    - Industrial biotech treatments (enzymes).
- Reduce corrosion in industrial water systems units and pipes and deposition of solids from process water in industrial processes.
    - Anti-corrosion materials and coatings.
    - Appropriate water treatment: salt-separation treatment integrated into an industrial re-use strategy in order to limit corrosion (Chloride) and scaling (Aq).

Towards more innovative treatment and process solutions.

- Catalysts for water remediation (S).
- Catalytic combined processes for adsorption and/or oxidation (nano-materials) (W).
- Optimization of membranes for integrated reactive and hybrid separation.
- Optimisation and development of membrane technology and/or system design to achieve higher performance, flux and selectivity, with respect to new contaminants in water streams (such as organic and pharmaceutical compounds, and ions originating from electronics) (W).

Sustainable treatment of brines

- Energy saving membrane concentrate treatment (Aq)
- Low fouling selective membrane for electro-dialysis treatment (Aq).

Development and efficient use of sustainable chemicals and technologies for water and wastewater treatment.

- Product design of chemical and biotech solutions/products for water and wastewater treatment (flocculation, coagulation, etc.) (with reduced environmental impact, optimised dosing, more selective reaction and energy optimisation) (S).
- Products and materials for filtration, separation technologies (membranes, adsorbents, etc.)

Waste streams valorisation: valuables recovery, selective separation of pollutants aiming at an improved quality of the remaining waste water stream:

- Selective separation of inorganic compounds with functionalized membrane (Aq).
- Selective separation of organic compounds through:
    - Functionalized membranes (Aq).
    - Membranes and PI integration.
- Selective separation of bio nutrients (e.g. phosphates and nitrates):
    - Coupled to water recovery: Valorisation of nutrient rich streams for biomass production and biomass valorisation; Valorisation of fermentation residue streams

Design of products to ensure sustainable wastewater treatment during the use and disposal phases of products.

- Self-cleaning materials and coatings, so that less water is used and polluted (S).

Biotechnology:

Design of the industrial processes towards sustainable water and wastewater treatment.

- Industrial biotechnology (IB).
  - ❑ Optimization and integration of processes for water and energy efficient production of bio-based platform chemicals (bio-refineries) (S).
  - ❑ Optimize biomass extraction (S).
  - ❑ Enable higher feed concentrations for fermentation systems (S) (Sp).

In-process optimisation in material and product usage, maintenance, etc.

- Reduce bio-fouling and scaling in industrial water systems (S) (W).
  - ❑ Material surface properties/ treatment.
  - ❑ Industrial biotech treatments (enzymes).

Development and efficient use of sustainable chemicals and technologies for water and wastewater treatment

- Product design of chemical and biotech solutions/products for water and wastewater treatment (flocculation, coagulation, etc.) (with reduced environmental impact, optimised dosing, more selective reaction and energy optimisation) (S).
- Products and materials for filtration, separation technologies (membranes, adsorbents, etc.)

Waste streams valorisation: valuables recovery, selective separation of pollutants aiming at an improved quality of the remaining waste water stream:

- Selective separation of bio nutrients (e.g. phosphates and nitrates):
  - ❑ Coupled to water recovery: Valorisation of nutrient rich streams for biomass production and biomass valorisation; Valorisation of fermentation residue streams

Advanced Manufacturing and Processing:

Design of the industrial processes towards sustainable water and wastewater treatment

- Reaction & Process Design (RPD): examples cited
  - ❑ Optimize current process or rethink/ redesign processes to optimize sustainability (with the objective to optimize water quality (incl. reduced pH shift for IB) while improving water use; energy, and raw materials consumption and minimize waste) (W)(S) = process intensification, including IB (e.g. solid state fermentation).
  - ❑ Catalysts can contribute to achieving zero waste emissions and selectively use the energy in chemical reactions (S).
  - ❑ On-line monitoring systems, in order to steer towards an optimal water quality (Sp).
  - ❑ Selective separation processes: optimization of membrane separation for innovative downstream processes (S) (W).
  - ❑ Optimization of membranes for integrated reactive and hybrid separations, aiming at an improved effluent quality.

Towards more innovative treatment and process solutions.

- Optimize the current water processes or rethink/redesign processes aiming at an improved effluent quality (W)(S).
- Cost effective oxidative or electro-oxidative treatments with control of by-products (Aq).
- Novel concentrate treatment options (such as membrane crystallization) (also reuse) (W).

- Innovative processes to remove salts from liquid effluents/further development and proliferation of small and compact water desalination devices (W).
- Optimized on-site treatments of aqueous waste streams (S).

Sustainable treatment of brines

- Energy saving membrane concentrative treatment (Aq)
- Low fouling selective membrane for electro-dialysis treatment (Aq).
- Crystallization (precipitation or thermal) processes with by-product control (Ag).

Development and efficient use of sustainable chemicals and technologies for water and wastewater treatment

- Product design of chemical and biotech solutions/products for water and wastewater treatment (flocculation, coagulation, etc.) (with reduced environmental impact, optimised dosing, more selective reaction and energy optimisation) (S).
- Products and materials for filtration, separation technologies (membranes, adsorbents, etc.)

Design of products to ensure sustainable wastewater treatment during the use and disposal phases of products.

- Product design and formulation of consumer goods (e.g. formulation of medicines) (S).
- Self-cleaning materials and coatings, so that less water is used and polluted (S).

WATER-ENERGY NEXUS

Nanotechnologies:

Reduce scaling in industrial water systems (S) (W).
Reduce corrosion in industrial water systems (S) (W).

- Anti-corrosion materials and coatings.
- Appropriate water treatment: salt separation treatment integrated into an industrial re-use strategy in order to limit corrosion (Chloride) and scaling (Ac).

Reduce the energy levels that are needed for water and steam related production processes.
Catalysts for water and/or steam based reaction systems (temperature) (S) (Sp).

Advanced Materials:

Water treatment technologies.

- Advanced material / product design for water filtration (e.g. nano-membranes) towards a more energy-friendly treatment (S)
- Reconsideration of forward osmosis, pressure-retarded osmosis and reverse electro-dialysis as alternative membrane techniques for process water production and that generate power from salinity gradients (W)
    - Use of renewable energy: water treatment systems coupled with renewable energy sources for a significant reduction in energy consumption (W, Sp).

Reduce scaling in industrial water systems (S) (W).
Reduce corrosion in industrial water systems (S) (W).

- Anti-corrosion materials and coatings.
- Appropriate water treatment: salt separation treatment integrated into an industrial re-use strategy in order to limit corrosion (Chloride) and scaling (Ac).

Reduce the energy levels that are needed for water and steam related production processes.

- Catalysts for water and/or steam based reaction systems (temperature) (S) (Sp).
- Low energy water treatment processes, e.g. pressure reduction in membrane technologies like forward osmosis (S) (W).

Biotechnology:

Reduce bio-fouling in industrial water systems (S) (W).

- Biotechnology.

Reduce corrosion in industrial water systems (S) (W).

- Anti-corrosion materials and coatings.

Appropriate water treatment: salt separation treatment integrated into an industrial re-use strategy in order to limit corrosion (Chloride) and scaling (Ac).

Advanced Manufacturing and Processing:

Water treatment technologies.

- Advanced material / product design for water filtration (e.g. nano-membranes) towards a more energy-friendly treatment (S)

Reduce scaling in industrial water systems (S) (W).
Reduce the energy levels that are needed for water and steam related production processes.

- Low energy water treatment processes, e.g. pressure reduction in membrane technologies like forward osmosis (S) (W).

Energetic conversion/valorisation of by-products / compounds within wastewater (Sp).

CHEMWATER VISION 2050 FOR WATER-ENERGY NEXUS:

6. SUSTAINABLE AND EFFICIENT WATER MANAGEMENT WILL BE BASED ON EFFICIENT AND REDUCED ENERGY USE.

7. ENERGY SOURCES WILL BE DIVERSIFIED AND MAINLY BASED ON THE USE OF ONSITE ENERGY PRODUCTION AND THE UTILISATION OF RENEWABLES, LEADING TO ZERO OR MINIMUM CONTRIBUTION TO CARBON FOOTPRINT.

By 2050 sustainable and efficient water management should also mean lower energy consumption and the utilization of renewables, leading to zero or minimum carbon footprint. It will be increasingly important to have a clear understanding of water use associated with different types of energy. To make desalination sustainable, renewables will have to be employed and the environmental impact of brines produced during this process will have to be minimized. These types of initiative can be very complex as the water related drawbacks of some renewables will have to be considered.

CHAPTER 2: Actions needed to address societal challenges

SUSTAINABLE AND COMPETITIVE BIO-BASED INDUSTRIES

The overall objective is to accelerate the conversion of fossil-based European industries to low carbon, resource efficient and sustainable ones. Research and innovation will provide the means to reduce the Union's dependency on fossil fuels and contribute to meeting its energy and climate change policy targets for 2020. Synergies will be sought with the 'Leadership in Enabling and Industrial Technologies' specific objective.

New design of processes: Processes using less water - Sustainable use of water in process.

- Implementation and improvement of Industrial Biotechnology (IB) processes, examples cited:
    - Replace ‘classic’ processes by IB processes (W)(S).
    - Optimization and integration of processes for water and energy efficient production of bio-based platform chemicals (bio-refineries) (S).
    - Integration of downstream processing and bioprocess (e.g. development of water based chemo-enzymatic routes: biocatalytic process design/integration of biocatalysts into industrial processes) (S).
    - Industrial biotech application of membrane technology for water removal (S).
    - Optimize current processes or rethink/redesign processes e.g. moving from IB batch to continuous IB processes to reduce water use for cleaning activities (S) (W).

In-process optimisation in material and product usage, maintenance, etc.

- Reduce bio-fouling and scaling in industrial water systems (S) (W).
    - Material surface properties/ treatment.
    - Industrial biotech treatments (enzymes).

Towards more innovative treatment and process solutions.

- Cost effective oxidative or electro-oxidative treatments with control of by-products (Aq).

Reduce bio-fouling in industrial water systems (S) (W).

- Material surface properties/ treatment.

Biotechnology.

REDUCING ENERGY CONSUMPTION AND CARBON FOOTPRINT THROUGH SMART AND SUSTAINABLE USE

The energy sources and consumption patterns of Europe's industries are largely unsustainable, leading to significant environmental and climate change impacts. The development of near-zero-emission industries and mass take-up of energy-efficient approaches by companies will require not only technological advances, but also non-technological solutions.

CHEMWATER VISION 2050 FOR NON TECHNOLOGICAL - SOCIETAL PERSPECTIVES FOR WATER:

1. THE EUROPEAN CHEMICAL INDUSTRY AND ALIGNED SECTORS WILL BE A BENCHMARK SECTOR FOR SUSTAINABLE WATER MANAGEMENT

8. A SYMBIOTIC APPROACH FOR ECOLOGICAL AND ECONOMICAL EFFICIENT USE OF WATER AND OTHER RESOURCES, INTEGRATING INDUSTRIAL, URBAN AND RURAL/AGRICULTURAL RESOURCE FLOWS WILL BE WIDELY IMPLEMENTED.

9. THE EUROPEAN CHEMICAL INDUSTRY WILL FULLY EXPLOIT THEIR POSITION AS AN ENABLER FOR THE ENTIRE ECONOMY TO PROVIDE OPPORTUNITIES FOR OTHER SECTORS TO DELIVER INNOVATIVE SOLUTIONS TO WATER RESOURCE MANAGEMENT CHALLENGES.

10. STAKEHOLDERS WILL HAVE RELIABLE, INNOVATIVE AND SUSTAINABLE INDUSTRIAL WATER MANAGEMENT SOLUTIONS AVAILABLE.

Unlock the potential of efficient and renewable heating-cooling systems

Sustainable cooling & heating.

- Innovative processes and technologies for cooling and heating (with less or no water) (S).
- Alternative sources of water for cooling (W).
- Stronger linkage between cooling and process water (S)
- More environmentally friendly cooling processes (S)
- More efficient technologies to recover (low temperature) heat (S)

Reduce bio-fouling in industrial water systems (S) (W).

- Material surface properties/ treatment.

Efficient heat exchanger / Thermal storage (S).

- Recovery of low heat energy(S).

NEW KNOWLEDGE AND TECHNOLOGIES

Sustainable cooling & heating.

- Innovative processes and technologies for cooling and heating (with less or no water) (S).
- Alternative source of water for cooling (see alternative sources) (W).
- Stronger linkage between cooling and process water (S)
- More environmentally friendly cooling processes (S)
- More efficient technologies to recover (low temperature) heat (S)

Sustainable treatment of brines

- Energy saving membrane concentrate treatment (Aq)
- Energy saving distillation processes (Aq).

Provide water qualities to industries' specifications which are 'fit-for-use", so that no further treatment is needed (Sp) (S).

Water treatment technologies.

- Advanced material / product design for water filtration (e.g. nano-membranes) towards a more energy-friendly treatment (S)
- Reconsideration of forward osmosis, pressure-retarded osmosis and reverse electro-dialysis as alternative membrane techniques for process water production and that generate power from salinity gradients (W)
    - ❑ Use of renewable energy: water treatment systems coupled with renewable energy sources for a significant reduction in energy consumption (W, Sp).

Efficient heat exchanger / Thermal storage (S).

- Improved technologies for energy recovery (W)(S.)
- Recovery of low heat energy(S).

Energetic conversion/valorisation of by-products / compounds within wastewater (Sp).

CLIMATE ACTION, RESOURCE EFFICIENCY AND RAW MATERIALS

Internal recycling and reuse, focusing on Sustainable/Advanced reuse and water loop closure.

- Knowledge on water quality demands, in order to aim at optimal reuse (Sp).

Promote the sustainable supply and use of raw materials, covering exploration, extraction, processing, recycling and recovery

General issues

- Assessment of water quality demands, in order to aim at optimal reuse (Sp)

Alternative source: rain water

- Natural systems for water storage during periods with excess of water (e.g. aquifer recharge, wells) to face temporary water scarcity. (Sp)

Alternative source: groundwater

- Consider artificial groundwater recharge; assess chemical and thermal quality.

Alternative sources: water symbiosis

- Wastewater treatment technologies designed for reuse of waste water collected and transported from one production site/industrial park/areas to another (S)
- Reliable treatment adapted to a high variability of influents (load, composition and quantity) on each industrial sector, urban area (Aq)
- Selective removal of pathogens
- Selective removal of valuables (e.g. N,P,K for agriculture)

Towards more innovative treatment and process solutions.

- Optimization of membranes for integrated reactive and hybrid separations.
- Optimisation and development of membrane technology and/or system design to achieve higher performance, flux and selectivity, with respect to new contaminants in water streams (such as organic and pharmaceutical compounds, and ions originating from electronics) (W).
- Novel concentrate treatment options (such as membrane crystallization) (also reuse) (W).
- Innovative processes to remove salts from liquid effluents / further development and proliferation of small and compact water desalination devices (W).
- Optimized on-site treatments of aqueous waste streams (S).

Sustainable treatment of highly loaded liquid streams.

- Tailored wastewater treatment technologies.

Sustainable treatment of brines

- Energy saving membrane concentrative treatment (Aq)
- Low fouling selective membrane for electro-dialysis treatment (Aq).
- Crystallization (precipitation or thermal) processes with by-product control (Ag).

Waste streams valorisation: valuables recovery, selective separation of pollutants aiming at an improved quality of the remaining waste water stream:

- Identification of priorities and appropriate reuse opportunities (S).
- Selective separation of inorganic compounds with functionalized membrane (Aq).
- Selective separation of organic compounds through:
    - ❑ Functionalized membrane (Aq).
    - ❑ Membranes and PI integration.
- Selective separation of bio nutrients (e.g. phosphates and nitrates):
    - ❑ Coupled to water recovery: Valorisation of nutrient rich streams for biomass production and biomass valorisation; Valorisation of fermentation residue streams

Reduce corrosion in industrial water systems (S) (W). Appropriate water treatment: salt separation treatment integrated into an industrial re-use strategy in order to limit corrosion (Chloride) and scaling (Ac).

Strengthen eco-innovative technologies, processes, services and products and boost their market uptake

All forms of innovation, both incremental and radical, combining technological, organizational, societal, behavioral, business and policy innovation, and strengthening the participation of civil society, will be supported. This will underpin a more circular economy, while reducing environmental impacts and taking account of rebound effects on the environment.

Alternative sources: water symbiosis

- Wastewater treatment technologies designed for reuse of waste water collected and transported from one production site/industrial park/areas to another (S)
- Reliable treatment adapted to a high variability of influents (load, composition and quantity) on each industrial sector, urban area (Aq)
- Selective removal of pathogens
- Selective removal of valuables (e.g. N,P,K for agriculture)

New design of processes: Processes using less water - Sustainable use of water in process.

- RPD (Reaction and Process Design): described as optimisation or rethink/redesign of processes resulting directly or indirectly to water saving; This includes Technology development towards process intensification (S) (W) (Sp)
    - Optimization of membrane separation for innovative downstream processes.
    - Dry technologies.

Towards more innovative treatment and process solutions.

- Optimization of process wastewater stream management.
- Catalyst for water remediation (S).
- Catalytic combined processes for adsorption and/or oxidation (nano-materials) (W).
- Integrated physical/chemical/biological treatment (S).
- Optimization of membranes for integrated reactive and hybrid separations.
- Optimisation and development of membrane technology and/or system design to achieve higher performance, flux and selectivity, with respect to new contaminants in water streams (such as organic and pharmaceutical compounds, and ions originating from electronics) (W).
- Novel concentrate treatment options (such as membrane crystallization) (also reuse) (W).
- Innovative processes to remove salts from liquid effluents / further development and proliferation of small and compact water desalination devices (W).
- Optimized on-site treatments of aqueous waste streams (S).

Sustainable treatment of highly loaded liquid streams.

- Tailored wastewater treatment technologies.

Sustainable treatment of brines

- Energy saving membrane concentrative treatment (Aq)
- Low fouling selective membrane for electro-dialysis treatment (Aq).

- Crystallization (precipitation or thermal) processes with by-product control (Ag).

Development and efficient use of sustainable chemicals and technologies water and wastewater treatment.

- Product design of chemical and biotech solutions/products for water and wastewater treatment (flocculation, coagulation, etc.) (with reduced environmental impact, optimised dosing, more selective reaction and energy optimisation) (S).
- Products and materials for filtration, separation technologies (membranes, adsorbents, etc.)

Waste streams valorisation: valuables recovery, selective separation of pollutants aiming at an improved quality of the remaining waste water stream:

- Selective separation of bio nutrients (e.g. phosphates and nitrates):
    - ❑ Coupled to water recovery: Valorisation of nutrient rich streams for biomass production and biomass valorisation; Valorisation of fermentation residue streams

Reduce the energy levels that are needed for water and steam related production processes.

- Low energy water treatment processes, e.g. pressure reduction in membrane technologies like forward osmosis (S) (W).

Energetic conversion/valorisation of by-products / compounds within wastewater (Sp).

Conclusion

Will the chemical industry be able to achieve any of the positive visions for 2050 presented in this document? Their success will depend on how well professionals from a range of industries can effectively work together in order to respond to societal, economic, and environmental challenges.

The activities undertaken included stakeholder consultations (outcomes of three ChemWater vision 2050 workshops) and a situational analysis (Report on Chemistry-Water synergies, D2.1&2.2) which generated the requisite information to develop the Joint Research and Development Roadmap (JR&DR) that will define the series of steps that are necessary in preparation of ChemWater's Joint Implementation Action Plan (JIAP).

ANNEX

Barriers	
Finance & costs	Lack of sufficient funding for R&D
	New technologies not competitive;
	Prohibitive cost of new technologies
	Potential for increased energy consumption
	Insufficient investment in required infrastructure
	Increased operating cost: increased energy consumption, additional monitoring, etc.
	Insufficient investment in, poorly targeted, or poor quality R&D
	Potential for increased energy consumption and increased operating cost
	Prohibitive cost of new technology or the required infrastructure
	Insufficient investment available
	Need for significant capital investment
	Prohibitive cost of removing pollutants;
	cost of pilot lines and scale-up of new technologies
	Competition for investment with other sectors
	Continuity of renewable energy supply
Technological	New technologies not adopted fast enough
	Insufficient quality of produced water
	Generation of more concentrated waste streams
	Constantly decreasing detection limits and new emerging contaminants
	Slow adoption of and lack of trust in the new emerging processes
	Challenge of achieving multiple pollutant removal with fewer stages;
	Unavailability of new technologies
	Constantly emerging new pollutants
	Energy storage systems
	Lack of highly productive recovery technologies (cost competitive)
Health & Safety issues	Emerging health and safety issues and new risks
Skills & education	Lack of relevant skills and knowledge;
	Competition for quality graduates with other sectors
Regulatory Framework	Licensing barriers to accessing new sources;
	Lack of regulations / regulation constrains
	Disposal or reuse of generated waste streams
Others	Geographical location prevents easy access
	Competing R&D priorities within the sector;
	Need for effective dialog with other sectors
	Public acceptance
	Current infrastructure (pipelines)
	Adoption of new practices slow
	Lack of effective routes to market for developed solutions
	Long lasting approval process for new products/technologies
	Lack of trust – IP rights
	Ineffective dialogue
	Conflicts of interest between stakeholders;
	Local or regional bureaucracy