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HEALTHY SOCIETY

NATIONAL SMART SPECIALIZATION 1. HEALTHY SOCIETY

SECTION I - NEW PRODUCTS AND TECHNOLOGIES

I. RESEARCH AND DEVELOPMENT OF MEDICINAL PRODUCTS

- 1. Methods, tools and processes leading to the obtainment of medicinal products: chemical (innovative and generic), biological and biosimilar medicines.
- 2. New active substances, new applications of known active substances and combinations of active substances.
- 3. New forms and embodiments of single-ingredient and multi-ingredient medicines.
- 4. The development of innovative formulations, nano-structures, and media for medicines.
- 5. Technologies aimed at accomplishing the effect of controlled, prolonged administration, release or delivery of a medicinal substance.
- 6. Bio-catalysis in the process of producing medicinal products (new cell models, expression systems, clone selection methods, cultivation media and cultivation processes).
- 7. Methods aimed at improving the pharmacodynamics and pharmacokinetics of the medicine (dosage reduction with a similar therapeutic effect).
- 8. Technologies aimed at cost saving or increasing the efficiency, safety and efficacy of therapy, new technologies increasing the likelihood of patient compliance with the doctor's recommendations.
- 9. The use of new cellular models, *in vitro* and *in vivo* models with better properties, purification methods and the efficacy and safety assessment of biological and biosimilar medicines, as compared to those used in reference products.
- 10. Synthetic biology in medicine the use of synthetic biological systems (including, for example, modified microorganisms, cell lines) to obtain new drugs, vaccines and therapeutic solutions (e.g. cell therapies and gene therapies).

This area covers the development of medicinal products from the discovery phase, through the pre-clinical phase, to the clinical phase and registration.

II. ADVANCED THERAPY MEDICINAL PRODUCTS (ATMP), BIOLOGICAL PRODUCTS

Work relating to the innovative use of stem and/or progenitor cells and/or other cells/tissues administered in autologous and allogeneic systems. Research and development projects can be basic, pre-clinical and clinical.

- Advanced therapy medicinal products based on the application of stem cells, progenitor cells and other cells (e.g. mature cells derived from individual immune system organs and cells, etc.) delivered directly to the body or via carriers (e.g. encapsulation, biodegradable membranes, a scaffold with an active substance or human/animal material and/or colonized by stem cells or others cells from a tissue bank; other types of scaffolds, dressings, stents, implants, etc.)
- 2. Biological products, including innovative applications of protein products (e.g. cytokines, chemokines, hormones, antibodies, gene vectors, viruses; products with xenic cells).
- 3. Isolated human cells intended for alternative therapies.
- 4. Tissue banks necessary for the manufacturing and/or storage of medicinal products, compatible with the requirements for preclinical and clinical testing: GMP/GLP/GCP.

III. RESEARCH AND DEVELOPMENT OF INNOVATIVE DIETARY SUPPLEMENTS AND FOODS FOR SPECIAL NUTRITIONAL USES

- 1. Methods, tools and processes leading to the obtainment of innovative dietary supplements and foods for special nutritional uses
- 2. New bioactive substances with better bioavailability and tolerance, used to prevent diseases of affluence and increase the efficacy of a specific therapy.
- 3. New technological solutions to improve the bioavailability of substances contained in dietary supplements and foods for special nutritional uses.
- 4. Technologies aimed at accomplishing the effect of controlled administration, release or delivery of substances contained in dietary supplements and foods for special nutritional uses.

IV. BIOINFORMATICS

Models, algorithms and software for identifying molecular targets of therapy, molecular structure modelling, medicament design and disease diagnostics.

V. MEDICAL DEVICES AND PRODUCTS

- 1. Development, design, implementation and production of innovative medical devices, instruments and products, including dental ones, used to conduct or support therapy or medical diagnostics, with the aim of implementing new forms of therapy or diagnostics, improving therapeutic or diagnostic effectiveness, reducing side effects of therapy, reducing the costs of therapy or diagnostics, as well as reducing the effects of functional limitations.
- 2. Development and implementation of technological solutions to allow the implementation of new methods of treatment, compensation of functional limitations, including motor and perceptual disability, rehabilitation, preventive healthcare or effectiveness improvement of existing methods in these fields.

This area covers diagnostic, therapeutic, rehabilitation and compensation devices.

VI. MEDICAL TECHNOLOGIES

- 1. Regenerative medicine technologies
- a. Development and implementation of new techniques of tissue engineering and regenerative medicine.
- b. Development of technologies and tools aimed at organ, tissue and cell regeneration.
- c. Creation of new biomaterials to repair damaged cells and tissues.
- 2. Artificial organs

Innovative medical devices, instruments, products, such as implants designed to replace or support impaired organ functions for therapeutic purposes, including the use of a technical device (prosthesis) as a temporary aid for an impaired organ during its treatment in order to regenerate and restore its efficient function and/or as a long-term/permanent support/replacement for the impaired organ's function.

In addition to medical products and instruments in-built as elements of artificial organs, this area also covers technical support devices, including for artificial organ function monitoring, a necessary safety- and efficacy-improving procedure to enhance patient life comfort in treatment using artificial organs, in particular implantable sensors to monitor the operation of supported organs or other biological functions of the patient; systems allowing remote monitoring of the operation and condition of supported artificial organ and of the patient, with a view to increasing the safety and efficacy of patient treatment with the use of the artificial organ at home and in the workplace.

3. Material technologies in medicine

Development of new materials intended for manufacturing implants, artificial organs or other medical applications or new technologies for manufacturing materials. This area also includes tissue and genetic engineering allowing the production of hybrid implants.

VII. IT MEDICAL TOOLS

- 1. Design and development of IT solutions for the sampling and analysis of medical data for diagnostic and therapeutic purposes, in particular IT systems to collect, process and analyse medical data and information, by text, sound, and image analysis or other forms necessary for the diagnosis, treatment and monitoring of patients.
- 2. Design and development of solutions allowing the integration of various IT systems used in the healthcare system to facilitate the safe collection and storage of medical data, including protected personal data, creating algorithms to support medical decisions, as well as assisting in the customization, coordination and optimization of medical care.
- 3. Design and development of IT solutions to support disease diagnosis, in particular systems based on artificial intelligence, extensive reasoning systems or systems based on computer simulations of various degrees of complexity (from simulations at the molecular or cellular level, through organ-level simulation to comprehensive whole-body simulation).
- 4. Design and development of IT solutions to support treatment based on computer simulations at the stage of planning and providing therapy.

The proposed activities in this field should use and create innovative IT and software solutions, as well as advanced computational and simulation methods, including machine learning algorithms and Big Data analysis algorithms, developed in cooperation with healthcare specialists and paying customers.

The area DOES NOT INCLUDE IT systems for the purposes of billing medical services or collecting data required by legal regulations and not directly related to diagnostics and treatment.

SECTION II - DIAGNOSTICS AND THERAPY OF DISEASES

I. DIAGNOSTIC IMAGING AND DIAGNOSTICS BASED ON OTHER DETECTION TECHNIQUES

Modern and efficient disease diagnostics based on imaging techniques and innovative detection techniques includes:

- 1. Identification, validation, design and implementation of new biomarkers of diseases of affluence, based on imaging diagnostic methods in well-characterized groups of people (e.g. predisposed to disease, in the early stages of disease).
- 2. The development and application of modern diagnostic imaging methods and other techniques, allowing for early identification of pathological structural lesions within systems and organs affected by diseases of affluence, as well as for dynamic functional assessment associated with it.
- 3. Validation of the already identified markers/diagnostic tests based on the imaging diagnostic methods relating to diseases of affluence in large populations of risk groups and/or the general population.

The implemented design and implementation activities should result in the marketing (or preparation for marketing) of new methods of clinical diagnostics and markers/tests (or validation of the already existing ones) based on imaging diagnostics or based on other techniques or more effective diagnostic algorithms.

II. MARKERS/TESTS

Development of innovative and effective methods of diagnostics of diseases of affluence:

- 1. Markers/tests for early detection of predisposition to diseases of affluence, supplying procedures to prevent the development of the disease or delay its occurrence or slow down/alleviate its course.
- 2. Markers/tests for early detection of diseases of affluence, enabling an early initiation of treatment.
- 3. Markers/tests enabling personalized therapy of diseases of affluence.

A prerequisite for the development of new diagnostic tests is the identification of novel markers of diseases of affluence, based on studies carried out in well-characterized groups of people (e.g. people with a predisposition to the disease or in the early stages of the disease). Research and development projects aimed at developments in the "Diagnostics" area include new sensitive and specific markers, validation of the already identified markers related to diseases of affluence in large populations of risk groups and/or the general population. Progress in the development of new methods of diagnosing diseases of affluence is based on new research models of diseases of affluence and on innovative technologies, especially large-scale ones, based on genomics, transcriptomics, epigenomics, proteomics and metabolomics. The completed activities should result in the marketing or preparation for marketing of new diagnostic markers/tests, medical products, more effective diagnostic algorithms or the validation of the already existing methods and tests.

III. TELEMEDICINE

- 1. Creating solutions, technologies, products, tools, applications, algorithms which, through the use of modern information and communication technologies, will improve the existing ones, but most of all create new methods of acquisition, analysis, archiving and safe exchange of information about the patient's health, both between the patient and a medical professional ("MP"), as well as between professional groups within the medical industry, which are located in geographically distant places. The immediate goal of the solutions created within this model should be to support diagnostic and therapeutic processes related to the safe transmission of medical data and information, through the analysis of text, sound, image or other forms necessary for diagnosis, treatment and monitoring of patients and the exchange of information between MPs or MP groups.
- 2. Development of innovative solutions based on information and communication technologies (ICT) used as methods of non-invasive and safe collection and remote exchange of health information between the health care system and a sick or healthy person. The proposed solutions should be used in: diagnostics; therapies, including invasive procedures performed remotely; preventive healthcare; medical rehabilitation; coordinated care; health monitoring with devices, sensors and accessories; registration and analysis of biological signals of significant importance for health; improving compliance with recommendations, including compliance with the treatment plan; post-surgical and post-traumatic rehabilitation; recreational physical activity; education of sick and healthy persons by promoting healthy lifestyles; improving the quality of life of patients and/or people undergoing diagnosis; professional training of health care workers; creating large medical databases; integration and unification of scattered health data systems with Electronic Medical Data systems. An important goal of innovative activities in the field of telemedicine should be the development and use of ICT solutions and medical products to help reduce health care costs and/or improve the quality of services provided and/or compensate for differences, as well as facilitate and shorten the waiting time for access to the health care system and/or assure health safety to elderly persons, persons with chronic diseases and disabilities, while also making their use more convenient and simple for end users

IV. COORDINATED HEALTHCARE

Coordinated Healthcare comprises activities covering stages of health care, such as health promotion and preventive health care, risk and disease progression assessment, therapies and rehabilitation, which are to be integrating, comprehensive and continuous, as well as coordinated education on coordinated health care at different levels of education and targeted at different audiences.

This area includes:

- 1. Early detection of constitutional and somatic genomic changes (e.g. in DNA) and biochemical changes (e.g. micronutrient concentrations), help in identifying groups at high risk of developing genetic diseases (especially cancer), and in detecting genetic diseases in the early stages of development.
- 2. Development and implementation of population screening programs and preventive programs to allow diagnosis and initiation of therapy at the earliest stage of the disease.
- 3. Identifying risk factors for distress associated with civilizational burdens that directly or indirectly increase the incidence of mental disorders,
- 4. Healthy eating in health and illness as well as promoting healthy behaviours in various aspects of life, using the universal design concept.
- 5. Development and implementation of technological solutions to allow the implementation of new methods of compensating for functional limitations, including those resulting from motor and perceptual disability, preventive health care or the efficacy improvement of the existing methods in these areas.
- 6. Disease risk and/or progression assessment, including aspects of clinical, social, psychological, genetic burden and daily routine assessment, including eating habits and lifestyle.
- 7. Activities ensuring the preservation or promotion of work-life balance, particularly through the dissemination of mental hygiene and stress-reducing measures to allow maintaining physical and mental health and limiting or slowing the progression of diseases that have already occurred.
- 8. Methodology of risk assessment in the field of: activity limiting or increasing the risk of diseases, individualized cognitive and mental training, allowing for early detection of the risk of a disease or mental disorder, socio-economic determinants having a direct impact on the risk of diseases, and the integration of these factors with medical and clinical factors of the pathogenic process.
- 9. Assessment of the risk and/or progression of rare diseases, chronic diseases, diseases of affluence, in which there is limited potential for effectiveness/safety improvement of pharmacotherapy, including multi-specialist and innovative care, ensuring the extension of life expectancy life quality improvement, with consideration given to economic outcomes.
- 10. Coordinated programs and therapies, with consideration given to all the essential elements of the treatment process with a view to its optimization, integration and adjustment to individual patient needs, by incorporating methods of physical activation, supporting mental condition and hygiene, as well as changing or modifying dietary habits in the surgical and conservative treatment, taking into account personalized enteral and parenteral nutrition and a proper diet.
- 11. Joint activities and programs by partners, such as medical and psychological institutions, specialists in physiotherapy, psychology and/or psychotherapy, dietetics, social workers and employers, leading to education for changing the way of life, pace of life, hygiene (including mental) of life, including provision of services and/or products needed in this area, characterized by pro-health value or pro-health psychological behaviours.
- 12. Research on new therapies for diseases of affluence, based on innovative technologies of personalized medicine (in the field of genomics, transcriptomics, epigenomics, proteomics, metabolomics) and personalized therapy based on a biopsychosocial model (including methods of working with the patient that take into account the psychological and psychotherapeutic profile, living conditions, available financial, non-financial and other support).
- 13. Treatment of chronic and rare diseases and of persons with disabilities as well as physical and mental ailments includes multi-specialist, integrated care for the patient and his/her family.
- 14. Development of ICT tools aimed at the exchange of information about the patient's health condition, coordination of activities between medical specialists in various medical entities, as well as education of individual professional groups of medical personnel and the patient's social environment. This also includes remote technical solutions increasing the patient's involvement in the treatment process through self-assessment of the health condition, assessment of the treatment process and cooperation with the medical team providing coordinated patient care.
- 15. Implementation of integrated rehabilitation activities and programs ensuring recovery and of social and professional activity within the framework of cooperation between specialists in various fields, including in the field of medicine, telemedicine, medical engineering and compensation technologies,

physiotherapy, psychology, dietetics, career counselling, law (by creating multidisciplinary teams of specialists).

V. NEW PREVENTIVE AND/OR THERAPEUTIC GOALS

The therapy of diseases of affluence should be based on the development and implementation of:

- 1. New therapies in diseases of affluence, based on medicinal products (chemical, biological, biosimilar, innovative and generic medicines)
- 2. Patient management algorithms based on the results of personalized diagnostics.
- 3. Diagrams for the selection and validation of the therapeutic efficacy of a chemical particle.
- 4. Protocols for monitoring and evaluation of therapeutic efficacy, e.g. on patient's own cell line models.

The condition for proposing and preparing for the implementation of targeted (personalized) therapy is the complete (to the extent possible) identification of the underlying disease, e.g. of genetic, metabolic, etc. origin, as well as the possibility of predicting and assessing the efficacy of the proposed therapy on models of cell lines, bacteria or in silico with the simultaneous possibility of assessing the efficacy and stability of the proposed therapy. Development and implementation of new, uniquely important targeted therapies, including combined therapies allowing life quality improvement for the patient in the case of comorbidities, efficacy evaluation, monitoring and modification during therapy.

The progress and development of new therapies is closely related to the development of DIAGNOSTICS and uses its effects, introducing new, unique assessment models for therapeutic efficacy and reducing negative effects for the patient.

VI. CLINICAL TRIALS

Clinical trials include:

- 1. Prospective clinical trials, including randomized trials, on patients and/or healthy persons, carried out in order to assess the efficacy and/or safety of new, innovative therapeutic methods using medicines and/or medical products. Projects in the field of clinical trials may encompass biopsychosocial models, including without the use of pharmacotherapy, of a therapeutic, diagnostic, screening, preventive, prognostic or epidemiological nature.
 - a. Early-phase clinical trials aimed at assessing the safety, pharmacokinetics, pharmacodynamics, as well as determining the optimal dosage, etc., of new medicines and treatments, and the evaluation of new diagnostic methods. This is especially true for innovative, personalized targeted therapies as well as the identification and verification of appropriate prognostic biomarkers.
 - b. Clinical trials of subsequent phases, aimed at assessing the efficacy of a medical and/or other therapeutic intervention or diagnostic method, as well as observational and epidemiological studies.
 - c. Research related to biopsychosocial factors, rehabilitation and/or physiotherapy, psychotherapy (including in particular cognitive and behavioural methods), health-related quality of life, social support, physical activity, healthy eating, cost-effectiveness of non-pharmacological therapies, and research on models of coordinated patient care.
 - d. Research on clinical trial technology. Development of innovative technological solutions (models, processes and devices) to increase patient safety, reduce costs, optimize the number of participants, increase assessment accuracy and shorten the duration of clinical trials.

Solutions should address:

- models and software for analysing mass data sets (Big Data) in order to profile predictive research (e.g. identifying molecules drug candidates), in bioinformatics, trials relating to the identification of innovative medical procedures and standards (secondary data analysis) and in screening tests conducted as part of clinical trials,
- development of new devices for use in clinical trials (e.g. lab-on-the-chip, in silico) and devices for collecting, transmitting and processing biosignals,
- information and communication technologies (ICT) to collect data and monitor participants in clinical trials,
- legal and administrative solutions aimed at efficient and quick procurement of permits and concluding contracts to allow for the effective and safe conduct of clinical trials,
- facilitating measures in the development, documentation assessment and financing of earlystage clinical trials related to new therapies developed in Polish laboratories or by Polish institutions.

SECTION III - MANUFACTURING OF PRODUCTS

I. MEDICINAL PRODUCTS: BIOLOGICAL, BIOSIMILAR, INNOVATIVE, GENERIC, AND MEDICAL PRODUCTS AS WELL AS DIETARY SUPPLEMENTS AND FOODS FOR SPECIAL NUTRITIONAL USES

- 1. Methods of executing the production process, developing new methods of producing biotechnological medicines, including biosimilar and biobetter medicines, i.e. products manufactured with the use of living organisms.
- 2. Development of manufacturing technologies for generic and biosimilar medicines and active substances never used before in the development and production of reference medicines.
- 3. New, innovative, improved technologies for: storage (biobanks) of selected cell line master clones and working clones, biocatalysis, fermentation, purification, filtration, packaging, storage and qualitative testing of biological medicines.
- 4. Development of new technologies for the production of innovative and generic medicinal products, biological and biosimilar medicines, as well as medical products, dietary supplements and foods for special nutritional uses.
- 5. Methods of implementing modern production technologies and formulation improvement resulting in a change in the pharmacodynamic and pharmacokinetic properties.
- 6. Production of preparations based on modern pharmaceutical technologies.
- 7. New technologies of delivering active substances to the patient's body, including the use of modern carriers in pharmaceutical technology.
- 8. Technologies of modified release of active substances.
- 9. Manufacture of nanostructured materials for medical purposes.
- 10. Technologies for the production of one-component and complex products using modern formulations.
- 11. Manufacture of products used with a new indication or dosage and taking advantage of known active substances.
- 12. Manufacture of new forms of medicines based on known substances or using modified or improved technologies of their administration
- 13. Search for and production of innovative and more efficient expression systems, cell lines, culture media and methods of biocatalysis, fermentation, purification, filtration, packaging, storage and qualitative testing of biological medicines
- 14. Development of innovative analytical techniques, methods of synthesis and isolation of impurities in medicinal products.
- 15. Development and validation of new analytical methods for active substances in medicines as well as and finished medicines.

II. ACTIVE PHARMACEUTICAL INGREDIENTS (API)

Definition: substances with indicated biological activity and declared pharmaceutical utility, of natural or synthetic origin, in particular: secondary metabolites or their compositions, biopolymer materials produced by biotechnological methods and biosimilar substances, natural substances produced by chemical synthesis methods, chemical conjugates and bioconjugates, synthetic substances, molecular and supramolecular complexes, nanomaterials, radiopharmaceuticals, as well as molecular and diagnostic probes. In particular, innovative forms and embodiments of active substances of generic medicines, including nano-particles and nano-formulations, nano-preparations, new pharmaceutically acceptable salts and complexes, with different degrees of dispersion or immobilization on target surfaces or particles.

- 1. New technologies for the production of active substances, innovative, generic and biological medicines with the use of materials, solvents, catalysts and new processes.
- 2. New technologies for the production of active substances in medicines to reduce the environmental impact (e.g. in harmony with the principles of green chemistry).
- 3. New technologies for the production of active substances in medicines, increasing their quality (content and impurity profile, in terms of the stability of substances and preparations) and/or reducing time demand and expenditures.

III. DERMATOLOGICAL AND COSMETIC MEDICINAL PRODUCTS FOR EXTERNAL USE

Process and product innovation with respect to the production of new active ingredients and innovative formulas used in the cosmetics industry. In particular, technologies for the production of active raw materials that are sustainable and do not exploit the natural environment, e.g. cell, tissue and complex cultures (including stem cell cultures, cultures of microorganisms, including microalgae). Searching for new chemically or biotechnologically modified active substances of various origins and searching for new areas of application for already known active ingredients. Searching for new active substances used in cosmetics with high therapeutic activity and the development of a technology for their production. Development of innovative methods of production of active ingredients used in cosmetics under laboratory conditions.

- 1. Innovative protective cosmetics.
- 2. New, innovative chemically/biotechnologically modified active substances used in cosmetics of various origins, with high biological activity in preventive health care and health protection.
- 3. New, innovative base substances for cosmetic masses.
- 4. Modern research methods for assessing the safety, efficacy and mode of action of an active substance used in cosmetics and of a finished cosmetic product containing it.

Innovative forms of delivery of active substances of a cosmetic

IV. MEDICINAL PRODUCTS OF NATURAL ORIGIN

Research on innovative therapeutically active preparations of natural origin in the following disease states:

- 1. Pre-diabetic and pre-hypertensive states.
- 2. Conditions endangering the stability of the atherosclerotic plaque (prevention of heart attack and stroke).
- 3. Conditions related to chemo- and radiotherapy and immunosuppressive treatment.
- 4. Chronic inflammation.
- 5. Conditions associated with chronic hepatitis, pancreatitis and diseases of the gastrointestinal tract, i.e. of the small intestine and large intestine.
- 6. Research on the creation of new forms of medicinal products of plant origin micro- and nano-technologies.

AGRICULTURAL, FOOD, FORESTRY AND ENVIRONMENTAL BIOECONOMY

NATIONAL SMART SPECIALIZATION 2. INNOVATIVE TECHNOLOGIES, PROCESSES AND PRODUCTS OF THE AGRICULTURAL, FOOD AND FORESTRY SECTOR

I. COMMON ELEMENTS FOR INNOVATION IN THE AGRICULTURAL/FOOD AND FORESTRY SECTORS

- 1. Optimization of production, processing and storage processes in line with the idea of sustainable development.
- 2. Genetic research, ranching work, molecular and biotechnological methods as well as alternative production directions allowing for the obtainment of high-quality plant- and animal-derived raw materials.
- 3. Innovative systems and smart methods and tools for monitoring the course of the production process and assessing the quality of raw materials and finished products.
- 4. Innovative processing technologies in the agricultural, food and forestry industry, reduction of energy and water consumption, increasing the quality of production.
- 5. Acquisition and processing of bioactive compounds and other raw materials from plant material (including waste biomass) and animal material from the agricultural, food and forestry sectors for various industries.
- 6. Optimization of the management of waste and by-products of the agricultural, food and forestry industries, including for energy purposes.
- 7. Methods of monitoring and counteracting the effects of natural hazards such as natural disasters disturbing the sustainable development of agricultural and forest areas as well as food security.
- 8. Methods of monitoring the social effects of technological progress which disrupt the sustainable development of agricultural, forest areas and food security.
- 9. Processes, materials and measures to increase the efficacy of the conservation and exploitation of agricultural and forestry materials from natural disasters and the restoration of land affected by natural disasters to economic use.
- 10. Innovative business models for the organization of production, processing, storage, distribution and sale of agricultural, food and forest-based products.

II. SOIL AND AGRICULTURAL LAND

- 1. Innovative actions to improve soil fertility and productivity, such as:
 - counteracting soil degradation, improving the pH of acidic soils, increasing the absorption of fertilizers,
 - plant nutrients in soils, forms of their occurrence and plant availability
 - living organisms and organic matter in soil, humus compounds, humification processes, mineral-organic compounds
 - physical, mechanical and aqueous properties and the three-phase soil system, soil porosity and structure in connection with agricultural mechanization
- 2. Innovative reclamation of degraded soils and protection of agricultural land.
- 3. Rationalization of water management in plant and animal farming.
- 4. Actions to reduce the negative impact of agriculture on ground and surface waters.

III. BIOLOGICAL PROGRESS IN PLANT AND ANIMAL FARMING

1. Creative breeding of plants, animals and fungi with high utility value, with the possibility of using molecular and biotechnological tools, taking into consideration biodiversity and resistance to climate and environmental changes.

- 2. Innovative production of high-quality seed and nursery material with increased resistance to diseases and pests.
- 3. New sources of protein in animal nutrition, high-protein plants, with consideration given to the characteristics of these raw materials and health safety.
- 4. Varieties (or species) providing high biological value for use in processing and formulation of final food products.
- 5. Methods of improving and implementing breeding effects in plant and animal farming, with consideration given to increased productivity and environmental impact reduction.

IV. TECHNOLOGY OF PLANT AND ANIMAL FARMING

- 1. Methods of agricultural biologization for improving soil quality and the nutritional value of plant materials (including bio-preparations, microorganisms, integrated protection of cultivated plants and fungi against diseases and pests using innovative bio-preparations, biotechnological methods and agrotechnical procedures).
- 2. Solutions to increase the safety and quality of plant-based raw materials in the use of fertilizers and plant protection products, including the application of integrated pest management and sustainable production.
- 3. Detection and identification of pathogens and pests of plants and cultivated fungi, using innovative techniques.
- 4. Innovative methods to improve animal welfare and protect animal health.
- 5. Feeding methods and animal-keeping systems that have a positive effect on the nutritional value and pro-health value of animal products, including ones that enhance productivity and reduce environmental impact, with consideration given to animal welfare.
- 6. Milking automation and milking robots.
- 7. Increasing the efficiency of pollination with the use of pollinating insects, including bumblebees and solitary bees.
- 8. Methods of improving livestock hygiene and health condition on livestock farms.
- 9. Processes and systems for management optimization on various types of farms.

V. AGRICULTURAL MACHINES AND EQUIPMENT

- 1. Innovative technologies and machines for agriculture, including precision agriculture.
- 2. Development of energy-saving, environmentally friendly technologies, machines and devices for tillage, sowing, fertilization, planting, plant care and protection, harvesting, conservation and storage of agricultural crops, as well as for increasing agro-technical parameters and ensuring high-quality agricultural products.
- 3. Innovative, energy-saving, low-cost machines and devices working on farms, in cowsheds, piggeries and fish breeding pools.
- 4. Devices and systems for monitoring, support, evaluation and improvement of the (technological) production process, with consideration given to the latest analytical methods, e.g. remote sensing (GPS), comprehensive chromatography, spectral analysis, etc., in order to produce raw materials of superior biological, health and technological quality.
- 5. Machines, technical and organizational implementations for processing lines at all stages of the food chain on farms and in facilities for animal (including fish) slaughter, raw material purchase and processing, as well as animal products, with consideration given to factors reducing contamination with pathogenic bacteria.

VI. ORGANIC AND MINERAL FERTILIZERS, PLANT PROTECTION PRODUCTS AND GROWTH REGULATORS

- 1. Innovative organic and mineral fertilizers and biological preparations, with a dedicated application or controlled release of ingredients.
- 2. Innovative, biologically active (natural and synthetic) substances intended for manufacturing plant protection products and veterinary medicines.
- 3. Modern formulations and functional forms of plant protection products and biocidal products, limiting their negative impact on humans and the environment, compatible with integrated pest management.
- 4. Innovative organic and organic-mineral fertilizers and microbiological vaccines for enriching soils with biomass and rebuilding their proper microflora.

VII. PRODUCTION, WAREHOUSING, PRESERVATION

- 1. Technologies and devices for the collection and storage of agricultural and agricultural/nutritional products to reduce in-storage and in-transport losses or increase product shelf-life across the food supply chain.
- 2. Smart warehouses, piggeries, barns, farms, fish breeding pools that use renewable energy sources to supplement the energy needs of buildings and livestock structures.
- 3. New technologies of production, packaging and storage to extend food product shelf-life and enable high quality maintenance, taking into account food safety.
- 4. New packaging and storage technologies to enable food quality monitoring, for example with the use of active and smart packaging.

VIII. PROCESSING OF AGRICULTURAL PRODUCE AND ANIMAL PRODUCTS

- 1. High-quality food production, with consideration given to:
 - product innovation in terms of composition, nutritional value and bioavailability of ingredients,
 - •reformulation of existing products aimed at quality improvement,
 - •improving the existing and introducing new, innovative food production and processing technologies,

•activities aimed at minimizing (to the extent possible) food, nutrient and bioactive substance processing and preservation,

•activities aimed at maximizing the share of natural raw materials and limiting the use of food additives,

- •measures to limit or eliminate anti-nutritional ingredients and allergens in food.
- 2. Production and quality assessment of foods for special nutritional uses and other products with designed nutritional and health characteristics, adapted to various consumer groups.
- 3. New processing methods and technologies for meat products with an increased dietary value.
- 4. Innovative processing of agricultural products, including vegetables and milk, promoting quality and increasing consumer awareness of health-promoting nutritional values.
- 5. Innovative food preservatives that allow the distribution of fresh products to the consumer.
- 6. Production and quality assessment of organic, traditional and regional food.
- 7. Research, characterization and implementation of solutions (including technological ones) for raw materials of agricultural and agricultural/nutritional origin, with consideration given to their suitability, application as well as health and food safety in the fodder industry.
- 8. Innovative production and quality assessment of fodder and pet food.

IX. FOOD AND THE CONSUMER

- 1. Creating innovative communication and educational tools to help consumers make informed food choices.
- 2. The use of innovative technologies to create tools supporting better nutrition planning and diet assessment at the individual and collective level.
- 3. Innovative methods of increasing the recognisability of high-quality food.
- 4. Developing innovative tools for detecting food adulterations.
- 5. Development of tools and modern research techniques as well as food quality markers (including the bioavailability of ingredients) for the purposes of assessing the impact of food products on human health.
- 6. Developing methods of analysis and selection of dedicated food at the population and individual level.

X. MODERN FORESTRY

- 1. Processes of obtaining woody plants with increased resistance characteristics and/or processes giving consideration to climatic, soil, aqueous and other conditions of biocoenoses, as well as systems for production and sourcing of plant-derived raw materials by means of remote sensing in order to determine forest features.
- 2. Environmental management using LCA techniques in the forestry and wood industry.
- 3. Research on biodiversity to improve the quality of trees and raw materials for the wood industry.
- 4. Modern methods of sourcing, selecting, nurturing and implementing selected tree and shrub species, with consideration given to selected genotypes of trees in order to select the desired performance characteristics of wood for selected wood industries, for the breeding sector and the sustainable use of plantation wood processing, development of processes for using DNA methods in forestry.
- 5. Modern systems for monitoring, early warning (e.g. satellite observations) and organization of fire containment and limitation of fire-related losses.
- 6. Development of high-energy crops with high weight gain, resistance and high dryness for fuel production.
- 7. Innovative measures and methods for the protection of trees against biological pests.

XI. INNOVATIVE WOOD-BASED AND WOOD-DERIVED PRODUCTS

- 1. The use of wood and forest biomass to produce materials that can replace other non-renewable raw materials.
- 2. Development of technology, application of engineering wood, use and offering of glued structures, construction components made of wood, construction of wooden houses for residential and other utility purposes.
- 3. Searching for new innovative uses of wood and wood-based materials as utility materials, wood biocomposites, including those made from recyclable materials.
- 4. Products, processes and technologies for obtaining wood and wood-based materials with extended durability under conditions of indoor and outdoor use, increased resistance to destructive factors, including biotic, fire, atmospheric factors, and photolytic aging, intended for: furniture, construction joinery, flooring, boatbuilding products, wooden garden architecture.
- 5. Modern means of protecting wood and wood-based materials, protective measures against erosion and for stabilizing biologically active substances, including ecological wood protection measures based on natural biocides, plant extracts and synthesized extracts that mimic natural ones.
- 6. High-performance, energy- and material-saving machines and lines for sawing, treatment and processing wood and wood-based materials, including pulp, paper and cardboard.
- 7. Research on wood drying technologies in connection with technologies limiting wood swelling and shrinkage.
- 8. Innovative adhesives for wood-to-wood and wood-to-non-wood combinations, varnishes/oils/stains and fillers, with consideration given to the needs of construction carpentry, flooring industry, wood-based panels and furniture.

- 9. Modern construction joinery with increased durability, including with the use of micro-coatings, nanotechnology and mimetics.
- 10. Large-scale structures made of wood and wood-based materials as the main structural element.
- 11. Technologies for modern wooden construction based on renewable raw materials, especially wood.
- 12. Development of wood-derived materials for applications in modern construction: new-generation materials with better properties, lower emissions, superior biodegradability performance, as well as resistance to biological agents (fungi, insects, rodents) under normal conditions.
- 13. Technologies for the extraction of bioactive compounds from forestry products and waste from the wood industry, including from conifers, for economic use.
- 14. Modern, biodegradable, reusable, removable wooden, wood-based, paper and cardboard packaging.
- 15. Products, processes and technologies for the management of waste from industries using wood, optimization of the management of post-production residues from solid wood processing into products with added value.

XII. CUSTOMIZATION OF FURNITURE PRODUCTION

- 1. Special-purpose furniture, including fitted furniture; high-comfort furniture; furniture eliminating health deficits, furniture supporting proper growth and fitness, eliminating the negative impact of civilizational factors, as well as furniture integration with digital and electronic systems.
- 2. Process innovations in furniture design understood as the work of interdisciplinary teams (market research, design brief, prototype building, testing, improvement and implementation for production, market verification), including the development and calibration of tools for early-stage evaluation of the product's prototype, design and logistical efficiency.
- 3. Search for and study of the possibility of using new and alternative materials as well as materials with new functional properties (including micro- and nano-technological modifications) for the furniture industry.
- 4. Innovative structures and production processes of furniture fittings and accessories.
- 5. Technical and technological innovations increasing efficiency, reducing material consumption and energy consumption in furniture production.
- 6. Development of modern systems for consolidating and assembling wood and wood-based elements and accompanying materials in the furniture industry.
- 7. Innovative furniture production systems, including the development of mass product customization or 3D printing.

XIII. INNOVATIVE PROCESSES AND PRODUCTS IN THE PULP-AND-PAPER AND PACKAGING INDUSTRIES

- 1. Technologies and research focused on smart tools, methods and processes for the production of pulp, paper, cardboard, corrugated cardboard and derived products, aimed at minimizing the share of the basic raw material for the protection of forest resources (including ones with an increased share of waste paper and other fibres, including synthetic ones), while also achieving high strength parameters.
- 2. Technologies and processes for the production of pulp and paper products to achieve the effect of reducing the consumption of energy carriers, water, and reduction of CO2 emissions and products with new utility functions.
- 3. Smart packaging, highly specialized improvements to increase the environmental friendliness, durability and safety of food and of their structure and design.
- 4. New specialized technological solutions focused on the development and implementation of technologies that minimize waste generation in the production of paper and cardboard and new forms of their management.

NATIONAL SMART SPECIALIZATION 3. BIOTECHNOLOGICAL AND CHEMICAL PROCESSES, BIOPRODUCTS AND PRODUCTS OF SPECIALIST CHEMISTRY AND ENVIRONMENTAL ENGINEERING

I. DEVELOPMENT OF (BIO)TECHNOLOGICAL PROCESSES FOR THE PRODUCTION OF INNOVATIVE (BIO)PRODUCTS

- 1. Development of biological systems (including those in the field of genetic and metabolic engineering and bioinformatics), construction and modelling of effective biotechnological tools and analytical techniques for the identification and testing of bioproducts properties.
- 2. Biomass and waste as a medium for the production of new tools for biotechnology (including the cultivation of macro-and micro-algae, bacteria, fungi and other organisms).
- 3. Development of new sources of biocatalysts and unique metabolites, construction and modelling of effective bio-catalytic tools for the processes of biosynthesis and bioconversion, bio-refining and biotransformation and for the needs of processes used in environmental protection.
- 4. Development of bioprocesses based on the use of biomass and waste from the agricultural, food, forestry and herbal industries, in order to obtain substrates for the needs of various industries, including chemical, cosmetic, pharmaceutical, agricultural, textile, packaging, pulp and paper industries and the manufacture of other products.
- 5. Bio-refining of renewable resources, including waste from the agricultural, food, forestry and herbal industries (with the use of microorganisms, including microalgae and microscopic fungi) for their comprehensive management and use in the production of compounds with added value.
- 6. Innovative technologies for the production of biofuels, fodder protein and bio-components.
- 7. Biotechnological methods of obtaining substrates for the production of polymers and specialized chemistry products as well as the processes of their purification and processing.
- 8. Technologies that use renewable natural resources for the production of plant protection products, fertilizers, bio-stimulants and surfactants with improved properties.
- 9. Technologies for the production of bioactive materials for medical and multifunctional applications for the needs of various branches of the economy.
- 10. Bionic engineering in the modification and functionalization process of polymer materials (including bionics of constructions, structures, material properties, bio-chemical processes, biological resistance, ergonomics and other phenomena).
- 11. Biodegradation of polymeric materials for the production of biologically active oligomers and new polymer structures.
- 12. Processes of synthesis and modification of biodegradable polymers from renewable, petrochemical and waste materials (including industrial, agricultural and municipal waste).
- 13. Development of modern purification processes for biotechnological products and specialized chemical products.
- 14. Modern unit operations in advanced technological processes.
- 15. Technologies for the synthesis and biosynthesis of specialized intermediates used in the production of biologically active substances, plant protection products, biocides and veterinary medicinal products.
- 16. Technologies using renewable raw materials for the production of monomers, polymers and plastics with the use of these polymers.

II. ADVANCED BIOMASS PROCESSING FOR SPECIALIST CHEMICAL PRODUCTS

- 1. Production of specialized market products from plant and animal raw materials and their derivatives by chemical, physicochemical or biochemical processes.
- 2. The use of by-products from biomass processing for the production of specialized products.
- 3. Production of specialized products through biotechnological and chemical processing of biomass and production of intermediates to support such processing.

- 4. The use of renewable raw materials in the synthesis of polymers and plastics with the use of these polymers.
- 5. Effective management of biomass in thermal processes
- 6. Effective methods of biomass conversion to biochar for agriculture, industry and sewage treatment plants
- 7. Development and practical use of comprehensive technologies for the processing of plant, animal and waste materials from the agricultural/food, chemical, energy industries, as well as wastewater treatment plants, landfills, etc. for the production of semi-finished products for further processing for the chemical, pharmaceutical, household chemicals and other industries.
- 8. Manufacturing technologies aimed at extending the product chain, producing new or improved materials as well as chemical and biochemical products, covering the entire life cycle.

III. BIOPRODUCTS AND SPECIALTY CHEMICALS

- 1. Dietary and medicinal products and food additives of plant origin (including extracts from herbal, fibrous and oil plants), animal and microbiological plants.
- 2. Innovative, effective technologies of production, processing, refinement and modification of natural fibres, as well as fibres from renewable raw materials.
- 3. Polymer, polymer-fibre composites, including plant materials, bionanocomposites, integrated multilayer and multifunctional composites.
- 4. Nano- and microfibres, fibrous nanomaterials, bionanocoatings and multilayer compositions produced using modern processing techniques from biopolymers and thermoplastic polymers (including natural polymers, biothermoplastics and synthetic polymer equivalents).
- 5. Innovative (bio)polymers and (bio)plastics (including biodegradable polymers from renewable raw materials and petrochemical raw materials, polymers obtained by microbiological synthesis, polymers synthesized with the use of biocatalysts, natural polymers with thermoplastic properties, polymers with bioactive and biomedical properties, natural polymer compositions -synthetic, biosensory polymers).
- 6. Technologies of processing polymers and biopolymers into technical utility products (films, paper and cardboard, fibres, nonwovens, injection moulds, composite products), processing techniques from solutions and polymer melt, searching for and application of safe, efficient (organic, inorganic, ionic) solvents.
- 7. Modern methods of producing specialty (bio)polymers using radiation techniques (grafting and crosslinking) intended for specialist products such as films, insulations, micro-foams, heat-shrinkable polymers, coatings, and also for medical applications.
- 8. Modern functional additives in the production technologies of polymeric materials that improve their functional properties.
- 9. Fibrous biomaterials and innovative polymer materials for specialized technical, hygienic, medical, agricultural and other applications.
- 10. Biosensors (including polymer sensors, polymer-fibre sensors, textronic materials, biomimetic sensors, bio-electronic sensors, bio-composite sensing systems.
- 11. New and generic biologically active substances for the production of plant protection products, biocides and veterinary medicines (searching for new biological activities, technologies of production and processing, extraction, biotransformation, utility forms).
- 12. Development of bio-preparation formulations for their application in biosynthesis processes, biocatalysis, biomass and waste processing, and in the manufacture of products.
- 13. Innovative auxiliaries and additives used in chemical and biochemical production and further processing, new specialized additives for polymer and biopolymer materials.
- 14. (Bio)agrochemicals, (bio)fertilizers and agents improving soil properties and structure, bio-fertilizers stimulating plant growth, slow-release fertilizers, agrobiosorbents, biological preparations keeping nutrients in the root layer of crops in the soil, microbiological vaccines, (bio)pesticides, (bio)surfactants.
- 15. New technologies for the production of biocatalysts and homogeneous and heterogeneous catalysts with high selectivity and durability for technological processes.
- 16. Biochemical and chemical methods of producing hydrogen with the purity required in fuel cells.

- 17. Materials, components, electrolytes for the production of cells for electromobility.
- 18. Technologies for the processing of secondary raw materials and by-products with the use of chemical and biochemical processes.
- 19. Methods of using lignocellulose as a renewable chemical raw material, including purification, separation of components, refinement and modification in order to obtain the desired and repeatable quality parameters.
- 20. Methods and processes of obtaining cellulose with specifications compatible with the requirements of the defence industry.
- 21. Biodegradable and biocompostable polymers and monomers for their preparation.
- 22. Processes of purification of biotechnological products and specialized chemical products.

IV. MODERN BIO-TECHNOLOGIES IN ENVIRONMENTAL PROTECTION

- 1. Methods of biological removal of fatty and petroleum pollutants, biodegradation of organic substances of anthropogenic origin in waste streams.
- 2. Modern fermentation processes for the processing of agricultural and food industry waste and municipal waste.
- 3. Bio-hydrometallurgy process for the removal or recovery of metals from municipal and industrial waste.
- 4. Prevention of eutrophication processes by removing phosphorus and/or nitrogen compounds from aquatic ecosystems, municipal and industrial wastewater.
- 5. Development and implementation of new bio- and phyto-remediation technologies for the water-soil environment.
- 6. Integration of biological and physico-chemical processes in the treatment of industrial wastewater to allow the closure of the water cycle/recovery of water and energy.
- 7. Development of methods of deodorization of municipal and industrial waste and livestock manure.
- 8. Technologies for the treatment of exhaust gas emissions to the air.
- 9. Technologies for the purification of technological and waste gases to allow for their further use.
- 10. Biological methods of protection against pests in agricultural and forestry crops as well as food storage and sanitary hygiene (pheromones, repellents, biopesticides, etc.).

SUSTAINABLE ENERGY

NATIONAL SMART SPECIALIZATION 4. HIGHLY EFFICIENT, LOW-EMISSION AND INTEGRATED SYSTEMS OF GENERATION, STORAGE, TRANSMISSION AND DISTRIBUTION OF ENERGY

I. GENERATION OF ENERGY

- 1. Combined production cogeneration, trigeneration, polygeneration
 - Technologies that improve the efficiency and flexibility of combined generation installations and new methods of combined energy generation.
 - Adaptation of combined systems to use new fuels or fuels of lower quality parameters
 - New or improved technologies for the use of waste or low-temperature heat generated as a result of technological or technical processes
- 2. High-temperature nuclear reactors.
 - Development and implementation of high-temperature nuclear reactor technology for the production of industrial heat.
 - Production of process heat for industry and cogeneration using high-temperature nuclear reactors.
- 3. Development of degassing, fast and high-temperature pyrolysis technology
 - Development and implementation of fast pyrolysis technology
 - Development and implementation of high-temperature pyrolysis technology, in particular associated with high-temperature hydrolysis
- 4. Pure coal
 - New or improved technologies of electricity generation from coal to increase the efficiency and/or minimize the emission of pollutants and the need to store unused combustion by-products, as well as the use of coal gasification technology for the purposes of chemical production and energy
 - The use of coal bed methane mining technology, including at the pre-mining stage of the mine
 - Entrapment and disposal of methane discharged through shafts and ventilation systems
 - New technologies related to coal gasification and technologies of fuel cells with a solidified oxide electrolyte, SOFC (Solid Oxide Fuel Cell)
 - Thermal processing of hard coal and lignite to the form of charcoal in combination with the use of heat for the production of electricity as well as process and municipal heat
 - Production of charcoal, in particular: composite fuels, smokeless coal, activated carbon, biocoal, charcoal, technical and organic charcoals
 - Intensification of coal and biomass gasification and pyrolysis processes with maximization of pyrolysis gas production with the highest possible hydrogen content
- 5. Solutions that improve the service life of machines and energy devices, while also reducing noise
 - New technical and material solutions improving the service life of power-generating machinery and equipment.
 - New or improved methods of technical condition monitoring, prediction and analysis for power-generating machines and devices, including the use of SHM (Structural Health Monitoring).
 - Reduction of noise and vibrations accompanying energy generation processes.
 - New or improved methods and systems for monitoring parameters inside power boilers.
 - New solutions improving the technical potential for controlling the operation of power boilers.
 - New solutions to improve the quality of electricity.
- 6. Improving energy conversion efficiency

- New or improved methods of increasing the efficiency or improving the flexibility of energy production.
- The use of waste heat, low-temperature heat and other forms of dissipated energy, including the energetic use of noise and vibrations.
- Optimization of energy production and use through modern control and monitoring systems energy management systems.
- Use of new forms or methods of energy conversion (e.g. Energy Harvesting).
- Increasing the use of energy-saving drives (IE2, IE3, IE4) to reduce the energy consumption for industrial purposes
- Gasification of solid primary energy carriers to maximize energy efficiency, combined with the elimination or reduction of methane (CH₄) and carbon dioxide (CO₂) emissions
- Combination of natural biodegradation with biogas recovery
- Replacing the technology of using natural gas as a mineral in favour of agricultural and landfill biogas from sewage treatment plants, pyrolysis gas and gasification of hard coal and lignite.
- Thermal processing of biomass based on the entrapment of chemical carbon in the form of charcoal or biochar, combined with the production of energy based on volatile parts, with no or minimized share of elemental carbon. (BECCS energy with a negative balance of CO₂)
- 7. Improvement of fuel quality parameters
 - New or improved methods to improve the calorific value of fuel parameters.
 - Real-time monitoring of changes in fuel quality parameters.
 - New methods to maintain the assumed fuel parameters in real time
 - New methods of regenerating solid and liquid fuels that do not meet the quality requirements.
- 8. Fuel cells
 - New technologies for generating electricity (also in combination) with the use of fuel cells (for mobile or stationary applications).
 - Construction of new hybrid systems with the use of fuel cells.
 - New or improved fuel cells.
- 9. Advanced diagnostics of power plants
 - New diagnostic methods of pressure and rotating equipment.
 - Technologies of non-destructive testing.
 - Monitoring the parameters of power units using new measurement methods.
- 10. Power generation control systems
 - New equipment and IT systems for controlling power units.
 - New or improved technologies and systems supporting the design of energy installations.
 - New or improved service support systems.

II. SMART GRIDS / SMART ELECTRICAL NETWORKS

This area includes solutions to increase the efficiency and reliability of power supply, as well as the operational safety of transmission and distribution networks. The area covers the problems of network traffic management, protection of individual elements and the entire network against failures, with particular emphasis on blackouts, energy efficiency and loss reduction, proper integration and management of distributed sources within the network, as well as other tasks related to demand management and implementation of new load equalization methods, voltage adjustment and other parameters of electricity quality, as well as issues related to IT network security (cybersecurity). Achieving a high level of network intelligence is possible through the use of smart measurement techniques, control methods, as well as appropriate IT tools, including effective and safe solutions and ICT means.

- 1. Smart solutions in power networks
 - Smart protection and restitution automation in power systems
 - Smart tools used to optimize the operation and control of transmission and distribution networks
 - Smart operator decision-making support systems
 - Smart and adaptive measurement and decision systems for the needs of Smart Grids
 - Automation and security systems for large transmission and distribution networks, including the use of WAMS, FACTS, HVDC, etc.
 - Smart systems of isolation of island operation and re-synchronization with the power system
 - Virtual power plants and their use to regulate the operation of the electrical power supply system and distributed energy of different power sources.
 - Closed distribution systems and their use to promote distributed energy
 - Means, methods and algorithms for managing the demand for electricity (Demand Side Response, Demand Side Management)
 - Energy interfaces of many energy carriers, their power supply and metering
 - Integration of distributed energy sources and energy storage with the power system
 - Smart management of distributed resources
 - Distributed electricity quality monitoring systems
 - Methods and means of improving energy efficiency and reducing energy losses in transmission and distribution networks, including products, services and engineering tools
 - Integration of power grids, telecommunications networks and IT systems that form smart power grids
 - Development of methods and algorithms for predicting insolation and wind exposure for the purposes of integrating renewable energy sources within smart power grids
- 2. Smart metering and ICT in energy
 - Digital metering systems, including remote metering systems (Advanced Metering Infrastructure AMI) new designs of AMI elements, communication technologies and smart software of AMI Central Systems, interoperability and interchangeability of AMI elements
 - Development of new techniques and data transmission technologies for the needs of the power industry
 - Development of techniques for assuring the cybersecurity of systems related to the measurement and management of Smart Grid networks.
 - Development of new cyber security techniques development of software, devices and IT security services in the power industry
 - Integration of metering and reading systems for many utilities (electricity, water, gas, heat), including solutions for Smart Cities
 - Applications of PMU (Phasor Measurement Units) in transmission and distribution networks

III. ENERGY STORAGE

- 1. E-mobility
 - The use of electric vehicle batteries as energy storage in the optimization of the operation of power grids
- 2. Methods and technologies of energy storage with the use of various carriers
 - The use of excess energy for the production of carriers to enable the storage of alternative fuels (including, among others, hydrogen and synthetic methane)

- New or improved energy storage technologies
- New technologies to improve the efficiency of pumped storage sources
- New or improved energy storage technologies using air and compressed gas energy
- Energy storage using phase-transition materials
- Innovative technologies of energy storage using chemical compounds, including heat accumulators
- New solutions in the field of accumulators and batteries, including lithium-ion, acid and flow, supercapacitors EDLC and LIC,
- Automatically/remotely controlled systems that enable smooth regulation of supply and demand for renewable energy sources through energy storage
- Integration of energy storage with the national power grid at various voltage levels, including the identification of concepts for and barriers to their removal necessary for the dissemination of energy storage technologies
- Integration of energy storage with renewable energy installations
- Mobile energy storage in the form of high-temperature heat optimization of heat production in relation to the demand of local cogeneration systems
- The use of energy storage in distributed hybrid systems (including batteries, kinetic storage flywheel, accumulator batteries with internal storage, pump hydroelectric power plants)
- The use of energy storage to provide system services (reactive power compensation, harmonics, reduction of power swing and voltage changes, reduction of peak loads)
- Electric vehicle charging management
- Fast battery charging terminals
- Developing ways to advance the electromobility sector in the context of power grid operation
- 3. New generation energy storage technologies
 - Supercapacitors research towards the development of a new type of devices in order to enable their application in the power industry.
 - Searching for new solutions allowing for the scaling of technologies of various energy storage media and methods increasing the efficiency and lifetime of storage facilities
 - Research and development of new types of materials or technologies used in the energy storage process in order to increase its safety and efficiency
 - Technologies of nickel-zinc storage devices as a technology favouring the use of domestic deposits of zinc and nickel
 - New technologies of energy storage using local resources of biomethane and syngas

IV. RENEWABLE ENERGY SOURCES

This area relates to the use of locally available renewable energy sources and fuels, in order to increase the energy independence of a specific area (including autonomous energy regions) and the use of new, effective technologies in the field of production, processing and storage of energy from renewable sources, and obtaining liquid fuels in order to reduce demand for energy from conventional sources. Energy can be generated independently from each source, based on smart synergistic modular systems combining several of the same sources or various renewable energy sources with technical parameters selected depending on the local potential and availability of selected energy sources (including synergy of RES and the construction industry). The main goal of activities in this sector is to improve the efficiency of energy generation.

- 1. Wind energy
 - Optimizing the construction of local wind farms on a micro and mini scale

- Innovative technologies for generating electricity from wind energy, aimed at increasing the efficiency of the process of wind energy conversion into electricity (including wind turbines with a vertical axis of rotation)
- Development and improvement of tools for forecasting energy generation from wind farms
- New or improved technologies in the field of offshore wind energy, contributing to increasing the efficiency of wind energy conversion to electricity or reducing investment costs.
- Development works on alternative (mastless) wind technologies

2. Solar energy

- Innovative solar technologies to generate heat
- Photovoltaic cells based on new materials and other new technologies that allow the production of energy from solar sources
- New technologies enabling the improvement of the efficiency of energy production and other operational features in photovoltaic cells
- Development and implementation of optimal solutions for the multi-directional use of photovoltaic farms, in particular agro-photovoltaics.

3. Hydropower

- Development of new efficient technologies enabling the use of water as an energy raw material, while limiting their negative impact on the natural environment
- Development works relating to the technology of mobile hydropower technologies (units floating in the river current)
- Improving the efficiency of water-to-electricity conversion systems.
- 4. Geothermal energy
 - Efficient and environmentally friendly energy production based on geothermal heat
 - New technologies for exploration and exploitation of geothermal waters, including technologies for the management of used-up geothermal waters.
 - Geothermal use of inactive, deep boreholes.
 - The use of groundwater and surface water heat to generate heat with the use of high-power heat pumps (> 1MW)
 - Development of a methodology for the implementation of an innovative technology of heat accumulation and consumption in groundwater levels (ATES technology aquifer thermal energy storages)

5. Biomass, biogas, biofuels and other energy carriers derived from the processing of waste biomass of plant and animal origin and other types of plant biomass, excluding over-exploitation of forest areas

- Innovative processes and technologies for the pre-treatment of biomass and the acquisition of biomass raw materials
- New technologies to improve the quality of biomass and new technologies allowing for the effective pre-treatment of biomass by physical and/or chemical methods to allow for the intensification of the processes of obtaining liquid and gaseous biofuels and bioliquids for stationary applications
- New or improved biogas production technologies (including development and research on the processes of biogas purification to bio-methane with simultaneous development of methods of waste CO2 use, production of bio-fertilizers energy agriculture)
- Development of technologies for the preparation and injection of bio-methane into the distribution and direct networks

- New or improved biomass gasification technologies for energy purposes (including, but not limited to, innovative small-scale technologies up to 5MW for biomass combustion, excluding co-combustion)
- New and improved biomass degassing technologies for energy, heating or both; combined with the production of charcoal, biochar as natural fertilizer or activated carbon
- Innovative processes leading to the production of liquid biofuels and biocomponents, other chemical compounds from biomass of a second or subsequent generation:
- New or improved technologies for the combustion or total gasification of sludge and residues after prior use in a biogas plant. Treatment of ash residues.
- 4. Biogas plants
 - Analyses of the use of bio-waste in rural communities
 - Analyses of the possibilities of energy crops farming on low-quality lands in terms of their use in biogas plants and studying the impact of an increased amount of energy crops on food prices in the country
 - Analysis of the use of municipal bio-waste in biogas plants, (analysis of the possibility of segregating biodegradable waste in urban areas)
 - Technologies for obtaining biofuels and bioliquids to enable the reduction of the amount of waste and by-products
 - Production of fuels, biopolymers, chemicals and fertilizers based on secretion and/or synthesis of valuable chemical compounds in biorefinery processes
 - Development of a concept for the construction of a biomass refinery (bio-refinery) in Poland
- 5. Generation of electricity from surrounding renewable sources using methods related to "energy harvesting."

V. PROSUMER ENERGY

This area includes user-friendly technologies and systems, the use of which will contribute to increasing energy efficiency and improving the quality of power supply to customers in low voltage distribution networks to which prosumer installations are connected. Research should aim at creating conditions for the development and dissemination of these solutions, and at activating the consumer group to introduce them.

- 1. Prosumer energy sources
 - Innovative, highly efficient microgeneration devices and systems for heat and/or electricity, using any source of primary energy
 - Integrated systems for the production of various energy carriers: electricity, heat, cold
 - High-efficiency, small-scale energy conversion and use systems, located near or directly on the user's premises.
 - New, innovative low-power renewable sources integrated with energy storage
 - Innovative energy-efficient prosumer energy microsystems with defined and measurable efficiency, cheap and easy to use
 - The use of innovative technological solutions in micro-sources: photovoltaic (including new materials for photovoltaic applications), fuel, biological and microbiological cells using thermoelectric, piezoelectric as well as other phenomena in order to generate electricity and heat.
 - New mobile sources of electricity (means of overland and water-borne transport) in relation to electricity storage and increasing the reliability of power supply to prosumer systems.
 - New systems enabling the use of post-process energy on a micro scale

- Innovative systems that use watercourses, water currents, etc. to produce electricity for the needs of consumers and local systems
- 2. Prosumer installations and low voltage distribution networks with distributed generation
 - New methods of integrating electricity and heat sources and accumulators in microinstallations, small installations and energy clusters/autonomous energy regions. New management and control systems for low voltage grids with energy sources and storage
 - The use of micro-sources for the needs of voltage regulation in the power grid-
 - New efficiency-improving measures and solutions for power supply for various energy carriers, including voltage regulation and active and reactive power flows in networks with a large share of micro-sources.
 - The use of energy storage, including mobile storage, to support energy management and to provide support services related to the improvement of power quality.
 - Development of new services (including engineering tools) to design new technologies for prosumer energy.
- 3. Information technologies in prosumer energy
 - New information technologies in determining connection conditions and forecasting the operation of power grids with the participation of prosumer energy (Virtual Power Plants).
 - New GIS technologies in low voltage networks.
 - New systems of supporting prosumer energy.
 - Smart prosumer service systems with the participation of HAN home computer networks.
 - Development of open protocols and standards for data exchange in energy networks and installations.
- 4. Development of implementation models of the so-called energy islands based on local sources of primary carriers, e.g. biomass as part of small-scale energy, in particular for the needs of small local communities located far away from energy production and distribution centres.

VI. ENERGY FROM WASTE, ALTERNATIVE FUELS AND ENVIRONMENTAL PROTECTION

- 1. Management of post-mining, industrial and municipal waste
 - Development of waste energy management technology in WtE processes (including in a combined system).
 - Development of technologies for the purification of gases generated in the process of energy waste management in terms of optimization of production costs and the possibility of their management.
 - Research on the preparation of new mixtures of waste to increase their calorific value and therefore ensuring the possibility of their application in the energy sector.
 - Innovative systems for generating electricity (also in combination) with the use of waste hydrocarbons and by-product hydrogen in technological processes (e.g. production of hydrochloric acid, fertilizers, refineries).
 - Development of technologies for the energy management of post-mining waste mainly coal sludge, overgrowth and non-class coals.
 - New and improved technologies of processing waste from hard coal and lignite mining into building aggregates previously sourced from the environment, e.g. gangue into expanded clay, overgrowths into concrete fillers.
- 2. Fuel gasification

- Development of pyrolysis and gasification technologies in the energy direction as well as towards obtaining a range of fuels and products obtained by various methods.
- Development of technology for gas purification after the gasification process, allowing direct use of generating units (including fuel cells and gas turbines) for energy generation.
- Development of gasification technology that allows the use of different fuels in the same device, e.g. biomass and waste (including fluidized bed gasification).
- Innovative systems using biological and thermal gasification processes with the use of solutions for the purification and refining of the produced gas.
- 3. Reduction and management of harmful compounds from emissions and by-products from the energy production process
 - New technologies reducing harmful gases in the energy production process using chemical and physical processes.
 - New or improved technologies to minimize the production and use of combustion by-products (UPS).
 - New or improved technologies for the reduction/management of harmful compounds from emissions, including NOx (also methods of ammonia slip reduction), SOx, dust, heavy metals, carbon dioxide (CCU).
- 4. Alternative fuels
 - New or improved processes of biomass or waste conversion to fuels with parameters enabling safe use in currently manufactured production units.
 - New or improved processes for the production of fluid alternative fuels (liquid and gaseous fuels, including biohydrogen) for energy purposes from selected waste (or other undeveloped materials) as a raw material WtL ("waste to liquid") processes.
 - New or improved technologies related to the use of compressed natural gas (CNG) and liquefied natural gas (LNG)

NATIONAL SMART SPECIALIZATION 5. SMART AND ENERGY-SAVING CONSTRUCTION

I. MATERIALS AND TECHNOLOGIES

- 1. Materials with enhanced parameters, in particular: construction and insulation materials with increased resistance to aging processes, vapour-permeable, low built-in energy, high fire resistance, low emissivity, thermo-reflective and manufactured from plant-derived materials, as well as technologies for their manufacturing.
- 2. Materials and technologies used to revitalize buildings, including legacy buildings.
- 3. Thermo-modernization materials and technologies to be used on the existing thermal insulation which require insulation improvement.
- 4. Materials used to accumulate heat and cold and technologies of their production.
- 5. Materials and technologies for producing high-performance coatings that hinder the development of fungi, bacteria and algae.
- 6. Materials with variable physical parameters, regulated by the parameters of the external environment and/or the energy management system in the building, including materials with variable thermal, spectral, humidity and other properties, and technologies for their production.
- 7. Transparent materials and technologies for their production; windows, glazing systems with variable optical parameters for solar radiation.
- 8. Long-lived roofing and other materials, characterized by high resistance to degrading factors, which protect buildings against weather conditions, including those with variable absorption properties, and technologies for their production.

- 9. Materials and technologies that protect buildings against overheating and/or limit heat loss.
- 10. Research and technologies related to the processes of heat and moisture transport in building partitions depending on the used insulating materials and thermal modernization technology.
- 11. Materials and technologies of sunlight illumination systems with high efficiency and controllability.
- 12. Materials and technologies of passive solar systems integrated with the building's envelope.
- 13. (Active) solar thermal energy materials and technologies integrated with the building.
- 14. Photovoltaic materials and technologies integrated with the building's envelope.
- 15. Multifunctional energy materials and technologies (heating, cooling, ventilation, air conditioning, electricity production) of building envelopes.
- 16. Energy-saving lighting, serviceable modular luminaires for energy-saving lighting with minimized built-in energy, luminaires increasing the cooling efficiency and durability of their components, as well as materials and technologies of their production.

II. ENERGY SYSTEMS OF BUILDINGS

- 1. An integrated approach to building management systems.
- 2. Smart building technologies and systems with particular emphasis on new algorithms optimizing the use of energy from renewable sources integrated with the building and local accumulation systems, advanced production and energy demand forecasting systems.
- 3. Technologies and systems integrating groups of smart buildings and infrastructure of smart cities.
- 4. Systems allowing for easy and better use of the functions of smart buildings, including accessibility and control (gesture and speech control) with the use of cameras, visual identification of threats (e.g. fire or flood), user identification by an smart building.
- 5. Smart prepayment systems for utilities delivered to the building.
- 6. Active façade systems to protect against overheating.
- 7. Building energy distribution systems depending on availability and temporary needs, preceded by the development of a prioritization system for the use of various energy sources in the integrated energy system of the building.
- 8. Smart lighting systems.
- 9. Development of algorithms and building management systems influencing the user awareness of energy use within the DSM (Demand-Side Management) system.

III. DEVELOPMENT OF MACHINES AND DEVICES

- 1. Waste-free/low-waste technologies and technological lines aimed at cost reduction and/or efficiency improvement in the production of materials, construction products, and implementation of construction investments.
- 2. Technological lines, machines and related devices, enabling the production (prefabrication) of building partition modules with high thermal resistance and low built-in energy.
- 3. Machines and devices that reduce the energy and labour consumption of the construction process and increase work safety.
- 4. Devices and energy management systems that allow automatic and smooth use in buildings with multiple power sources.
- 5. Direct current devices and systems for power supply to building.
- 6. BMS/HMS (Building/Home Management System) controllers permanently installed in household appliances/lighting, adapted to work with the building's BMS.
- 7. Devices and systems for conversion, storage and use of renewable and waste energy.
- 8. Devices that integrate energy conversion and storage systems.
- 9. Micro- or small-scale devices with high efficiency for converting the energy contained in the environment into electricity, heat and cooling for use in construction.
- 10. Equipment and systems for rationalization of the use, acquisition, purification and treatment of water.

IV. DEVELOPMENT OF APPLICATIONS AND PROGRAMMING ENVIRONMENTS

- 1. Creation of the Software Development Kit, an open development environment, which would make it possible to create higher-level applications in graphic form in order to control the operation of devices in smart buildings and interaction between individual devices in a network.
- 2. Integrated diagnostic applications for remote monitoring and testing of BMS/HMS systems.
- 3. BMS/HMS applications/systems/interfaces that improve safety, support building management and improve the quality of life of both elderly people with partial disabilities and people with disabilities (visually impaired, deaf and mute, motor impairments).
- 4. Development of communication and data exchange standards between active elements of smart buildings and local systems.
- 5. Design, construction and testing of communication modules ensuring data exchange and management of active elements of smart buildings.
- 6. Design, construction and testing of integrated energy management systems for autonomous local systems.
- 7. Design, testing and implementing algorithms to optimize the resource management of autonomous local systems.

V. INTEGRATED DESIGN

- 1. Development and standardization of libraries supporting BIM.
- 2. Design methods and tools leading to Smart Construction, including the use of computer simulation techniques, BIM (Building Information Modelling) techniques in all design phases (development of tools supporting the design, modelling and simulation of energy-efficient buildings, both in terms of the technologies used and the simulation of the economic effect of financial outlays and payback time).

VI. ENERGY AND ENVIRONMENTAL VERIFICATION

- 1. Programmes supporting and automating the energy audit of facilities undergoing modernization and monitoring of the effects.
- 2. Development of tools for energy and environmental verification in terms of embedded energy consumption and the use of the full life cycle method LCA.
- 3. Validation of integrated zero-energy building systems under real operating conditions ("experimental building network" in different systems).
- 4. Methods and tools for assessing the quality of (existing and erected) building elements to determine the actual characteristics of structures.
- 5. Research, technologies related to the impact of building infrastructure systems on health and work efficiency.
- 6. Innovative range control systems for the parameters of building products having an impact on the final energy efficiency of the building.

VII. PROCESSING AND RECYCLING OF MATERIALS

- 1. Development of technologies for the reuse of materials, construction elements and insulation (recovery, including recycling) in construction.
- 2. New technologies and technological lines for the production of materials and products for the construction industry with the use of accompanying raw materials, by-products and waste.

NATIONAL SMART SPECIALIZATION 6. ENVIRONMENTALLY FRIENDLY TRANSPORT SOLUTIONS

I. INNOVATIVE MEANS OF TRANSPORT

- 1. Optimization of means of transport by reducing weight and size while maintaining functionality (reducing energy consumption and pollutant emission, material consumption, increasing efficiency).
- 2. Intermodality of means of transport, including diffusion of technical and technological solutions between transport systems.
- 3. Infrastructure for the operation of innovative means of transport.
- 4. Modular construction of means of transport, including replacement of drive units.
- 5. Special and specialized means of transport, including unmanned units.
- 6. Means of transport powered by alternative energy sources with infrastructure for their operation.
- 7. Autonomous means of transport.

II. PRO-ECOLOGICAL DESIGN SOLUTIONS AND COMPONENTS IN MEANS OF TRANSPORT

- 1. Alternative drives and power sources in transport, including inductive contactless energy transmission systems for means of transport.
- 2. Drives using renewable energy and energy sources from waste and biofuels, as well as electric drives.
- 3. Innovative processing systems and components, including energy recovery and storage.
- 4. Optimization and improvement of the design and functionality of components in means of transport.
- 5. Innovative recycling, recovery and disposal systems.
- 6. Innovative systems to reduce harmful emissions.
- 7. Design and development of safety systems for means of transport.
- 8. Innovative elements of equipment for means of transport.
- 9. Biomechanical systems in the elements of transport equipment.

III. TRANSPORT MANAGEMENT SYSTEMS

- 1. Organizational and technical measures to enable the implementation of preferences for collective transport.
- 2. Organizational and technical measures to enable the implementation of preferences for green means of transport.
- 3. Organizational and technical measures to enable the development of road freight transport.
- 4. The development of smart transport systems, including modal transport and optimal energy management.
- 5. Smart pro-ecological systems for managing access to protected zones.
- 6. Smart traffic safety management systems in transport.
- 7. Communication systems of the means of transport with the environment.
- 8. Systems minimizing the impact of means of transport on the environment, including systems and technologies for assessing the impact of means of transport on health and safety.

IV. INNOVATIVE MATERIALS IN MEANS OF TRANSPORT

- 1. Innovative metal materials.
- 2. Innovative polymer materials.
- 3. Innovative composite materials.
- 4. Innovative coverings and coatings.
- 5. Innovative hybrid materials, including organic sheets or bionic structures.

- 6. Innovative materials based on secondary raw materials.
- 7. Innovative consumables, including low-emission energy carriers.

V. INNOVATIVE TECHNOLOGIES FOR THE PRODUCTION OF MEANS OF TRANSPORT AND THEIR PARTS

- 1. Modification and construction of new technological lines and production systems for means of transport, components and parts, including recycling.
- 2. Innovative systems of design and quality assessment in the field of methods, techniques, measurement infrastructure and procedures for (technical) quality control at all stages of production and finished products, including the assessment of their functional properties using modern measurement techniques.
- 3. Innovative logistics and supply chain management systems.
- 4. Innovative systems of knowledge management and information flow in enterprises.
- 5. Innovative methods of reducing the impact of production processes on the environment.
- 6. Innovative production technologies, including joining, modelling and processing technologies.

CIRCULAR ECONOMY - WATER, FOSSIL RAW MATERIALS, WASTE

NATIONAL SMART SPECIALIZATION 7. CIRCULAR ECONOMY - WATER, FOSSIL RAW MATERIALS, WASTE

Circular economy is an economic model in which – while maintaining the performance condition – the following basic assumptions are met:

- a) the added value of raw materials/resources, materials and products is maximized or
- b) the amount of generated waste is minimized and the generated waste is managed in accordance with the hierarchy of waste management methods (waste prevention, preparation for re-use, recycling, other recovery methods, disposal).

The above assumptions should be met at every stage of the life cycle (raw material acquisition, eco-design, processing and production, waste and sewage, substitution).

The National Smart Specialization *Circular Economy (KIS GOZ) – water, fossil resources, waste* indicates preferential areas of support for research, development and innovation (R&D&I), serving to transform the Polish economy towards a circular economy model. This change is related not only to technological and product innovations, but also to new solutions, including systemic, legislative, organizational, financial and educational solutions, with consideration given 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-mining areas of rock raw materials
 - New technological solutions to improve the technology of explosive rock mining
 - Innovative tools and technical solutions for high-performance hard rock mining in open-pit mines.
- 2. Metallic raw materials
- 3. Hard and brown coal
 - Innovative technologies improving the operational efficiency of OCT systems.
 - Models, algorithms and software for improving the working efficiency of multi-bucket wheeled excavators under the operating conditions of working low-thickness seams
 - Innovative solutions and technologies for selective mining of multi-deck deposits with multibucket wheel excavators
 - Innovative technologies of exploitation of hard-to-cut rocks in brown coal mining
 - Innovative solutions improving the efficiency and safety of basic machines in mining.
 - New solutions enabling the adaptation of mining technology to geological and mining conditions
 - Modern methods of detecting and preventing the occurrence of serious threats, including landslide, fire, water, etc.
 - Models, algorithms and software for improving and modelling/forecasting energy consumption in mining processes
 - Innovative mining control technologies (mining technology with consideration given to the effort of machines, IT support in the management of mining and operation in mines)
- 4. Natural gas
 - a. Technologies of exploration, identification and development of natural gas deposits:
 - Modern technologies of exploration and identification of gas deposits
 - Smart deposit monitoring and decision support systems in the exploration and development of gas deposits.
 - Local development of gas from deposits that cannot be connected to a gas network
 - Innovative methods of gas hydrate deposit identification, including marine geophysics

- Innovative tools dedicated to surface geophysics (apparatus, sensors, detectors)
- b. Innovativetechnologies for deposit exploitation and extraction intensification:
 - New drilling technologies for accessing old and partially depleted deposits
 - Modular, container drilling systems as elements of smart gas mines

5. Petroleum

Technologies for exploration, recognition, extraction and exploitation of conventional and unconventional crude oil deposits:

- Mining techniques and technologies to maximize the extraction of deposits
- Integrated oil basin analysis methods for the detection of hydrocarbons
- Production intensification techniques (secondary and third methods: injection of water,
- superficially active agents, CO2, microbiological and chemical methods)
- New technologies for making deposits available, including tight oil deposits
- Automated, unmanned oil mines (smart oilfields)
- 6. Water
 - Solutions for the improvement of the ecological status of degraded rivers, aquatic ecosystems and water-dependent ecosystems (restoration and revitalization), aimed at reducing the grey water footprint (including counteracting eutrophication)
 - Techniques and methods of revitalization of small water bodies and watercourses, allowing the ecosystem's water resources to be increased
 - Biochemical remediation and storage of surface waters with hydrodynamic infiltration for stabilization and protection of exploited aquifers
 - Solutions for effective protection of main groundwater reservoirs against anthropogenic threats in post-industrial and degraded areas
 - Techniques of biomonitoring and bio-indication of water resources
 - System solutions for building database resources and integrating distributed data sources as components of the national data resource on the state of the environment
- 7. Horizontal issues
 - a. Minimizing waste generation
 - Waste-free or low-waste innovative technologies for obtaining raw materials
 - Methods, tools, processes and technologies to reduce waste generation at the stage of sourcing raw materials
 - Reducing the amount of waste generated through selective sourcing at the stage of raw material extraction
 - b. Preparation for re-use
 - c. Substitution
 - New metallic and composite materials aimed at producing substitutes for critical and hazardous metals

II. ECODESIGN

- 1. Creating resource-efficient and energy-efficient new, improved, reworked or renewed products
- 2. Creation of products using raw materials recovered from waste and sewage
- 3. Increasing the durability and extending the shelf life of the devices and products used
- 4. Providing substitutes for hazardous, complicated and burdensome substances in the recycling process
- 5. Development of substitutes for non-renewable resources and water
- 6. Ensuring a new use and/or re-use of products, their parts and materials

III. PROCESSING AND PRODUCTION

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

- 2. Metallic raw materials
 - a. New technologies and equipment for the enrichment of metallic minerals:
 - Technologies for the recovery of metals from ores with difficult enrichment characteristics
 - Technologies for comprehensive recovery of useful ingredients from anthropogenic secondary raw materials
 - Innovative technologies for the enrichment of low-quality polymetallic ores
 - New designs of equipment for the enrichment of mineral resources
 - b. Metallurgical technologies (pyro- and hydrometallurgical) for the production of non-ferrous metals from primary and secondary raw materials:
 - Innovative technologies for melting and refining metals.
 - New solutions for the construction of energy-saving metallurgical units for smelting ores and metal concentrates, as well as for processing fusion products
 - Technologies for obtaining metals from waste and semi-finished products from metallurgical processes (slags, dusts, sludges)
 - Recovery and processing of waste energy from technological gases from metallurgical units as well as solid and liquid materials
 - Development of leaching methods, including pressure leaching, of metal ores and concentrates.
 - Innovative methods for the selective separation of metals from aqueous solutions (precipitation, ion exchange, electrochemical)
 - Hydrometallurgical methods of recovery of accompanying metals, including critical ones
 - c. Innovative technologies of deep metal processing, including:
 - Production of functional materials by liquid-phase methods.
 - Development of new casting alloys with improved functional values in relation to the existing ones (new methods of controlled crystallization and structure refining, selection of new alloying additives).
 - Shaping the structure and properties by the methods of plastic working, heat treatment and thermo-chemical treatment.
 - Production of powder metallic and composite materials with the use and development of techniques of atomization, high-energy grinding, mechanical, chemical and plasmochemical synthesis.
 - Manufacture of products by additive manufacturing.
 - d. Modification of existing and new technological lines and devices for metal processing processes, enabling continuous processes, reducing the number of separate technological operations, as well as ensuring the production of nano-structured products
 - e. Innovative technologies of metal processing, production and application of protective and functional layers, using chemical, electrochemical methods, thermal spraying and laser surface functionalisation:
 - Methods and materials for the protection of steel structures against environmental exposure
 - Utility coatings for modern construction and new engineering applications
 - f. Processing of refractory metals, with particular emphasis on domestic raw materials
- 3. Hard and brown coal
 - Technologies of gasification, thermal decomposition by thermolysis and pyrolysis, drying for the production of secondary raw materials and new products.
- 4. Natural gas
 - New technologies of production and adaptation of gaseous fuels to network parameters
- 5. Crude oil
 - a. Crude oil processing technologies:

- Techniques and technologies that allowed yield maximization from white products.
- Techniques and technologies to optimize the conversion of processed crude oil
- Techniques and technologies optimizing the management of by-products and waste from crude oil processing
- Technologies to manufacture products of improved quality and niche products
- b. Application of new materials and technological solutions:
 - Technologies and materials that optimize energy processes (the possibility of processes operating in high-temperature and -pressure areas) minimizing process losses, allowing for better yields
 - Technologies for the use of natural gas in crude oil processing (including hydrogen production)

6. Water

- a. Quality improvement
 - Water treatment through innovative technological methods and device designs as well as the use of new-generation reagents which allow minimizing the consumption of natural resources, as well as the use of secondary raw materials
 - Control and adjustment of water treatment processes, tests and methods for water quality assessment as well as tools and IT systems for controlling the condition and monitoring of water quality
 - Methods, processes, materials (including secondary raw materials) aimed at maintaining the biological and chemical stability of water and minimizing the amount of by-products (and waste) generated in the water disinfection processes.
 - Methods and processes for removing 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 crisis situations
 - Methods, processes and technologies for purifying groundwater from pollution with hydrocarbon substances and other chemical substances
 - Modelling and intensification of water purification processes in hybrid systems
 - New measurement techniques and research methods for the identification of micropollutants in water.
- b. Use
- Technologies for the recovery and use of rainwater, geothermal water, salt water and brackish water leading to the production of water intended for consumption and economic purposes
- System solutions for closing and integrating water circuits and recycling process waters in municipal and industrial systems as part of industrial symbiosis
- Technologies for reducing losses in water distribution systems
- IT monitoring systems aimed at increasing the efficiency of the use of water resources
- Monitoring and metering technologies for increasing the efficiency of water resources use, i.e. reducing water consumption and losses in water systems, using information and communication techniques and spatial information systems
- Technologies of small-scale retention and use of rainwater in urban and rural areas, as well as in technological circulations and for economic needs
- Smart rainwater collection and drainage systems integrating the potential of natural, quasinatural and canal (infrastructure) retention
- Engineering, spatial and organizational solutions for retention, treatment and management of rainwater in urban spaces and in areas with low urbanization as an alternative to "collect and drain" solutions
- 7. Horizontal issues Minimizing waste generation
 - Waste-free or low-waste innovative production/processing technologies

- Methods, tools, processes and technologies to reduce waste generation
- Reducing the amount of generated waste through its selective collection at the production stage
- Minimizing waste generation by introducing innovative materials
- Minimizing the formation of by-products of combustion of energy resources

IV. WASTE AND SEWAGE

- 1. Innovative waste recycling technologies
 - Waste processing technologies by mechanical, thermal, cryogenic, biological, microbiological, physical and chemical methods
 - Waste processing security technologies
 - Waste treatment technologies that reduce emissions of CO2 and other greenhouse gases to the air
 - Technologies for the recovery of scarce and critical raw materials from waste
 - Technologies for processing multi-material, multi-layer and composite waste
 - Development of products from thermal waste treatment, including pyrolysis, thermolysis, gasification, plasma technologies, etc.
 - Recovery technologies, including recycling of metals from waste
 - Technologies for processing post-production and post-operational waste
 - Technologies relating to waste from vehicles decommissioned from road use and WEEE, which is difficult to process
 - Waste processing technologies from mining of energy resources and non-energy and mineral waste
 - Equipment and lines for recovery, including waste recycling
 - Technologies for the management of materials obtained from waste processing
 - Selective technological processes of obtaining highly processed chemical compounds from waste
 - Multi-material and composite products based on waste for use in various branches of the economy
 - New and improved technologies for the use of waste in the form of fly ash, slag, ash-slag mixture and post-reaction products from installations in construction
 - Development of energy-saving installations for drying and management of biodegradable fractions for their further use as a raw material
 - Development, research and support of composting infrastructure: introduction of the selection of wet biodegradable waste and implementation of technology for the process of obtaining full-value compost
- 2. Innovative technologies of material recovery from wastewater
 - Technologies for the recovery of nitrogen and phosphorus from process streams and remanagement
 - Technologies for the recovery and bio-sequestration of inorganic carbon from process streams (including gas)
 - Technologies for the recovery of trace elements and metals from process streams
 - Technologies for the recovery of organic compounds (including cellulose, PHA) from process streams
 - Solutions enabling the use of industrial wastewater streams carrying organic compounds as substrates in heterotrophic wastewater treatment processes
 - Technologies for the management of raw materials generated in the sedimentary part of the sewage treatment plant.
 - Closing water and sewage circuits with the use of pre-treated wastewater, treatment of postprocess water for municipal and industrial needs.

- 3. Innovative technologies for wastewater treatment and water recovery from wastewater
 - Wastewater treatment through innovative technological methods and device designs as well as the use of new generation reagents and preparations
 - Methods, processes, materials for removing persistent organic pollutants (POPs) from sewage, including biologically active substances.
 - Development of wastewater disinfection methods, with consideration given to reduction of the possible formation of harmful by-products
 - Nanotechnologies in wastewater treatment
 - Improved high-performance anaerobic wastewater treatment methods, including integrated anaerobic-oxygen systems
 - Technologies for water and wastewater treatment in the mining industry
 - Methods, tools and processes for reducing the amount of nutrients released to surface waters, including the use of industrial water reservoirs as biological surface water treatment plants
 - Technologies of individual wastewater treatment systems giving consideration to the removal of biogenic compounds and intensifying the removal of organic pollutants, as well as leading to technical and technological reliability and enabling the control of treatment effects
 - Increasing the efficiency of wastewater treatment and sludge conditioning processes
 - Smart measurement systems, IT programmes for wastewater quality monitoring, as well as for supervising wastewater disposal systems and processes
 - Modelling of wastewater and rainwater treatment processes and systems
 - Methods, tools, devices and processes leading to the improvement of sewage management in rural areas and areas with scattered buildings
 - Technologies for minimizing and removing substances of emerging concern (CEC)
 - Reducing water consumption by developing systems for the recovery and use of "gray water"
- 4. Use, recovery and optimization of energy consumption in water and sewage management
 - Implementation of solutions aimed at optimizing energy consumption, including the use of renewable energy sources in water and sewage management.
 - Technologies that use sewage and sludge as substrates for energy.
 - Technologies for neutralizing sewage sludge with organic co-substrates to increase the energy efficiency of sewage treatment plants.
 - Innovative systems that associate energy from renewable sources with wastewater treatment processes in household wastewater treatment installations and other dispersed sewage storage and treatment installations.
 - Development and implementation of technological solutions for the use of energy from wastewater in combined energy systems, including wastewater treatment systems integrated with water and heat recovery.
- 5. Innovative technologies of energy recovery from waste
 - Technologies for optimal production and use of alternative fuels obtained from waste (without RDF)
 - Technical development of power generators, gas turbines, furnaces for the safe combustion of fuels obtained from waste
 - Innovative solutions for energy recovery from waste, excluding combustion and coincineration.
 - Technologies of product recovery from waste by thermal decomposition
- 6. New safe methods of waste disposal
 - Waste protection technologies through mineralization, solidification and stabilization
 - Technologies of protection against gas, odour and dust emissions
 - Technologies for storing waste that cannot be used in other management processes
 - Methods of using anthropogenic minerals in the reclamation of post-mining areas

INNOVATIVE TECHNOLOGIES AND INDUSTRIAL PROCESSES (HORIZONTAL APPROACH)

NATIONAL SMART SPECIALIZATION 8. MULTIFUNCTIONAL MATERIALS AND COMPOSITES WITH ADVANCED PROPERTIES, INCLUDING NANOPROCESSES AND NANOPRODUCTS

I. ADVANCED MATERIALS AND NANOTECHNOLOGIES FOR MEDICAL PURPOSES AND HEALTH PROTECTION, AND HYBRID MATERIALS WITH LIVE CELL TISSUES

- 1. New materials, including composite and nano-structured ones, as well as innovative technologies for their production in the field of incremental technologies and hybrid biodegradable polymeric materials with controlled bioactivity, and hybrid fibrous structures for applications in regenerative medicine, polymer nanocomposites and nanocomposite fibres, for medical and hygienic purposes, for innovative devices, instruments and medicinal products and dental services in order to provide and support medical diagnostics as well as therapies and methods of regenerative medicine.
- 2. New materials, including composite and nano-structured materials for products, medical and dental implants and stents with different chemical and phase compositions of the core and outer layers as well as anisotropic, biomechanical, biocompatibility, biodegradability, adjustable degradation time and nanocomposite materials for porous scaffolds for cell cultures and innovative technologies for their production using incremental, hybrid and surface engineering methods as well as with the use of tissue engineering methods
- 3. New materials, including composite, nano-structured and engineering-biological hybrid with the participation of living tissues and cells for medical implants, including dental implants, stents, artificial organs and hybrid engineering-biological implants, as well as innovative technologies for their production using incremental and hybrid methods.
- 4. New composite and nano-structured materials acceptable to the human body for medical nano- and microimplants, biocompatible fluorescent nano-markers, for pharmaceutical nanocapsulation, for applications in bioimaging and drug transport, for diagnostics and treatment, in order to allow the creation of smart medical and telemedical nano-laboratories, and the design and development of innovative technologies for their production.
- 5. New smart composite and nano-structured materials for dressings, for surgical and hygienic devices in order to allow the dosing of medicines and nano-pharmaceuticals, with a regulated time of biodegradation and separation from the substrate, as well as innovative technologies for their production.
- 6. Technologies and nanotechnologies of special-purpose surface and nanostructural layers for products used in medical instruments and medical and dental implants, as well as in food industry equipment.

II. ECOMATERIALS AND BIOMIMETIC, BIONIC AND BIODEGRADABLE COMPOSITE AND NANOSTRUCTURAL MATERIALS

- 1. New functional materials, nanomaterials and nanocomposites for the protection of the natural environment, including protection against pollution and against greenhouse gas emissions, used in low-emission systems and the strategic substitution of environmentally hazardous materials, free from harmful substances, ensuring good environmental protection, more adapted to recycling, and innovative technologies for their production.
- 2. New materials, technologies and structures for material, technological and construction conversions with a view to ensuring sustainable development, reducing production costs and energy consumption, elimination of harmful substances or their emission, reduction of the consumption of scarce elements and the development of related engineering design methods and computer-aided engineering design methods.

- 3. New economical materials and nanomaterials, including alloys and structures with relevance to environmental development, for water filtration, for moisture or mist collectors, solar collectors, solar cookers, dispersed thermoelectric roofing and innovative technologies for their production;
- 4. New composite and nano-structured eco-materials with regulated degradation or resorption time, made from
 - natural raw materials, biopolymers reinforced with plant fibres and amenable to controlled degradation.
- 5. New and biologically inspired metal technologies, materials and structures and their superhydrophobic surfaces, vessel-shaped cooling channels, hierarchical alloys/foams/composites and new multifunctional materials, nanomaterials and biomimetic and bionic nanocomposites, as well as new multifunctional composites and structural nanocomposites, bionic layers and structures, and innovative technologies for their production.

III. ADVANCED MATERIALS AND NANOTECHNOLOGIES IN RENEWABLE ENERGY AND FOR TRANSFORMING, STORAGE AND RATIONALIZING ENERGY MANAGEMENT

- 1. New multifunctional materials, nanomaterials and nanocomposites for the acquisition, transformation, storage of energy and rationalization of energy management.
- 2. New advanced materials, nanomaterials and nanocomposites for high-efficiency photovoltaic energy acquisition using mono- and polycrystalline silicon and inorganic and organic materials in the production of perovskite and dye cells, with the use of conductive polymers and anti-reflective coatings, containing particles, thin coatings, carbon nanotubes and graphene, heat transfer fluids, multiphase materials and receptors and their combinations as well as innovative technologies for their production.
- 3. New advanced materials, nanomaterials and nanocomposites for the integration of energy storage technologies in the electrical network for the application of advanced functional particles, fibres, layers and coatings to integrate storage devices into the electrical network and through the use of high-capacity cables and superconductors, high-voltage cables and accessories, medium voltage materials and electrical accessories, smart new materials for extreme conditions and surface treatment of existing materials for protection and performance improvement in the context of energy storage in the electricity grid and new composites based on copper, silver or aluminium, containing various allotropes of carbon, including graphene, intended for the electrical industry, for heat dissipating materials, low- and high-voltage contacts, and electricity transmission cables.
- 4. New advanced materials, nanomaterials and nanocomposites ensuring the selection of energy storage methods by transforming electricity into chemical energy carriers, materials for permanent high-capacity proton exchange membranes, electrolysers for the production of hydrogen under pressure, for permanent storage of hydrogen in a state of low pressure and direct synthesis of hydrocarbons, and for photochemical water dissociation reactors using new catalysts based on advanced materials.

IV. MULTIFUNCTIONAL COMPOSITE AND NANO-STRUCTURAL ULTRALIGHT, ULTRA-DURABLE MATERIALS WITH RADIALLY INCREASED HEAT STRENGTH AND RESISTANCE

- New advanced lightweight materials, nanomaterials and structural nanocomposites with increased mechanical properties, metal matrix composites with both micro- and nano-structured reinforcement, containing various light components, such as Mg, Al, Ti in structural and thermal applications such as Cu, Al, low friction, wear-resistant, impact-resistant, for electrical applications, as biocompatible materials, new low-density and high-strength materials, highly ductile steels and alloys, multilayer and composite polymer materials and foams with high strength and reduced unit weight, as well as their innovative technologies.
- New advanced light high-strength intermetallic materials, in the field of aluminides, silicides and tough lanthanides and cermets, new nanocrystalline Mg, Al or Li hydrides with very fast absorption and desorption kinetics for hydrogen storage, materials, nanomaterials and nanocomposites as well as precipitation-hardened Al – Li – Sc, Al – Mg – Sc core-shell alloys for highly durable specialized components and their innovative technologies.

- 3. Technologies of advanced light and new solid metallic glasses based on Mg, Al, Ti, Fe as well as composites and nanocomposites with amorphous, nano-crystalline and crystalline structures for applications in specialized structural, functional, biomedical, wear- and corrosion-resistant elements and microelements, and their innovative technologies.
- 4. Technologies of advanced, ultra-light, new cellular structures with a metal, polymer, ceramic and composite matrix as well as hybrid structures, resistant to destruction, metal foams, micro- and nano-skeleton, mesh and hybrid structures.
- 5. New advanced materials including high-entropy multi-component metal alloys providing unique structural properties and greater phase stability for applications at high temperature, heat-resistant alloys W, Ta, Re, Hf, Nb, Mo, V and platinum for operation in the most extreme high-temperature and oxidizing environments and for fusion applications, as well as new metal-ceramic composite materials with unique properties and their innovative technologies.
- 6. Technologies of new advanced fine-grained superplastic deformed Ti or Al alloys and high-strength steels such as TRIP, TWIP and TRIPLEX, with superbainite structure, new ODS steels and bearing steels.
- 7. Technologies of new advanced lightweight composites with a polymer matrix and hybrid composites with fibrous reinforcement to increase the mechanical properties and reducing the weight of the finished product.

V. ADVANCED MATERIALS AND NANOTECHNOLOGIES FOR SAFETY APPLICATIONS

- 1. Technologies of new advanced materials, nanomaterials and polymer and hybrid nanocomposites with fibrous reinforcement with enhanced mechanical properties and reduced weight, using spatially formed fibrous structures or a formed structure using the 3D printing technique, additionally reinforced with inorganic or organic fibers, integrated with sensors, intended for Personal Protective Equipment and smart specialist clothing.
- 2. Technologies of new advanced multilayer composite materials and hybrid surface engineering technologies using laser technologies and ceramic-metal composite materials.

VI. ADVANCED MATERIALS AND NANOTECHNOLOGIES FOR PRODUCTS WITH HIGH ADDED VALUE AND HIGH IMPORTANCE FOR INDUSTRIAL VALUE CHAINS

- 1. New methods of producing sintered and ceramic materials, including superfine grains, and innovative products produced by these technologies, methods of powder metallurgy and powder production, in the field of atomization, cold spraying, spray forming and coating, other innovative techniques of moulding, incremental sheet metal moulding, explosive or creep moulding, isostatic densification, new machining technologies, as well as increasing metal production and moulding, near-net-shape precision machining, heat, thermo-plastic and surface treatment, joining and recycling techniques.
- 2. New technologies of additive, selective laser sintering and melting and 3D printing, along with the appropriate devices, new innovative solid and porous materials, including hybrids and gradients with a gradient of properties or with properties changing in a designed way in their volume or anisotropic materials, multi-layered composites with a composition that varies continuously, from metal to ceramics or with different core and surface composition and properties, composites consisting of materials with different physical and chemical properties, melting points, thermal conductivity, absorption, adapter to the requirements for creep resistance, abrasion resistance, passivation, corrosion resistance, innovative materials with geometrically designed internal structure, filled with mesh and bar structures or sandwich structures with special mechanical properties , with controlled stiffness or elasticity, as well as the ability to damp or dissipate vibrations to an extent other than that allowed by the properties of the base material itself, hybrid materials doped by volume or surface with powders different in size or composition from the base material.
- 3. Innovative technologies for the production of individual, short-series products with new functionalities, characterized by a complex shape, with adjustable porosity, and "smart" thanks to integration with sensors and effectors, with a short time to implement into production, multi-material products and products made from materials impossible to produce with other technologies, from components with

various ranges of melting and boiling points, for applications in various industrial and economic sectors, as well as in medicine and health care.

- 4. New innovative technologies for the production and processing of nano-crystalline multifunctional alloys by methods of intensive plastic deformation by torsion, cyclic compression extrusion, multiple angular channel pressing, hybrid methods of rolling, hydrostatic extrusion and alternating forging for various structural elements, by pressure casting with infiltration, micro-casting and imprinting of alloys, composites and solid metallic glasses used for specialized micro-device components, integrated electromechanical microcircuits (MEMS), nano-structured matrices as well as hierarchical surface coatings, in Cu, by electroplating for use in boilers, heat exchangers and pipelines.
- 5. New advanced hybrid technologies for materials and related end products with nanostructure and nanofunctionality shaping during the standard process of products or semi-finished products, in additives crystallizing in nanoparticles during injection moulding of a metal layer or during forging or spontaneous creation of hierarchical structures during coating, for the production of customized products or semi-finished products from advanced materials, nano-foams and nanocomposites, after ensuring an increased level of reliability and repeatability of industrial processes.
- 6. New and developed micro-fluidization devices based on polymer materials by 3D printing or injection of polymer or ceramic materials in the production of microfluidic integrated electromechanical MEMS microcircuits, for nozzles and filters, for sensors, lab-on-chip systems, printed biochemical materials, soft substrates on micro- and nano-biological applications, biomedical and biophysical sensors, biocompatible or non-toxic scaffolds for active cell growth as well as for reducing the cost of rapid production and prototyping of a new range of disposable products, where production costs must be kept to a minimum, and for their use in practical applications after the transition from a laboratory or smalllot scale to industrial applications with an increase in the level of reliability and repeatability of relevant industrial processes.

VII. FUNCTIONAL MATERIALS, NANOMATERIALS AND COMPOSITES WITH ADVANCED PHYSICAL, CHEMICAL AND UTILITY PROPERTIES

- 1. Technologies for the production and processing of new advanced materials, smart and integrated nanomaterials and nanocomposites in the form of 2D and 3D, advanced light composites with a polymer matrix, metal, organic fibrous materials, textronic, as well as metal materials, with the participation of nanoparticles from carbon materials, for the purpose of providing new functionalities, communicating and interacting with the environment and archiving data about its condition and responding to external stimuli, changing their physical properties, viscosity, shape, and colour due to changes in temperature, stress, electric field, solar energy, and with the ability to collect, store and transmit data, to be used for sensors in self-diagnosing, self-detecting or self-repairing elements under operating conditions, for functional composite gradient materials, with variable magnetic properties, in order to damp vibrations and sound and generate thermal energy from smart conductive polymers.
- 2. New advanced functional materials with non-standard electrical and thermal conductivity for end-product industries, for capacitors, thermal coatings, energy-efficient building insulation boards, and with the use of new devices and manufacturing processes for additive manufacturing and 3D printing, in order to advance integration with multifunctional nano-materials and their use in large-scale practical applications, much larger than the existing limited niche applications, following the shift from laboratory scale to industrial applications, with increasing levels of reliability and repeatability of such industrial processes.
- 3. New innovative technologies for the production and processing of nano-structured advanced materials, with new functionality, superhydrophobic, self-cleaning, self-healing systems, smart biomimetic textiles and papers with controlled shape change and memory, self-organizing systems to produce energy, for applications in the sectors of industry and economy where industrial design is highly important, in order to obtain added value of products through the use of new material and non-material functionalities as well as design and production of radically new products with a highly competitive market advantage
- 4. New technologies enabling the use of paper and textiles for functional electronic components or devices with promising technical, economic and environmental advantages, for smart displays of labels,

packaging, biological tags, and in medicine due to the development of lab-on-chip devices and the related development of new technologies for the production of paper and textiles, with the use of reinforcing fibres and fillers to ensure the required porosity and the development of new paper and textiles, with appropriate organic, inorganic or hybrid coatings, treatment and functionalisation of the surface of paper and textiles using nanocellulose, plasma or gas, and the introduction of new materials including conductive materials, semiconductor insulators, electrochromic insulators, battery electrodes, as well as high-precision and cost-effective printing or other large-scale production technologies for inkjet printers and roll-to-roll processes.

5. Advanced multifunctional smart nano-structured materials for applications in electronics, optoelectronics, sensors, IT, photonics and communication, as well as their technologies.

VIII. MULTIFUNCTIONAL COMPOSITE NANOMATERIALS WITH A MATRIX OR REINFORCEMENT FROM NANOSTRUCTURAL CARBON MATERIALS AND OTHER NANOFIBERS, NANO-WIRES AND NANOTUBES AND THEIR TECHNOLOGIES

- 1. Technologies of advanced multifunctional nanostructured and nanocomposite materials, including metal, polymer and ceramic matrix reinforced with various types of nanostructured carbon materials, nanotubes, fullerenes, nanofibres, graphene, along with the development of the production scale (from laboratory to industrial) with increased levels of reliability and repeatability of appropriate industrial processes, and other organic and inorganic natural materials, i.e. halloysite and synthesized materials, titanium dioxide, nano-wires, nano-fibres, nano-tubes and other nano-structured objects, in order to obtain added value of products and unexpected effects in the form of improvement of mechanical and physicochemical properties through the use of new material and non-material functionalities as well as designing and manufacturing radically new and significantly evolving products with a highly competitive market advantage.
- 2. Technologies of advanced multifunctional nanostructured and nanocomposite materials with a matrix of various types of nanostructured carbon materials, nanotubes, fullerenes, nanofibers, graphene, decorated with noble metal nano-crystals in nano-sensor applications, with nano-layers of polymer complexes deposited on the fibres, in order to deposit metals on the surface and change the superficial, thermal, bactericidal and catalytic properties, in order for them to be used as reactors for matrix polymerization, with the development of the production scale, for applications in nano-sensors, nano-electronics, and drug nano-capsulation, for the purpose of obtaining product added-value, by using new functionalities and producing radically new and super-promising products.

IX. MULTIFUNCTIONAL LAYERS, PROTECTIVE, ANTI-WEAR NANO-LAYERS AS WELL AS SPATIAL, MULTI-LAYERED AND SELF-REPAIRABLE COMPOSITES AND NANOCOMPOSITS

- 1. New technologies of surface treatment by shaping the surface and applying layers, e.g. nano-structured layers, including the application of self-assembling monolayers, immobilization, patterning and application of diamond and diamond-like carbon coatings as well as electrophoretic and sedimentation deposition in order to ensure good biocompatibility and anti-corrosion resistance of the coatings and the possibility of application to elements with very complex geometry, with regard to the production of innovative devices, instruments as well as medicinal and dental products.
- 2. New nanotechnologies of antimicrobial surface treatment by applying surface coatings or modifying the surface morphology, for use in hospitals for surfaces of furniture, medical equipment and devices, surgical implants, as well as in water purification systems, textiles, packaging, food storage and household appliances, use of such technologies for practical applications after the transition from a laboratory scale to industrial applications with increased levels of reliability and repeatability of the relevant industrial processes.
- 3. New technologies of surface treatment by shaping the surface and applying layers, including nanostructured layers, through physical and chemical vapour deposition (PVD / CVD), ion implantation, and

ceramic and cermet coating in relation to metal construction materials, and physical and chemical vapour coating, pulsed laser deposition or EUV laser-plasma radiation, as well as the sol-gel method and electrophoretic deposition for non-metallic construction materials, used in various industrial sectors, including mainly in the machinery and electromechanical industry as well as applying polymer powder coatings, painting and varnishing with liquid polymer materials, hot-dip galvanizing with additional annealing, applying polymer film coatings and spray metallization, through laser ablation (PLD), hybrid technologies, with the use of laser treatments, methods of applying gradient coatings, physical and chemical vapour phase coating (PVD / CVD) for tool materials.

- 4. New nanotechnologies of surface treatment by applying nano-structured coatings or nano-texturing the surface for increased scratch and abrasion resistance high hardness, wear and corrosion resistance, enhanced colour or gloss, on self-cleaning building surfaces, on coatings of technical textiles with increased resistance and mechanical properties, on structural elements of machines, constructions and means of transport, in various sectors, including packaging, marine, water treatment, electronics, construction, automotive, energy, textiles and leather products and their use in practical applications with an increased level of reliability and repeatability of relevant industrial processes.
- 5. New technologies for the surface treatment of glass, micro- and optoelectronic and photovoltaic elements as well as functional products made of these materials, by shaping the surface and applying layers, e.g. nano-structured layers, through physical and chemical vapour deposition (PVD/CVD), solgel method, laser texturing, production of hybrid organic-inorganic coatings and new technologies of surface treatment of polymeric and fibrous materials, by creating gradient and self-deforming coatings, in-situ polymerization, physical and chemical vapour deposition of coatings (PVD / CVD), sol-gel method, EPD and ALD, as well as laser surface treatment, with an increased use of these technologies on an industrial scale.
- 6. New and developed nanotechnologies for the treatment of flame retardant and anti-electrostatic surfaces through the use of surface coatings or modification of the surface morphology, in order to eliminate or significantly reduce the accumulated charge in combination with flame retardant properties, in areas exposed to explosion of volatile substances, in warehouses, mines and landfills and packaging, when storing volatile substances and using them in practical applications after the transition from laboratory scale to industrial applications with an increased level of reliability and repeatability of the relevant industrial processes.
- 7. New multifunctional advanced structural, spatial, skeletal, layered composites and nanocomposites with a property gradient, with properties changing in a designed manner in their volume or anisotropic properties, and foams, with a matrix and/or metal, polymer or ceramic reinforcement, shaped with the use of laser selective sintering and melting as well as 3D printing techniques or by infiltration and impregnation, with an innovative geometrically designed 3D internal structure, with both micro- and and nano-structured, inorganic or organic fibres, carbon nano-materials and natural nano-tubes, using spatially formed fibrous structures, thin textiles or filled with mesh and bar structures, with a layer structure and using bionic honeycomb structures with special mechanical and physicochemical properties, with increased strength, thermal and acoustic insulation, resistance to the environment, impact and cracking, low density, and innovative technologies for their production.

X. MODELING OF THE STRUCTURE AND PROPERTIES OF MULTIFUNCTIONAL MATERIALS AND COMPOSITES, INCLUDING NANOSTRUCTURAL MATERIALS WITH ADVANCED PROPERTIES

- Computer-aided design of materials, especially newly introduced advanced materials, nano-materials and nano-composites, including atomic scale and multiscale modelling, microstructure and micromechanical simulation, using virtual reality tools and artificial intelligence and data mining methods, for virtual design, virtual processing and virtual testing of advanced materials for technical applications.
- 2. Modelling and simulation of degradation and damage of materials under operating conditions, in order to predict the behaviour of advanced materials in technical applications under virtual testing conditions.

NATIONAL SMART SPECIALIZATION 9. ELECTRONICS AND PHOTONICS

Glossary:

ASIC (Application Specific Integrated Circuit) - a specialized electronic integrated circuit

ASPIC (Application Specific Photonic Integrated Circuit) - a specialized photonic integrated circuit

Body Area Network - a sensor network whose elements are located on or inside living organisms

CIGS (Copper Indium Gallium Selenide solar cells) - copper-indium-gallium selenide solar cells

CW (Continuous-wave - a type of electromagnetic wave emission with a constant amplitude and frequency

FSO (*Free-Space Optical communication*) – a technology of wireless optical communication that uses light emission in free space to transfer data between two points

Harsh environment - difficult environmental conditions (e.g. outer space conditions, mining, metallurgy)

ITU-T (*International Telecommunication Union - Telecommunication Standardization Sector*) – ITU Telecommunication Standardization Sector

LED(*Light Emitting Diode*) - a light emitting diode classified as a semiconductor optoelectronic device, emitting radiation in the visible, infrared and ultraviolet range

MEMS (*MicroElectroMechanical Systems*) - a microsystem most often produced using semiconductor technology, consisting of mechanical and electrical components

MIR (Mid infrared - electromagnetic radiation in the mid-infrared range

MOEMS (*MicroOptoElectroMechanical Systems*) – a microsystem most often manufactured using semiconductor technology, consisting of mechanical, optical and electrical elements **M2H** (*Machine to Human*) – communication between human and machine

M2M (Machine to Machine) - communication between machines

NEMS (*NanoElectroMechanical Systems*) - a microsystem most often produced using semiconductor technology, consisting of mechanical and electrical elements, containing elements with nano-metric dimensions

NGN (*Next Generation Network*) - next-generation network; relates to key changes in the architecture of telecommunications networks that will take place in the coming years

NOEMS (*NanoOptoElectroMechanical Systems*) - a microsystem most often produced using semiconductor technology, consisting of mechanical, optical and electrical elements, containing elements with nano-metric dimensions

OLED (*Organic Light Emitting Diode*) – an electroluminescent diode with an organic light-emitting layer, classified as semiconductor optoelectronic devices, emitting electromagnetic radiation in the visible, infrared and ultraviolet range

PHM (Prognostics Health Monitoring - managing and predicting the service life of structures

SHM (Structural Health Monitoring) - monitoring the technical condition of the structure

ULP (*Ultra Low Power*) - a strategy for designing integrated circuits and systems in which the power consumption is reduced below that resulting from the current leakage of devices (transistors) through the use of special circuit solutions (e.g. gating transistors, etc.) while minimizing the deterioration of the speed of the system (circuit).

UV(Ultraviolet) – electromagnetic radiation in the ultraviolet range

VIS (Visible) - electromagnetic radiation in the visible range

I. INNOVATIVE SENSORS AND DETECTORS (DESIGN, TECHNOLOGY, MATERIALS)

- 1. Technology and construction of point and distributed fibre optic sensors, including those using classic and microstructural optical fibres.
- 2. Technology and construction of sensors, detectors and electromagnetic radiation detector arrays (UV-VIS-IR-THz).
- 3. Technology and construction of sensors, detectors and detector arrays of ionizing radiation.
- 4. Technology and construction of sensors using acoustic techniques.
- 5. Technology and design of MEMS/NEMS/MOEMS sensors.
- 6. Technology and design of flexible and/or printed sensors.
- 7. Technology and construction of electric and magnetic sensors.
- 8. Technology and construction of sensors and matrices of physical, chemical and biochemical sensors, including electrochemical, semiconductor, thermometric, mass and piezoelectric sensors.
- 9. Chemical sensors of gases and chemicals (photonic, conductometric and others).
- 10. Techniques and materials for the functionalisation of sensor elements.
- 11. Sensors for the measurement of biophysical parameters of living organisms and biological structures.
- 12. Sensors using biological structures (enzymes, proteins, nucleic acids and others),

- 13. Technology, construction, modelling and characterization of smart sensors and sensor networks.
- 14. Design and technology of biocompatible sensors and their encapsulation.
- 15. Spectrometric sensors, including sensors using THz radiation.
- 16. Integrated analytical systems, e.g. Lab-on-Chip

II. TECHNOLOGIES, MATERIALS AND DEVICES FOR PHOTOVOLTAICS

- 3. Technologies of innovative photovoltaic cells made of silicon materials, including technologies of thinfilm and hybrid cells.
- 4. Technologies of high-performance thin-film cells based on non-silicon materials (e.g. CIGS alloy, kesterites, perovskites, conductive polymers, composite polymers and others).
- 5. Technologies of third-generation photovoltaic cells, including quantum dots, plasmons, transition levels, multiplication of charge carriers, organic and dye structures (cells on flexible substrates, spectral conversion of light.
- 6. Technologies of transparent conductive layers and transparent semiconductors, e.g. flexible type n and p.
- 7. Technologies of photovoltaic modules using new materials for applications in systems integrated with the ground.
- 8. New techniques and devices for testing and diagnostics of photovoltaic modules and systems (including techniques for the analysis of energy yields).

III. FIBRE OPTIC TECHNOLOGIES, MATERIALS AND DEVICES

- 1. Technologies, methods and devices using innovative optical fibres (passive and active) and optical fibre components for telecommunications applications.
- 2. Technologies, methods and devices using active optical fibres for applications in amplifiers and fibre lasers.
- 3. Technologies, methods and devices using special optical fibres, including micro- and nano-structural ones with regulated transmission properties, polymer fibres and optical fibres integrated with composite materials.
- 4. Technologies, methods and devices using fibres specialized in non-standard functionalities (including supercontinuum generation and other non-linear effects, high power transmission and/or in unusual spectral ranges, unconventional mode or dispersion characteristics).
- 5. Fibre optic devices new-generation fibre optic lasers and amplifiers, including devices for unusual spectral ranges, such as VIS and MIR.
- 6. Technologies and diagnostics of fibre optic coatings for industrial applications, including high resistance to environmental exposure, including technologies for processing and joining such fibres.
- 7. Conductive polymers and composite polymers for optical fibre technologies.

IV. INNOVATIVE SOURCES OF OPTICAL RADIATION (MATERIALS, TECHNOLOGIES, DEVICES)

- 1. Laser sources of radiation in the VIS and UV area, including semiconductor lasers based on materials with a wide energy gap.
- 2. Semiconductor lasers in the infrared range (NIR and strand lasers (SWIR, LWIR and THz) based on superlattice active areas (QCL and ICL lasers).
- 3. Laser devices and systems that generate broadband radiation.
- 4. Technologies, materials and systems of solid-state lasers (and micro-lasers): (nano-, pico- and femtosecond) continuous and pulsed operation, non-linear conversion of optical frequencies.
- 5. Innovative light sources, including LED sources.

- 6. Organic electroluminescent materials, including printed, flexible materials, etc.
- 7. Structures and technologies of producing organic light emitting diodes (OLED).
- 8. Technologies of printed and flexible large-area displays.

V. SENSOR AND TELECOMMUNICATIONS SYSTEMS AND NETWORKS

- 1. Techniques for managing, processing and collecting data, optimization and self-organization of sensors and sensor networks.
- 2. Security of sensors and sensor networks as well as security systems for data transmission and collection.
- 3. Location in sensor networks (algorithms and techniques for locating and mapping).
- 4. Development of the Body Area Network sensor networks.
- 5. Design and technological solutions for creating autonomous sensor networks with a zero energy balance
- 6. Optical transmitters, receivers and processing devices as well as elements of fibre optic networks and technologies for NGN access networks and the core network.
- 7. Optical devices and systems to ensure the security of data transmission and/or processing at the physical layer level, including quantum cryptographic key distribution systems.
- 8. New techniques for modulation and demodulation of optical signals with increased resistance to interference and transmission distortion
- 9. New, complex coding methods and advanced detection techniques to increase information bandwidth.
- 10. Optical transmitters, receivers and processing devices for transport networks, effective optical power amplifiers, technologies related to the bandwidth optimization and energy consumption reduction.
- 11. Development of FSO technology to a throughput of 100 Gbps and distances of at least 10 km.
 - 12. Printed components and systems for wireless communication.

VI. INNOVATIVE CIRCUITS AND SYSTEMS OF ELECTRONICS, OPTOELECTRONICS AND INTEGRATED PHOTONICS.

- 1. Designs and technologies of innovative power and high frequency devices and modules, including THz electronics.
- 2. Technologies, structures, devices and materials for innovative solutions in photonics and electronics, including photonics and printed electronics.
- 3. Design and prototyping of specialized ASIC integrated electronics, including innovative algorithms and their hardware implementation.
- 4. Technologies and materials for optics and integrated photonics, including technologies based on semiconductor and dielectric platforms.
- 5. Structures, technologies and prototyping of MOEMS/NOEMS systems.
- 6. Prototyping and manufacturing of specialized integrated photonics ASPIC circuits
- 7. Prototyping and manufacturing of optical components and systems.
- 8. ASPIC/ASIC/MOEMS heterogeneous integration technologies.
- 9. Materials and technologies of assembly and hermetization (packaging) of electronic and photonic systems.

VII. INNOVATIVE TECHNOLOGIES AND PRINTED ELECTRONICS SYSTEMS

1. Materials and technologies for the production of electronic elements (including new compositions of pastes, inks) using various printing techniques (screen printing, ink jet, flexography, rotogravure)

and the deposition of thin layers.

- 2. Barrier materials for printed and flexible electronics.
- 3. Materials and technologies of substrates for the production of electronics and printed photonics components and systems.
- 4. Technologies of electronics and 3D printed photonics.
- 5. Printed electronic components and systems used in solutions for personal electronics, transport, healthcare, packaging, defence systems, structural systems and architecture, telecommunications, the Internet of Things, identification (e.g. RFID), energy storage and recovery (energy harvesting), food industry, agriculture and others
- 6. Smart collective and unit packaging, enabling monitoring of the state of the content and the environment, as well as interactive communication.
- 7. Smart storage systems cooperating with printed identification systems, also for the needs of Industry 4.0 systems.
- 8. Textronic elements conductive fibre-polymer materials obtained by printing or applying electrically active materials (including e.g. metal nanoparticles and/or carbon allotropes) by physical or chemical and other methods.
- 9. Textiles and other materials with electrically conductive layers for applications as barrier systems for protecting humans and sensitive electronic devices against the effects of strong electromagnetic fields of various frequency ranges.
- 10. Flexible photovoltaic cells and other alternative energy sources to power personal electronics, including those integrated with textiles.
- 11. Flexible light sources for integration into flexible structures.
- 12. Innovative printing systems for applications in the technologies of electronics, printed photonics and textronics production.

VIII. APPLICATION ISSUES

- 1. Sensors and sensor networks as well as electronic and photonic devices for medical applications (including diagnostics and biomedical sensors, biomedical implants, electronic tattoos, monitoring of vital functions, therapy, rehabilitation and for the needs of the disabled.
- 2. Sensors and sensor networks as well as electronic and photonic equipment for monitoring the state of the environment and hazards to public safety (including chemical, radiological and epidemiological hazards)
- 3. Sensors and sensor networks as well as electronic and photonic equipment for monitoring the technical condition and safety of engineering structures, industrial infrastructure and public facilities and/or predicting their safe operation time (SHM and PHM).
- 4. Sensors and sensor networks for smart buildings and cities, including the analysis and modelling of human behaviour and environment.
- 5. Sensors and sensor networks as well as electronic and photonic apparatus in agricultural applications, as well as forestry and agricultural/food industries.
- 6. Sensors and sensor networks as well as electronic and photonic equipment for modelling, simulation, monitoring and control and/or supervision of technological processes and products in production and post-production phases (up to disposal in circular economy processes).
- 7. Sensors and sensor networks as well as electronic and photonic equipment for the needs of advanced perimeter protection systems.
- 8. Sensors and smart sensor networks for the location of people and things as well as navigation in closed facilities.
- 9. Optoelectronic sensors and devices for advanced metrology and technical diagnostics, including nondestructive testing.
- 10. Sensors for controlling and self-diagnosis of machines and devices in M2M, H2M or M2H systems.
- 11. Sensor networks for the monitoring and control of land, air and water traffic in transport and industry.

- 12. Smart sensor networks and solutions supporting trade, especially electronic trade, and systems integrating electronic and traditional sales channels.
- 13. Photonic and sensor devices and systems for operation in harsh environments.
- 14. Devices and photonic systems for the spatial and surface treatment of materials and the production of elements.
- 15. Equipment for recording and processing images in various spectral ranges, including devices for robotics and navigation
- 16. Innovative electronic and/or optoelectronic control and measurement equipment

IX. HORIZONTAL ISSUES IN SENSOR AND PHOTONIC TECHNOLOGIES

- 1. Systems and technologies for sensor and photonic systems, including embedded systems and cyberphysical systems, controller systems, communication and power supply.
- 2. Techniques and systems of economical use and energy harvesting for the needs of autonomous sensor and photonic devices and systems.
- 3. Technologies for integration and miniaturization of heterogeneous and smart sensor, photonic and microelectronic systems.
- 4. Methods for co-simulation and co-design of integrated mixed signals and heterogeneous microsystems.
- 5. Methods of increasing the reliability of devices, as well as sensor and photonic systems.
- 6. Technologies for using fusion of data collected by various types of sensors.
- 7. Software and hardware cybersecurity of microelectronic and photonic devices and systems at the level of technology and design.
- 8. Smart mechatronic and opto-mechatronic systems.
- 9. Electronic systems supporting photonic (including laser) and detection systems.
- 10. Measurement techniques and devices for the characterization, testing and calibration of sensors as well as optical and photonic components and systems.

NATIONAL SMART SPECIALIZATION 10. SMART NETWORKS AND TECHNOLOGIES FOR INFORMATION, COMMUNICATION AND GEOINFORMATION

This specialization covers smart networks, information and communication technologies and geoinformation technologies, both as independent and related elements. However, consideration should be given to the potential arising from a combination of these two areas of research and implementation. A particularly important element is the use and development of models, architecture and artificial intelligence technologies based on information methods.

The term "smart grids" means ICT technologies and systems ¹used in a variety of infrastructures (e.g. energy, transport, telecommunications, health, factories, houses, cities, vehicles) to ensure optimization of operation, saving resources, including energy, environmental protection, ergonomics of use, benefits resulting from mutual communication and information exchange. Smart networks and systems are characterized by the following features²: autonomy, the ability to self-organize, adapt and make decisions, resistance to errors and failures, scalability, predictability of service quality assurance, open architecture, ICT security.

The term information and communication technologies ((abbreviated to ICT)), also known as information and communication technologies, information and telecommunication or information technologies), relates to a family of technologies that process, collect and transmit information in electronic form³.

The term "geoinformation technologies" includes technologies related to the acquisition, storage, processing, analysis, sharing and visualisation of geoinformation, i.e. information for which the location is determined in the adopted frame of reference and the relationships between objects and phenomena occurring in space are defined, read and illustrated. Geoinformation relates primarily to geographic (terrestrial) space, but geoinformation technologies can also be used to model other spaces. Geoinformation technologies usually use information and communication technologies, in particular solutions and methods in the field of geoinformatics and teleinformatics. Geoinformation technologies have a hybrid and transdisciplinary orientation that covers engineering, technical, exact and natural sciences.

 $^{^{1}}$ ICT system – a set of cooperating IT devices and software to ensure processing and storage, as well as sending and receiving data via telecommunications networks using a terminal device appropriate for a given type of network (definition within the meaning of the Telecommunications Act of 16 July 2004).

²R&D should include one or more of the features listed.

³Based on the definition taken from: "Information Society in Poland. Results of Statistical Surveys from 2006-2019", Information and Statistical studies, GUS, 2010

I. FUTURE INTERNET TECHNOLOGIES, INTERNET OF THINGS TECHNOLOGIES, EMBEDDED SYSTEMS

Development of innovative products, technologies, processes (or significant improvement of the existing ones) in the field of smart networks, within the following scope:

- 1. Smart network components
- 2. Solutions enabling the creation of services for new generation networks (including 5G)
- 3. Prototyping, testing and experimenting infrastructure for implementations
- 4. Optical, wireless network technologies
- 5. Internet of Things Solutions
- 6. Components of Semantic Web, Linked data,
- 7. Wearable devices

II. SMART NETWORKS IN INFRASTRUCTURES

Development of innovative products, technologies, processes (or significant improvement in the existing ones) in the field of smart networks, in relation to the following infrastructures:

- 1. Smart cities
- 2. Smart homes
- 3. Smart factories and enterprises
- 4. Smart Transportation Systems
- 5. Smart vehicles
- 6. Smart transmission networks for electricity, heating, fuel, water, sewage, communications, telecommunications (including smart network management systems)

III. ARCHITECTURES, SYSTEMS AND APPLICATIONS IN SMART NETWORKS

Development of innovative products, technologies, processes (or significant improvement in the existing ones) in the field of smart networks, within the following scope:

- 1. Integration of smart systems
- 2. Communication in crisis situations
- 3. Optimizing the use of communication network resources
- 4. Communication continuity maintenance
- 5. Ensuring the availability of communications
- 6. Self-organizing communication networks
- 7. Smart residential services, including smart healthcare, smart education, support for persons with disabilities
- 8. "Serious games" solutions and simulators
- 9. Decision-making support
- 10. Load and energy consumption management in data centres

IV. INFORMATION MANAGEMENT IN SMART NETWORKS

Development of innovative products, technologies, processes (or significant improvement in the existing ones) in the field of smart networks, within the following scope:

- 1. Analysis of data collected in clouds
- 2. Optimizing the efficiency and speed of cloud computing
- 3. Distributed systems and parallel processing

- 4. Virtualization
- 5. Processing of complex big data, data mining
- 6. Compression and reduction of data size
- 7. Effective verification, archiving and storage of data
- 8. Knowledge management in organizations
- 9. The use of social networks in the acquisition and analysis of data and in information distribution
- 10. Video image analysis for automatic detection of objects and events (video content analytics), optimization of visual information analysis
- 11. Hardware and software infrastructure to enable the foundation of large-scale data network systems and applications

V. HUMAN-TO-MACHINE AND MACHINE-TO-MACHINE INTERFACES IN SMART NETWORKS

Development of innovative products, technologies, processes (or significant improvement in the existing ones) in the field of smart networks, within the following scope:

- 1. Smart machine-to-machine interfaces
- 2. Smart human-to-machine interfaces HMI), in particular:
 - Biometric systems and solutions
 - Recognizing emotions, behaviour and gestures
 - Augmented reality
 - Imaging and analysis of visual information, adapted to the available communication and visual resources
 - Acoustic and voice communication

VI. STANDARDIZATION, SECURITY AND MODELLING OF SMART NETWORKS

Development of innovative (new or improved) solutions to support various cross-cutting areas of smart network construction and development:

- 1. ICT security in smart networks and systems
- 2. Cybersecurity
- 3. Privacy protection
- 4. Smart security systems
- 5. Supporting the development of methodologies and standardization processes, as well as their implementation
- 6. Modelling and automated testing methods (to improve the quality of software development, i.e. application development)
- 7. The use of geoinformation in the development of smart networks and systems

VII. METHODOLOGY AND TECHNOLOGY OF ARTIFICIAL INTELLIGENCE

Improving and developing new IT solutions in the field of artificial intelligence (AI), in particular in the following areas:

- 1. Architecture of AI solutions
- 2. AI models
- 3. Methods of data analysis and compilation of data sets for AI

4. AI computing technologies and techniques as well as methods of learning and acquiring knowledge (machine learning, machine reasoning)

5. Technologies for access to AI

6. Cybersecurity in the context of AI

7. Methods and tools for achieving or reliable evaluation of AI (legal, ethical, technically sound, and secure)

VIII. POSITIONING AND NAVIGATION

Development of innovative products, technologies, processes and methods methods (or significant improvement in the existing ones) in order to position, navigate and monitor an object within a defined space (while ensuring the necessary level of security), within the following scope:

- 1. Quality improvement of satellite and other spatial positioning systems (in particular with respect to accuracy and integrity).
- 2. Multimodal positioning of objects.
- 3. Indoor location systems.
- 4. Navigation and location applications that use information from multiple sources in real time.
- 5. Navigation and location applications with innovative methods of information transmission (including cartographic methods), in particular with innovative imaging methods.
- 6. Network-centric navigation systems.
- 7. Remote monitoring of moving objects.
- 8. Protection of GNSS systems against intentional and unintentional interference and secure GNSS systems for authorized users.
- 9. Building components for positioning and navigation systems (including satellite navigation systems) for the ground and on-board segment, including embedded software.
- 10. The use of smart networks in the development of location and navigation systems.

IX. ACQUISITION OF GEOINFORMATION

Development of innovative products, technologies, processes, and methods (or significant improvement in the existing ones) for obtaining spatial information, within the following scope:

- 1. Non-invasive measurement systems (e.g. short-range and satellite remote sensing and photogrammetry, aerial and terrestrial laser scanning, GPRs, radar observations, hyperspectral observations, thermovision).
- 2. Remote sensing, photogrammetric and other solutions to allow automated detection, identification of objects and their features as well as changes occurring in space based on the analysis of signals, data and images.
- 3. Mobile data acquisition (including mapping) and mobile GIS systems.
- 4. Acquiring geoinformation from existing web resources and analogue documents, in particular with the use of artificial intelligence methods
- 5. Instruments, sensors, systems for spatial data acquisition and imaging or new methods of integrating instruments, sensors and systems (including manned and unmanned mobile platforms).
- 6. Geodetic systems of measurement and control.
- 7. The use of smart networks in geoinformation acquisition systems.

X. GEOINFORMATION PROCESSING, ANALYSIS, SHARING AND VISUALIZATION

Development of innovative products, technologies, processes, and methods (or significant improvement in the existing ones) for the processing, analysis, storage, sharing and cartographic visualization of spatial information, within the following scope:

- 1. Construction of spatial knowledge bases.
- 2. The use of computational intelligence methods and semantic networks for multi-criteria geoinformation analysis (geobusiness intelligence).
- 3. Spatial data mining.
- 4. Harmonization of spatial data.
- 5. Fusions of various spatial data and automation of geoinformation processing.
- 6. Preparation of spatial data for the purposes of machine learning.
- 7. Solutions for the effective exchange of geoinformation in environments used by many users, including in real-time.
- 8. Modelling (including cartographic modelling), scenario analysis and forecasting of changes in space.
- 9. Monitoring of changes in space (e.g. based on Copernicus data, based on data from laser scanning) and the resulting update of spatial data.
- 10. Cartographic data visualization, e.g. spatial data visualization using Augmented Reality techniques, holography, contextual visualizations, visualizations with temporal aspects, infographics, 2D/3D visualizations.
- 11. The use of smart network solutions in the processing, analysis and sharing of geoinformation.

XI. GEOINFORMATICS

Development of innovative systems, applications, algorithms, functions, models, standards (or significant improvement in the existing ones) with the use of modern information and communication technologies, in order to ensure effective acquisition, storage, processing, analysis, sharing, and visualization of information about space, within the following scope:

- 1. Models and structures of spatial data, standards and formats of data recording, compression and exchange.
- 2. Spatial cloud computing.
- 3. Hardware and software infrastructure for the efficient processing of large-scale geoinformation.
- 4. Management of spatial big data.
- 5. Integration and harmonization of spatial data and web resources with spatial data
- 6. Effective filtering, aggregation and generalization of spatial information.
- 7. Ensuring the security of spatial data resources.
- 8. Real-time geo-information applications and applications that consider the time dimension (e.g. multitime applications).
- 9. Optimization of the routing and route planning process.
- 10. Integration of geoinformation systems with other IT systems, e.g. ERP, CRM, SCADA, BIM⁴, as well as banking and insurance systems.
- 11. Automation of the process of integrating state registers with spatial databases.

XII. INNOVATIVE APPLICATIONS OF GEOINFORMATION

Development of innovative products, technologies, processes, and methods (in particular related to smart network technologies) that will significantly improve the existing ones or create new ways of using geoinformation technologies within the scope of:

1. Smart city systems.

⁴ERP – enterprise resource planning, CRM – customer relationship management, SCADA – supervisory control and data acquisition, BIM – building information modelling

- 2. Smart Transport Systems, logistics, transport and shipping, and vehicle control.
- 3. National security, public safety, forensic, crisis management, rescue, as well as health protection systems.
- 4. Land, sea and air navigation and safety systems.
- 5. Smart management systems for transmission networks.
- 6. Vehicle, situation and phenomenon simulators (e.g. trainers and simulators for training crews, tactical simulators and "serious games" solutions).
- 7. Advanced spatial planning, spatial management, real estate management, and social geoparticipation systems supporting spatial management.
- 8. Advanced systems of smart farming and cultivation (e.g. precision agriculture, smart forestry).
- 9. Advanced systems used in geomarketing.
- 10. Advanced information systems supporting the implementation of EU directives that require geoinformation.
- 11. Advanced systems used in the study of the Earth (e.g. in geology, geophysics, archeology, mining).
- 12. Environmental monitoring and assessment systems
- 13. Systems aimed at mitigating climate change and geo-hazards, e.g. extreme geological, geomorphological, hydrological, meteorological and marine phenomena.
- 14. Systems for identifying and optimizing the use of natural resources and systems designed to counteract the negative effects of human (engineering, industrial, economic) activity and minimize the effects of such activities.

NATIONAL SMART SPECIALIZATION 11. AUTOMATION AND ROBOTICS OF TECHNOLOGICAL PROCESSES

I. PROCESS DESIGN AND OPTIMIZATION

- 1. Smart safety systems for automated systems and robots.
- 2. Designing advanced human-to-machine, human-to-system, machine-to-machine, and system-to-system interfaces.
- 3. Virtual prototyping of solutions in process automation and robotics.
- 4. Development and design of IT solutions for collecting and analysing data, supporting production processes, including systems based on artificial intelligence, expert systems, extensive reasoning systems, systems based on computer simulations at various levels of complexity, and multi-agent systems.
- 5. Optimization systems for auxiliary processes in automated and robotic processes.
- 6. Design, optimization, automation, and robotization of production processes.

II. TECHNOLOGIES OF AUTOMATION AND ROBOTIZATION OF PROCESSES

- 1. Technologies for smart control of devices, machines and robots in production systems.
- 2. Mobile technologies in devices, machines, robots as well as in manufacturing and logistics processes.
- 3. Sensor techniques, drives, power supply in processes, machines, devices and robots.
- 4. Manufacturing and assembly technologies in outer space conditions.
- 5. Methods, tools, instrumentation, materials and processes related to incremental technology.

III. DIAGNOSTICS AND MONITORING

- 1. Advanced systems for diagnostics and monitoring of processes, machines, devices, robots and complex systems using artificial intelligence methods and techniques, expert systems.
- 2. Smart measurement and quality control systems, including processes and products in production systems.

IV. CONTROL SYSTEMS

- 1. Innovative control systems for machines and devices, robots and innovative distributed and/or multiagent systems increasing the efficiency of manufacturing processes, including those resistant to interference and errors that occur during the autonomous operation of machines and devices.
- 2. Calculation software and systems for simulation, modelling and optimization of control systems.
- 3. Control systems for robots, vehicles and other mobile devices, including unmanned aerial vehicles.
- 4. Visual and tomographic systems in automation and robotization.

V. MACHINES AND DEVICES THAT AUTOMATE AND ROBOTISE PROCESSES

- 1. Unmanned systems and robots working under special operating conditions.
- 2. Mobile robots and exoskeletons.
- 3. Manipulators and grippers.

I.INDUSTRIAL DESIGN

1. Design making

Designing products, services, visual communication, interfaces, with consideration given to:

- Form design work on a complete novelty of shape, modernization of shape deep or superficial.
- Functions utility issues related to functional and ergonomic analyses, observation of user needs and preferences, as well as related to new concepts of use and operation.
- Technology related to the emergence of new technical possibilities, in the field of construction, such as material and production technologies.
- Creating new consumer and social needs.
- Creating information structures.
- Creating utility structures.
- Interaction design.
- User experience.
- 2. Tools supporting the pattern design process
 - Innovative design methods increasing the efficiency of design work.
 - Innovative design methods using advanced IT systems.
 - Methods of testing design concepts leading to the creation of new tools to support the design process, including using IT technologies.
 - Methods of building operating models used in the design process, in particular based on IT technologies.
 - Innovative tools for recording, communicating and presenting the effects of design work aimed at improving decision-making in the design process, in particular ones based on IT technologies.
 - Innovative tools for managing the work and communication of an interdisciplinary project team, including those based on IT technologies.
 - Innovative tools for testing design concepts in the pre-prototype phase.
 - Innovative tools for prototyping design concepts, in works whose end result is a tangible and intangible solution (system, process, organization, service), including UX and IT.

II. GAMES

1. Design related to video games

The works cover the entire production process of the game and are related to prototyping and designing and graphic design of game components, including:

- Innovative game concepts addressed to the current market and player needs and expectations,
- The main gameplay model, a set of main and secondary elements of game functionality, and their combinations and interrelations.
- Model of communication with the player, visual code and visual style, including a unique artistic layer that is to properly impress the player,
- Sets of animations, models and textures, models of behaviour of living creatures and mechanical devices.
- Game sound systems based on the real-time analysis of the game situation.
- Levels, interfaces, communities, characters, icons, items, vehicles, special effects, plants and vegetation models, weather conditions with impact simulation in day and night cycles.

- Innovative and more efficient production methods, production tools and business models.
- 2. Platforms, engines and processing techniques

This point covers technologies that form the basis for the production process and operation of each video game, i.e. primarily processing techniques and middleware (so-called engines):

- Design and development of innovative graphics and physics engines for games and their adaptation to the requirements of various platforms and devices (mobile devices, consoles, etc.).
- Motion and performance capture techniques.
- Innovative techniques for digitizing 3D images and objects.
- New and improved data optimization techniques and tools.
- 3. Application of artificial intelligence
 - Improving algorithms for solving basic problems associated with artificial intelligence and methods of their implementation in games.
 - Algorithms and models for simulating reliable behaviour of characters, groups of characters or the environment.
 - Mechanisms for automatic content generation.
 - Creating systems for collecting, storing and processing data resources, which are characterized by high complexity, variability and size (the so-called "Big data").
- 4. New tools and mechanisms of interaction

The user's interaction with a video game is a key aspect of its operation and at the same time an element that significantly affects its interest in the product and commitment to gaming. Therefore, the important research work is to be done in the field of:

- Modern tools to use innovative interfaces and mechanisms of interaction with the game and the environment, their adaptation to new hardware platforms and adaptation to the needs of persons with disabilities.
- The use of data from controllers and sensors in modern mechanisms of interaction with the game or in game mechanics.
- Methods and solutions that allow the creation and application of new narrative models and games with a non-linear plot.
- 5. Digital distribution and online multiplayer games

Developing modern methods of selling and distributing games and supporting technology development and infrastructure essential for online multiplayer games, including:

- Solutions, technologies and infrastructure for the provision and operation of games in the cloud, e.g. digital distribution, real-time data delivery (streaming), handling of external distribution systems, unifying the display of notifications.
- Creation of platforms and functionalities for advanced multiplayer games and interactions between users inside and outside the games, using various platforms and networks (e.g. Internet, LAN) as well as technologies and systems to protect against fraud.
- Development of a distributed infrastructure to allow for multiplayer games and building an environment for these games in a persistent state world.
- Development of innovative economic models for digital distribution and online games.
- Development of platforms providing content related to mobile and network games.
- 6. Tools and knowledge supporting the game development process
 - Tools and methods that use advanced methods of assessing the reaction, psychological and emotional state of the player.

- Tools that automate and facilitate the game testing and error detection processes including testing of elements created procedurally (automatically).
- Tools supporting communication and data exchange within the game development team.
- Tools supporting the process of creating video games for various platforms and devices.
- 7. Application of video games in other fields
 - Development of simulations, creation of virtual models of real systems and processes, simulation studies of system performance, capacity and behaviour,
 - Developing games for therapeutic and medical purposes,
 - Development of games for research and education.

III. MULTIMEDIA

- 1. Process support and optimization
 - Development of innovative methods or models supporting, optimizing and controlling the processes of content production and dissemination.
 - Tools and methods that use advanced methods of assessing the reaction, psychological and emotional state of the content audience.
 - Tools that automate and facilitate error detection, tests generated with the help of algorithms and procedures in content production processes.
 - Tools supporting communication, exchange or data transfer within content creation teams.
- 2. Shaping the market of creators and consumers
 - Models and tools for remote and direct measurement as well as analysis and evaluation of recipient preferences in order to increase the effectiveness of creative projects to meet more sophisticated population needs: measurements using subjective and objective indicators.
 - Models and tools for personalizing the audio-visual message based on the preferences and behaviour of recipients.
 - Development of innovative business models enabling co-financing and engaging audiences in the process of creating and producing audio-visual content and interactive solutions.
 - Tools and applications for creating innovative educational and presentation models using multimedia and interaction.
 - Technologies and solutions supporting innovative forms of disseminating content among various social groups.
- 3. Knowledge and tools supporting production and revitalization
 - Models, technologies, devices, applications for designing, managing and producing visual, audio and audio-visual content, including: network technologies, mobile, embedded hardware systems, stationary systems for automating production and post-production processes, innovative interfaces, interactive systems and time-generated multimedia engines in real time or automatically generated, systems using analysis and image and sound processing in multidimensional modelling.
 - Technologies, devices, applications and algorithms for the processing and digital reconstruction of copies stored on analogue or digital media, including: technologies that improve

and automate the processes of digitization, revitalization and adaptation of content to modern distribution channels.

• Technologies and solutions supporting the processes of modelling, prototyping, testing the functionality and usability of audio-visual and interactive content, products or services, including the creation and application of new narrative models and non-linear content.

- All creative technologies for the development and automation of pre-production, production and post-production processes of image or sound, as well as their sharing and storage, including techniques of digitization and processing of images and multidimensional objects as well as motion and performance capture techniques, as well as visual code, visual style, animations, models and textures, simulations, special effects, models of behaviour of living organisms and mechanical devices.
- 4. Distribution and content management
 - Creation of innovative content distribution channels dedicated to various social groups (including groups excluded economically, geographically, socially and health-wise), including: smart content streaming as well as real-time content delivery.
 - Models, tools, technologies, applications, interfaces for smart dissemination and distribution, including by ensuring permanent identification and effective protection of copies against illegal access and dissemination.
 - Tools, methods and technologies for measuring and controlling the maintenance of correct content distribution parameters.
 - Data resource management systems characterized by high complexity, variability or size.
 - Solutions enabling cross-system exchange of multi-element digital data.
 - Creating platforms and functionalities for multi-person or interactive user participation in content transmission, using various distribution channels.
 - Development of platforms related to mobile and network content transmission.
- 5. Archiving and smart access to content
 - Models, technologies, devices and applications for secure long-term storage of analogue or digitally captured content.
 - Technologies for searching or accessing content, including semantic image and sound analysers, and systems for smart indexing of multimedia content.
 - Complex digital data management systems and solutions compatible with international standards, enabling their inter-system exchange.

NATIONAL SMART SPECIALIZATION 13. INNOVATIVE MARINE TECHNOLOGIES FOR SPECIALIZED VESSELS, MARINE AND OFFSHORE STRUCTURES AND LOGISTICS BASED ON MARINE AND INLAND TRANSPORT

I. DESIGN, CONSTRUCTION AND CONVERSION OF SPECIALIZED VESSELS AND THEIR SPECIALIZED EQUIPMENT

- 1. Designing vessels and their modules, their systems and devices, including hardware and software solutions for modelling and simulating the behaviour of structures and systems and complete vessels.
- 2. Construction and conversion of vessels, as well as vessel blocks and sections, including those with reduced environmental impact, related to exploration and processing, off-shore services, ecological passenger and car ferries, aluminium ships and ship sections, vessels for navigation in Arctic conditions, sea and search rescue vessels, research vessels, low draft barges and pushers, yachts and motor boats, cranes and floating tanks, as well as other specialized vessels.
- 3. Unmanned/autonomous vessels, including for monitoring, inspection and operation of off-shore facilities, offshore hydrotechnical facilities, ships, port infrastructure, environmental status or assessment of sea resources and their operation.
- 4. Technological and technical solutions reducing the negative impact of vessels on the environment, including electric and hybrid drives powered by LNG and other alternative fuels, storage, distribution and refuelling systems for low-emission fuels and LNG, as well as infrastructure and solutions for reducing emissions of pollutants to water and air.
- 5. Technologies, systems and devices for vessels, including in the field of electric power engineering, ship automation and hydraulics, remote monitoring of ship operation, economic and energy efficiency, operation in accordance with environmental protection standards and remote control l in critical states, navigation and communication systems, control and assessment of the technical condition of ship equipment, ventilation and air-conditioning systems, propulsion devices and systems as well as energy storage and conversion.

II. DESIGN, CONSTRUCTION AND RECONSTRUCTION OF MARINE AND COASTAL STRUCTURES

- 1. Multifunctional, modular research and measurement platforms for field tests of innovative technical solutions in the exploitation of sea resources in real conditions, as well as simulators and object trainers.
- 2. Unmanned mobile platforms for diagnostics and monitoring of the condition of maritime structures as well as devices, techniques and measurement systems for the acquisition and processing of data regarding the marine environment.
- 3. Floating or stationary structures for offshore renewable energy conversion equipment (including wind farms or tidal and current wave energy converters) and platforms or distributed exploration, production and processing systems.
- 4. Components and equipment for off-shore facilities (including specialist cranes, grippers, overhead cranes, compensation or tensioning systems, specialized winch systems and hydraulic systems).
- 5. Marine structures for the development of aquaculture and technologies, devices and methods for breeding marine organisms.
- 6. Recreational, residential, educational and training facilities at sea.
- 7. Devices and units for the transport and handling of large-size marine supporting structures.
- 8. Technologies and devices with increased efficacy and energy efficiency used for the purposes of offshore production and water transport.
- 9. Development of hyperbaric technologies.
- 10. Design, technology, devices, systems and methods for exploring, estimating and sourcing resources from the sea and the seabed.
- 11. Design, technology, equipment, systems for maritime and inland alternative fuels terminals, including LNG.

III. PROCESSES AND DEVICES USED FOR LOGISTICS BASED ON SEA AND INLAND TRANSPORT

- 1. ICT systems and technologies for monitoring, integrating, controlling and managing the means of transport in water traffic, as well as transport infrastructure.
- 2. Systems of organization, supervision, navigation, e-navigation, decision-making support, risk management and safety of shipping and cargo transport.
- 3. Systems of passive and active protection of maritime facilities and infrastructure.
- 4. Energy-efficient technologies for handling cargo at seaports (e.g. defrosting carriages with bulk cargo).
- 5. Development of intermodal transport technologies along routes to/from ports.
- 6. Simulation systems and environments, using mixed or augmented reality as methods of controlling water transport.