# Description of the specialization

CE is the economic model in which – while maintaining the condition of efficiency – the following basic assumptions are fulfilled:

a. Value added of raw materials/resources, materials and products is maximised or
b. Amount of produced waste is minimised and waste is managed in accordance with the hierarchy of ways to handle waste (prevention of waste formation, preparation for reuse, recycling, other recovery methods, disposal).

These assumptions should be met at every stage in the lifecycle (acquisition of raw materials, ecodesign, processing and production, waste and waste water, substitution).

The National Smart Specialisation *Circular Economy* (NSS CE) – *water, fossil raw materials, waste* indicates the preferential areas of support for research, development and innovation work (R&D&I) for the transformation of the Polish economy towards the circular economy model. This change involves not only technological and product innovation, but also new solutions, including system, legislative, organisational, financial and educational, having regard to the value chain and all stakeholders.

I. ACQUISITION OF RAW MATERIALS

1. Rock raw materials
    - Technologies and processes of remediation and reclamation of post-exploitation areas of rock raw materials
    - New technological solutions allowing to improve the explosive rock working technology
    - Innovative tools and technical solutions for high-performance hard rock working in open-cast mines.
2. Metallic raw materials
3. Hard coal and lignite
    - Innovative technologies to improve the efficiency of operation of bucket ladder excavator – belt conveyor flight – dumping conveyor systems
    - Models, algorithms and software to improve the efficiency of multi-bucket wheeled excavators in conditions of exploiting low thickness beds
    - Innovative solutions and technologies for selective working of multi-bed deposits using multi-bucket wheel excavators
    - Innovative technologies to exploit hard-to-work rocks in the lignite-mining industry
    - Innovative solutions to improve the efficiency and safety of operation of

basic machinery in the mining industry.
    - New solutions allowing to adapt exploitation technologies to geological and mining conditions
    - Modern methods to detect and counteract serious risks, *inter alia*, related to landslides, fires, water, etc
    - Models, algorithms and software to improve and model/forecast the energy intensity of extraction processes
    - Innovative technologies to control the extraction (extraction technology taking into account the effort of machinery, IT support for management of extraction and mine traffic)
4. Natural gas
    a. Technologies to explore, recognise and manage natural gas deposits:
        - Modern technologies to explore and recognise unconventional gas deposits
        - Smart monitoring of deposits and decision support systems in the process of exploration and management of deposits
        - Local management of gas from deposits unfit for inclusion in gas networks
        - Innovative methods to recognise deposits of gas hydrates, including marine geophysics
        - Innovative tools dedicated to surface geophysics (apparatus, sensors, detectors)
    b. Innovative technologies to exploit deposits and intensify extraction:
        - New drilling technologies to share old and partially exploited deposits
        - Modular, container drilling systems as elements of smart gas mines
5. Crude oil
   Technologies to explore, recognise, extract and exploit conventional and unconventional crude oil deposits
    - Extraction techniques and technologies to maximise the extraction of deposits
    - Integrated methods to analyse petroleum pools for hydrocarbon detection
    - Production intensification techniques (secondary and tertiary methods: injection of water, surfactants, $CO_2$, microbiological and chemical methods)
    - New technologies to share deposits, including tight oil
    - Automated, unmanned crude oil mines (smart oilfields)
6. Water
    1. Solutions for improving the ecological status of degraded rivers, water and water-dependent ecosystems (renaturalisation and revitalisation), whose objective is to reduce the grey water footprint (including combating eutrophication)

2. Techniques and methods to revitalise small reservoirs and watercourses allowing to increase water resources ecosystem
3. Biochemical remediation and storage of surface waters with hydrodynamic infiltration for the stabilisation and protection of aquiferous levels being exploited
4. Solutions for the effective protection of main groundwater reservoirs from anthropogenic threats in post-industrial and degraded areas
5. Biomonitoring and bioindication techniques of water resources
6. System solutions in building database resources and integration of distributed data sources as components of the national resource data on the state of the environment

7. Horizontal issues
   a. Minimisation of waste generation
      - Waste-free or low-waste innovative technologies to acquire raw materials
      - Methods, tools, processes and technologies limiting waste generation at the stage of acquisition of raw materials
      - Reduction in the amount of generated waste by its selective acquisition at the stage of the extraction of raw materials
   b. Preparation for reuse
   c. Substitution
      - New metallic and composite materials, focused on the production of substitutes for critical and dangerous metals

II. ECODESIGN

1. Creating resource-efficient and energy efficient products, new, improved, reworked or renewed
2. Creating products using raw materials recovered from waste and waste water
3. Increasing the durability and extending the life of equipment and products used
4. Providing substitutes for substances which are hazardous, complex and cumbersome in the recycling process
5. Developing substitutes for non-renewable resources and water
6. Ensuring new applications and/or reuse of products, parts thereof, materials

III. PROCESSING AND PRODUCTION

1. Rock raw materials: technological solutions enabling control of the quality of products from plants processing rock raw materials

2. Metallic raw materials
    a. New technologies and devices to enrich metallic mineral raw materials
        - Technologies to recover metals from ores with difficult characteristics of enrichability
        - Technologies to comprehensively recover useful components from anthropogenic secondary raw materials
        - Innovative technologies to enrich low-quality polymetallic ores
        - New designs of equipment to enrich mineral resources
    b. Metallurgical (pyro- and hydrometallurgical) technologies to produce non-ferrous metals from primary and secondary raw materials:
        - Innovative technologies to melt and refine metals.
        - New solutions to design energy-efficient metallurgical aggregates to melt ores and metal concentrates as well as to process products of melting
        - Technologies to obtain metals from waste and semi-products from metallurgical processes (slags, dusts, sludges)
        - Recovery and processing of waste energy of technological gases from metallurgical aggregates and from solid and liquid materials
        - Development of leaching methods, including pressure leaching, of ores and concentrates.
        - Innovative methods to selectively extract metals from aqueous solutions (precipitation, ion exchange, electrochemical)
        - Hydrometallurgical methods to recover accompanying metals, including critical metals
    c. Innovative technologies of deep metal processing, including:
        - Production of functional materials using liquid phase methods.
        - Development of new alloys for casting with improved values in relation to existing alloys (new methods of controlled crystallisation and structure fragmentation, selection of new alloy additives).
        - Shaping the structure and properties using plastic processing methods, heat treatment and chemical-heat treatment.
        - Production of powder metallic and composite materials with the use and development of techniques for atomisation, high energy milling, mechanical, chemical and plasmochemical synthesis.
    d. Modification of existing and new technological lines and devices for metal processing processes, allowing to carry out continuous processes, reducing the number of separate technological operations, ensuring the manufacture of nanostructured products
    e. Innovative technologies for processing metals, manufacture and application of protective and functional layers using chemical and electrochemical

methods, thermal spraying and laser-based functionalisation of surfaces:
    - Methods and materials for the protection of steel constructions against environmental exposures
    - Utility coatings for the modern construction industry and new engineering applications

f. Processing of hard to melt metals, with particular focus on domestic raw materials

3. Hard coal and lignite
    - Technologies of gasification, thermal decomposition using the thermolysis and pyrolysis methods, drying and production of liquid fuels by direct liquefaction of hard coal and lignite
    - Enrichment of low quality coals through the use of pyrolytic conversion
4. Natural gas

   New technologies to produce and adapt gaseous fuels to network parameters
5. Crude oil
    a. Crude oil processing technologies:
        - Techniques and technologies to maximise yields of white products.
        - Techniques and technologies to optimise the conversion of processed crude oil
        - Techniques and technologies to optimise management of by-products and waste from crude oil processing
        - Technologies to manufacture products of improved quality and of niche products
    b. Use of new materials and technological solutions:
        - Technologies and materials to optimise energy processes (possibility of functioning of processes in high temperature and pressure areas) minimising process losses, enabling better yields
        - Technologies to use natural gas in crude oil processing processes (including hydrogen production)
6. Water
    a. Improvement in quality
        - Water treatment through innovative technological methods and designs of devices and the use of new generation reagents allowing to minimise the consumption of natural raw materials as well as to use secondary raw materials
        - Control of water treatment processes, tests and methods to assess the quality of water and tools and IT control systems of the state and water quality monitoring
        - Methods, processes, materials (including raw materials) aimed at keeping the biochemical stability of water and minimising the amount

of by-products (and waste) formed during water disinfection processes.
- Methods and processes to remove anthropogenic pollutants from water (pharmaceuticals, plant protection products, hormones, heavy metals), precursors of hazardous secondary pollutants and biodegradable fractions of organic pollutants
- Methods, processes, materials and system solutions used in water treatment and recovery technologies in emergency situations
- Methods, processes, and technologies to purify groundwater from pollution with hydrocarbons and other chemicals
- Modelling and intensification of water treatment processes in hybrid systems
- New measurement techniques and study methods to identify micropollutants in water.

b. Use
- Technologies to recover and use rainwater, geothermal, saline and brackish waters, leading to the production of water intended for consumption and economic purposes
- System solutions in the field of closing and integration of water circuits and recirculation of technological waters in municipal and industrial systems as part of industrial symbiosis
- Technologies to limit losses in water distribution systems
- IT monitoring systems aimed at improving the efficiency of using water resources
- Metering and monitoring technologies to increase the efficiency of using water resources, i.e. reducing water consumption and losses in water-supply systems with the use of information and communication techniques as well as spatial information systems
- Technologies of small retention and use of rainwater in urban and rural areas, as well as in technological circuits and for economic purposes
- Smart systems to collect and drain rainwater that integrate the potential of natural, quasinatural and channel (infrastructure) retention
- Engineering, spatial and organisational solutions of retention, treatment and management of rainwater in urban space and in low-urbanised areas as an alternative for “collect and drain” solutions

7. Horizontal issues – minimisation of waste generation
   - Waste-free or low-waste innovative production/processing technologies
   - Methods, tools, processes and technologies limiting waste generation
   - Reduction of the amount of generated waste by its selective acquisition at the production stage
   - Minimisation of waste generation by the introduction of innovative materials

- Minimisation of the formation of by-products of burning energy raw materials

IV. WASTE AND WASTE WATER

1. Innovative waste recycling technologies
    - Waste processing technologies using mechanical, thermal, cryogenic, biological, microbiological, physical and chemical methods
    - Technologies of protecting waste processing processes
    - Waste processing technologies, affecting the reduction of CO2 and other greenhouse gases into the atmosphere
    - Technologies to recover scarce and critical raw materials from waste
    - Technologies to process multi-material, multi-layer and composite waste
    - Development of products from thermal waste processing, inter alia, pyrolysis, thermolysis, gasification, plasma technologies, etc.
    - Recovery technologies including recycling of metals from waste
    - Technologies to process post-production and post-exploitation waste
    - Technologies of difficult-to-process waste coming from end-of-life vehicles and WEEE
    - Waste processing technologies from mining of energy and non-energy raw materials and mineral waste
    - Devices and equipment for recovery, including recycling of waste
    - Technologies to manage materials obtained from waste processing
    - Selective technological processes to obtain chemical compounds from highly processed waste
    - Waste-based multi-material and composite products for use in different branches of economy
2. Innovative technologies of material recovery from waste water

- Technologies to recover nitrogen and phosphorus from process streams and their reuse
- Technologies to recover and biosequestrate non-organic carbon from process (also gaseous) streams
- Technologies to recover trace elements and metals from process streams
- Technologies to recover organic compounds (inter alia, cellulose, PHA) from process streams
- Solutions allowing to use industrial waste water streams carrying a load of organic compounds as substrates in processes of heterotrophic waste water treatment
- Technologies to manage raw materials formed in the sludge part of waste water treatment plants.
- Closure of water-waste water circuits, with the use of initially treated waste water, treatment of post-processing water for municipal and industrial purposes.

3. Innovative technologies to treat waste water and recover water from waste water
   - Waste water treatment through innovative technological methods and designs of equipment and the use of new generation reagents and preparations
   - Methods, processes, materials for removing persistent organic pollutants (POP) from waste water, including biological active substances.
   - Development of methods of waste water disinfection with regard to reducing the possibility of formation of harmful by-products
   - Nanotechnologies in waste water treatment
   - Enhanced high-efficiency methods of anaerobic treatment of waste water, including integrated anaerobic-aerobic systems
   - Water and waste water treatment technologies in the mining industry
   - Methods, tools and processes to reduce the amount of nutrients introduced into surface waters, including the use of industrial water tanks as biological treatment plants of surface waters
   - Technologies of individual wastewater treatment systems including removal of biogenic compounds and enhancing removal of organic pollutants, as well as leading to obtaining the technical and technological reliability and allowing to control the effects of treatment
   - Increase in the efficiency of waste water treatment and sludge conditioning processes
   - Smart measurement systems, IT programmes for monitoring the quality of waste water and for controlling waste water drainage systems and treatment processes
   - Modelling of treatment processes and waste water and rainwater drainage systems

- Methods, tools, equipment and processes leading to improved waste water management of rural areas and areas with dispersed development
- Technologies to minimise and remove substances contaminants of emerging concern
- Reducing water consumption through the development of systems of recovery and utilisation of “grey water”

4. Use, recovery and optimisation of energy consumption in water and waste water management
    - Implementation of solutions to optimise energy consumption, including the use of renewable energy sources in water and waste water management
    - Technologies to use waste water and sludges as substrates to obtain energy
    - Technologies to dispose of waste water sludges with organic co-substrates in order to increase the energy efficiency of waste water treatment plants
    - Innovative systems combining energy from renewable sources with waste water treatment processes in backyard treatment installations and other dissipated installations to store and treat waste water
    - Development and implementation of technological solutions to use energy from waste water in combined energy systems, including waste water treatment systems integrated into recovery of water and heat
5. Innovative technologies of energy recovery from waste
    - Technologies of optimal generation and use of alternative fuels obtained from waste (exclusive of RDF)
    - Technical development of power generators, gas turbines, furnaces to safely burn fuels obtained from waste
    - Innovative solutions to recover energy from waste exclusive of burning and co-burning
    - Technologies to recover products from waste using the thermal decomposition method
6. New safe methods to dispose of waste
    - Technologies to secure waste through mineralisation, solidification and stabilisation
    - Technologies to protect from emission of gases, odours and from dusting
    - Technologies to store waste impossible to use in other management processes