Innovative and Applied Potential of Center of Competence ”Clean technologies for Sustainable Environment – Water, Waste, Energy for Circle Economy”

Project BG05M2OP001-1.002-0019: „Clean technologies for sustainable environment – water, waste, energy for circular economy“ (Clean&Circle) for creation and development of a Centre of Competence

Leading organization: Sofia University "St. Kliment Ohridski"

Partners

- University of Architecture, Civil Engineering and Geodesy;
- University of Forestry - Sofia;
- "Prof. Dr. Assen Zlatarov" University - Bourgas;
- Institute of Physical Chemistry "Academician Rostislav Kaishev" - Bulgarian Academy of Sciences;
- Institute of Organic Chemistry with Center for Phytochemistry - Bulgarian Academy of Sciences;
- Institute of Microbiology "Stefan Angelov" - Bulgarian Academy of Sciences;
- "Cleantech Bulgaria" Foundation.

Associate Partners

- Sofia Municipality
- Sofia Waste Treatment Plant;
- "Sofiyska Voda” AD,
- Interplast BG Ltd.,
- Energy Agency - Plovdiv,
- University of Modena, Italy

Project budget: The total cost of the project is BGN 23 667 925.86, of which BGN 20 117 736.97 European and BGN 3 550 188.89, national co-financing.

Term of implementation: 30 March 2018 - 30 November 2023.

Project aim: Building effective infrastructure and research capacity to develop innovations in the circular economy focusing on water, energy and waste management.

Brief project description: Three vertical and four horizontal modules lay the foundation of the Centre of Competence. The vertical modules are "Water", "Solid Waste" and "Transfer". The “Water” and “Solid Waste” modules will cover two main aspects: "Monitoring, Evaluation and Identification of Problems" and "Clean Technologies" – development of clean Technologies. In both modules, the horizontal priorities will include activities relating to the circular economy and achievement of energy and resource efficiency through:

1. Innovations through efficient operation of the water and waste treatment facilities and of the water supply and sewerage networks;
2. Increasing the share of the renewable and alternative energy sources by producing biogas, bioethanol, biodiesel, hydrogen, hydro power, combined with sediment bioremediation technologies and solving of crucial environmental problems;
3. Recovery of resources such as phosphorus, precious and rare metals, bioremediation of sludge, soils and sediments that have accumulated toxic pollutants;
4. Obtaining alternative resources - zeolite from ashes, slags, cake, new construction and composite materials from waste, RDF fuel, high quality bioreactors from composting plants, microbiological detoxification preparations, etc.

All activities in the CoC will be integrated into an electronic cloud for the exchange and rapid use of information, as well as for its structuring in dedicated electronic cards.

The innovation activity based on excellence in research and technology is an important priority. Real-time control of processes is planned through automated chemical, physical, technological, microbiological, and molecular methods. Sensors and biosensors will be developed to control and manage water treatment processes.

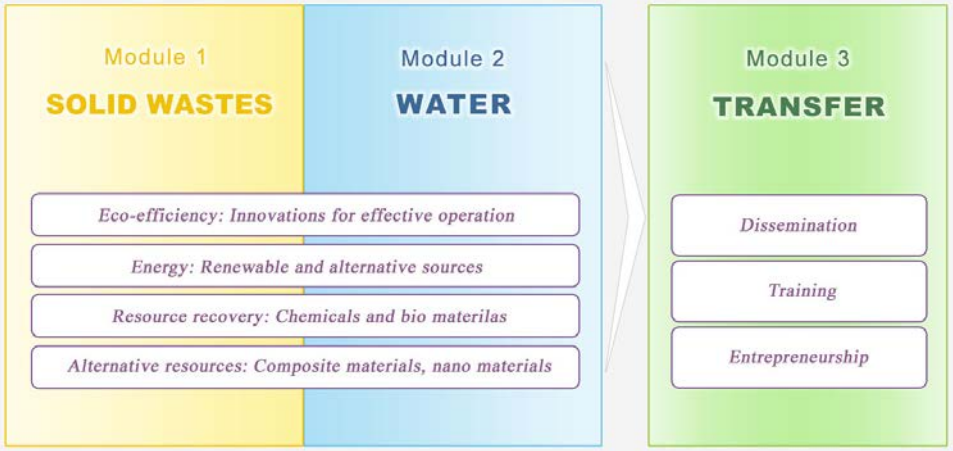

Fig. 1. Clean & Circle CoC Concept: The center will consist of three vertical modules that are connected in an information technology cloud - water, solid waste and transfer. Horizontal upgrading activities will be: eco-efficiency, energy, resource recovery and alternative resources.

The CoC will conduct top-level research to develop products, services and clean technologies with high resource and energy efficiency, and significant economic, social and environmental added value.

A key focus is placed on the vertical module "Transfer". It foresees activities related to training, dissemination of results, technology transfer and technological entrepreneurship. Large-scale actions for joint master's, doctoral and post-doctoral programmes are planned, where the training and qualification of specialists will be distinguished by the two types of interdisciplinary important for the EU Road map, respectively, between natural sciences and technical sciences for the purpose of creating holistic and operational clean technologies, and training for technology entrepreneurs, development of their soft skills and ability to reach the end of the technological process following the economic models of implementation and commercialization through start-ups and spin-offs creation.

As a result of the deployment of this module, Clean & Circle CoC will attract specialists with diverse key competences and qualifications, capable of team-working and achieving synergy.

A separate programme has been developed for implementation of each of the vertical and horizontal priorities, and the elements of these programs will be coordinated by the CoC's governing bodies and personally by the Project coordinator.

The project includes an investment part to build and equip the Centre of Competence, and renovation activities to improve the working conditions in existing laboratories. Within the project framework, 2 laboratory complexes with 11 laboratories and 1 accelerator for technological entrepreneurship and transfer with two laboratories will be built. They will facilitate the completion of the R&D tasks and activities planned.

Expected outcomes

1. **Expected results of the R&D programme of the CoC:**
   - Analyzed and evaluated potential for energy efficiency of residential and industrial water supply systems;
   - Suggested methods of reducing energy consumption in the operation of local water supply systems;
   - Increased energy capacity of sludge in existing sewerage systems;
   - Suggested alternative technology schemes where the aim is not only to purify the waste water but also to obtain products of high calorific value;
   - Implemented methods for ultrasound substrates treatment and presented algorithms to increase the yield of biogas by about 25% and methane in biogas;
   - Developed, automated, verified, commercialized and implemented system for control of the methanogenesis process based on fluorescence techniques;
   - Developed fuel and electrolysis cells to produce hydrogen from waste water

Established optimal technological regimes and technical solutions for application of microbiological fuel cells in the treatment of wastewater and sludge;

- Established a new approach for non-reactive purification of heavily contaminated with heavy metals (copper) and nitrates fluids;
- Pilot testing of the technology for treatment of real waste water and stabilization of unnecessary active sludge in order to obtain a cheap and an energy-efficient alternative for treatment of domestic and industrial waste water;
- The obtained innovative results will be presented at international conferences and will be published in international journals with an impact factor;
- Young specialists will be trained in the course of all project developments. These are masters and PhD students working on their master's thesis and dissertation papers;
- New specialized educational products will be introduced - modules of the disciplines taught at the partnering universities.

2. Developed new products for the economy

- "Solid Waste": glass-crystalline and ceramic materials; geopolymer materials; zeolites, pilot installations for: hydrothermal synthesis and treatment of materials, composites on silicate basis; database and maps of major enterprises, sources of waste products and links to enterprises that use the waste products as raw materials;
- "Water": Pilot installations of: household and industrial wastewater treatment technologies, bioremediation technologies; technology for purification of natural resources and waste products by plasma technologies; new highly selective methods for molecular indication of detoxification processes, anaerobic biodegradation processes, denitrification, nitrification and processes for biological elimination of phosphorus; microbiological preparations for purification with a prescription for use; development of strategies for control of technological processes, of receiving water basins or of technologically affected water basins with hydropower; biosensors; combustion and electrolytic cells to produce hydrogen from waste water; a high-selective indicator method for managing biogas production; map and data base for ranking of sources of pollution of the water basins with trivial and dangerous pollutants; manuals with verified mechanisms and algorithms to accelerate the water purification processes;
- Applications for the circular economy: Innovation in clean technologies for optimizing biogas and RDF production at the enterprises; increasing the efficiency of construction waste recovery; developing strategies for environmental risk assessment and management in enterprises and wastewater treatment plants; estimation of biodegradability of plasmids; toxicity assessment; evaluation of resources, waste, new materials and technological processes by chemical, physico-chemical, technological, microbiological, enzymatic and molecular-biological indicators, and expert data evaluation.

Strategic programme for development of the Centre's R&D and innovations

The Strategic programme for development of the Centre's R&D and innovations involves development of approaches and technologies for recovery of natural resources in the course of the disposal of waste and wastewater - recovery of phosphorus and other chemical elements, of bio-products, and obtaining of valuable products (microbiological and augmentation preparations) from wastes.

New construction materials will be developed from construction waste and residues from waste disposal technologies. Green zeolites, valuable material for water and air purification and concentration and extraction of new valuable chemical elements present in water as a pollutant will be generated from waste ashes from heat plants and incinerators. Adsorbents and catalysts, mesopores and nanocomposites, useful for effective water treatment, will be produced from agricultural waste. The valuable for agriculture - compost and bio-fertilizers enriched with macro- and microelements will be obtained.

Innovative approaches and technologies for efficient use of energy in water cycles will be developed. Special innovations will be implemented and tested in energy production technologies from the biomass of excess active sludge, biomass from algal technologies in water treatment plants, and biomass of plant and food waste.

Technologies will be developed to convert composite waste, non-recyclable construction waste

into RDF fuel. Technologies to produce hydrogen from pollutants in wastewater based on fuel and electrolysis cells will be developed.

All these innovative approaches and future technologies are the steps towards the introduction of resource and energy efficiency in the water and solid waste sectors, towards the restoration of biological and technical resources, and sustainable development of the economy, environment and society. They will lead to an increase in the competitiveness of the Bulgarian economy. A large part of the technologies envisaged are technologically advanced TRL-3, TRL-4. This means that technologies can go to pilot studies, scaling and verifying, and commercializing.

The new products from waste and wastewater with a high potential for inclusion in the circular economy are: valuable chemical elements, biosurfits, microbiological preparations, bioreactors enriched with macro- and trace elements recovered from waste, microbiological preparations, valuable materials for industry and purification technologies, construction materials, renewable energy from waste, etc.

Technologies for obtaining such products will be sought, developed, described, verified, scaled, and implemented. These technologies will be patented as national and international patents, while the shortest possible ways for their dissemination will be pursued and they will be implemented through commercialization based on spin-off and start-up small businesses or through innovative business models included in the large companies - associated partners of the CoC (through scaling and technology transfer).

The innovative products and the above-mentioned technologies will lead to economic development nationwide at a macroeconomic level as they will tackle key economic issues, such as recovery of construction waste, waste from thermal power plants and other industrial waste, as well as plant food waste, through scientific and innovative approaches.

From each waste a substantial product or raw material for other production will be obtained, which will lead to high economic efficiency on the one hand and to high environmental and social added value on the other. The opportunity for fast commercialisation and the introduction of products and technologies to the market will lead to an increase in the competitiveness of the Bulgarian economy in the field of clean technologies.

Each created technology will be accompanied by a business plan and the most effective and efficient channels for its economic and technological dissemination and realization will be selected.

Research, technology, training and business innovations will serve as a powerful driver for introduction of the key elements of the circular economy linked to resource and energy efficiency in the "water" and "waste" sectors. The distance between the scientific achievements, real technologies and business will be shortened and gradually eliminated. The ultimate goal of the sought-after scientific and technological innovations is to turn any waste into a substantial raw material or energy with its maximum value, i.e. in each new element the technological, economic, environmental and social potential will be sought and evaluated.

The implementation of the above-mentioned innovation chain of the circular economy will involve students - bachelors and masters, PhDs, postgraduates, young researchers. They will be trained according to the dual system of "learning by doing" and "qualification in the course of the scientific and technological innovations", which in turn will ensure the sustainability of the CoC and will enable the financial investment to start playing off.

Research infrastructure development plan

The project „Clean technologies for sustainable environment – waters, waste, energy for circular economy" (Clean&Circle) for creation and development of a Centre of Competence plans to build a distributed research infrastructure, according to the needs and tasks the partners will perform and the expected results of the project. The new research infrastructure will be built up in three stages, as follows:

Stage I: Construction of a new building for the needs of the Centre of Competence, with an acceleration of technology entrepreneurship, putting it into operation and substantial renovation of existing laboratories.

Expected results:

1. A new building of the CoC constructed and put into operation.

A new 4-storey building with an underground floor, rectangular in plan, with a corridor system, with a uniform distribution of the floors within a property, provided for the needs of the Centre of Competence with a decision of the Academic Council of Sofia University of 21.12.2016.

Stage II. Equipment and commissioning of the laboratory complexes and the accelerator for technological entrepreneurship of the CoC.

Expected results:

- Equipped specialized laboratory complex in the scientific area "waters";
- Equipped specialized laboratory complex in the scientific area "solid waste";
- The technology entrepreneurship accelerator equipped with a prototyping laboratory;
- Equipped common premises of the new CoC building;
- New laboratory complexes put into operation.

Stage III. Creation of CoC's common information system to integrate large amounts of data, to implement data analysis and forecasting methods, and to link applications, data and services with stakeholders in order to achieve competitive advantage.

Expected results:

Established common information system of the CoC with the capability to integrate large amounts of data, application of data analysis and prognostic methods, and liaison with stakeholders, as well as training of the partners and their customers to use the technology cloud.

The project envisages the first and third stages to be implemented in parallel and the second stage will start depending on the readiness to substantially modernize the scientific infrastructure of each partner.

Work packages to carry out the envisaged research activities of the project

Work Package 1: Water: Indication, monitoring and control

The objective is to assess the potential benefits or damages to preserving and improving the ecological status of the water intakes following application of the circular economy principles in the water sector, and in particular after increasing the amount of re-used water.

Work Package 2: Water: Clean technologies

The goal is to develop new or to improve existing water treatment and purification technologies prior to reuse. The technology upgrade will consist of exploring technologies consistent with the principles of sustainable development with inclusion of new materials and processes, innovative means of water treatment and purification. They will provide higher quality than the conventional water treatment technologies.

To this end, the research program includes development of technologies for complete water treatment, including pollutants, the removal of which is unresolved so far. It is envisaged to explore completely new purification technologies based on newly synthesized adsorbents and materials based on nanostructures from waste products of agriculture and industry. All technologies developed under laboratory or pilot conditions will be subject to the principles of the circular economy.

Work Package 3: Solid Waste: Identification, monitoring and innovative control and characterization methods

The envisaged tasks and activities of the work package fall entirely within the ISSS priorities for solid waste management and recovery. The characteristics for assessing their useful properties are outlined for the purpose of processing the accumulated industrial waste into new raw materials, materials and articles, and introduction of new environmentally friendly technologies - little and/or waste-free, according to the principles of the circular economy and resource efficiency. Qualitative characteristics leading to serious environmental problems are identified. The possibilities of risk assessment, methods for prevention, reduction and elimination of dangerous phenomena and products are explored.

Work package 4: Solid waste: Disposal and recovery technologies

The work programme envisages studies for production of materials and products through processing of the accumulated industrial and municipal waste from 5 large groups of solid waste: industrial waste (mainly from the metallurgical and extractive industries), construction (concrete, ceramics, glass, gypsum, plasters, heat-insulating mineral-fiber materials), ash waste from power plants, biomass from food waste and plants, and biodegradable municipal waste.

Work Package 5: Application of the circular economy in the "Water" and "Solid Waste" sectors

The aim of this work package is to develop research and technology approaches for resource recovery and efficient use of energy in the "Water" and "Solid waste" sectors. On the basis of this objective, the following tasks are formulated for implementation: 1/ Recovery of resources (chemical elements/ phosphorus), gypsum,

biosurfits, microbiological preparations from waters, sludge and solid waste; 2/ Efficient use of energy (renewable and alternative energy sources).

Time frame for carrying out research activities

The long-term joint work of the project partners creates preconditions for starting the research work from the first working month of the project. Preparatory R&D activities are foreseen until the purchase and commissioning of the equipment and construction/renovation of the necessary infrastructure, as well as simultaneous implementation of the activities of the individual modules. The construction of the research structure, including the construction of the new building, will take place in the first 32 project months (the third project year). During this time, the building of the scientific capacity and the envisaged technology development will take place at the existing and renovated premises of the project partners.

Specific practical objectives and tasks to be addressed by the research planned

- Preservation and improvement of the ecological status of the water intake;
- Need to create new or improve existing water treatment and purification technologies before reuse;
- Processing of accumulated industrial waste into new raw materials, materials and products and introduction of new environmentally friendly technologies - little and/or waste-free;
- Processing of accumulated industrial and household waste;
- Need to recover resources;
- Need for efficient use of energy and renewable and alternative energy sources.

Expected benefits of project implementation

The expected benefits of the project implementation will manifest in and will have impact on the following areas of industry, economy and society: energy and energetics, environment, closed water supply cycles, health and food, physical sciences and engineering, social innovation and e-Infrastructures.

Indirectly but with great influence, the benefits will affect the development of tourism in all its aspects - marine, rural, ecological, cultural, as well as the healthy lifestyles – i.e. prolonging the working capacity of the population.

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