Strategic Research Agenda NCC in Polymer Materials and Technologies for the 21st Century

Annex 5. Strategic Outlook and Prospects in the Field Ref. No. TACR/11-59/2021

An obligatory part (annex) of the project proposal is a document of between 10 and 30 pages, in which the applicants describe the current strategies and prospects of the EU and the Czech Republic, and how the submitted project will contribute to their implementation. The applicants will rely on their knowledge of trends in their field (as is often stated, "The researcher knows best about what is happening in his or her field"), and knowledge of strategic and normative documents of the EU and the Czech Republic. A specific description of the link to the Sustainable Development Goals (17 SDGs), the European "Green Deal", whether and how the project relates to an area/initiative, e.g., in the area of the "Fit for 55" package, the EU's digital agenda (e.g., the European data strategy), and economic, environmental, and social strategies, will be most welcome. Possible synergies of interdisciplinary collaboration will be described with an emphasis on the involvement of social sciences. Whether and what the potential of the project will be for further development in the given area, whether there are sufficient research and application spheres in the Czech Republic to address the given theme/range of themes, whether there is potential for involvement in transnational collaboration, especially the EU Horizon Europe framework programme, should also be included. The annex will also include a description of the material, technical, and personnel provisions for this "package" in the NCC project, and the method of evaluating the strategic agenda of the Centre.

1. Vision or brief objective of the project

1.1 Initial assumptions

17 Sustainable Development Goals:

The present project of the National Centre of Competence in Polymer Materials and Technologies for the 21st Century ("POLY-ENVI21") is based on the Sustainable Development Agenda and related 17 Sustainable Development Goals (SDGs) approved by the UN Summit.

In particular, the following links are also part of the initial assumptions for the project and are based on the defined objectives:

- "Healthy life of good quality": The project will address innovations in the field of polymer materials and technologies with a direct impact on the materials used and consumer habits, especially in the field of nano-technologies, antibacterial and antiviral modifications and product safety, all in the context of reducing the consumption of materials from non-renewable resources.

- "Drinking water": An integral research chapter will include sub-projects and solutions for the treatment of drinking water, as well as topics dealing with wastewater or polluted water – specifically, sub-solutions focused on the use of nano-technology in this area, including target implementations and applications.
- "Industry, innovation and infrastructure": This SDG is a cross-cutting theme that cuts across all the others and is also the basis for the approach to the proposed project. Industrial material and technological innovation of higher orders will be a prerequisite for the submission, acceptance and subsequent solutions of sub-project tasks.

- Sustainable cities and communities: Input polymers and final plastic products are one of the most important issues at the municipal level that will be addressed at the policy level in the coming years; the project aims to accentuate such sub-research directions and intentions that will, in their consequences, form an informed basis for decision-making at the municipal and national levels.

- "Responsible production and consumption": Sub-projects will have to demonstrate, as part of accepting them for the research agenda, that the project's effect associated with its implementation will have a positive impact on the energy intensity of production on the one hand, and on the other hand, will reduce the material consumption of the end user or application.

- "Climate measures": The project will be based on the basic definition of circular and sustainable behaviour – i.e. that the proposed solutions must and will meet the requirement to minimise inputs from non-renewable resources, reflect and respect the requirement for recyclability of final products/applications and will demonstrably contribute in a positive way to reducing the emission footprint of their solution.

- "Partnerships to meet objectives": the POLY-ENVI21 project consortium consists of renowned sites at a total of 10 participating universities in the Czech Republic; among other things, the project aims to create effectively functioning relationships between the sites and to set up a kind of "transfer" mechanisms in the transfer of knowledge and specialisations – in other words, again, there will be the creation of a functioning research organism that will not unnecessarily duplicate and overlap in its activities, but which will, on the contrary, create a functional environment for meaningful cooperation and thus maximise the capacity for excellent research and development in the functioning of technical education in the Czech Republic.
  Members of the consortium are also business entities in this structure:
  Clusters (see consortium membership below): The involvement of these professional industry associations will ensure a much wider and more effective dissemination of knowledge and outputs throughout the project and the sub-research activities, while at the same time ensuring greater reliance on input data and requirements for the sectors and industries concerned.
  Small, medium and large enterprises: The project involves companies that are innovation leaders in their field of activity and are ready to be active not only in terms of applying results and outputs, but also have the ability to influence the overall market behaviour of target customers and industries.

All of these objectives have therefore influenced the preparation of the POLY-ENVI21 NCC plan and agenda to a significant extent, but will be, in particular, influenced and guided by these objectives in the actual implementation. The individual research sub-tasks will be presented with this perspective and evaluated in their implementation.

Principles of the circular economy from a research approach perspective:

Polymers and plastic products can only achieve the principles of circularity and circular economy if the following assumptions and principles are respected in their development, creation, production and marketing:

- The initial research (or business/entrepreneurial) idea must work from the outset with the requirement to replace traditional (meaning 'non-renewable') resources by making maximum use of renewable resources and recycled inputs.
- The process must not be more energy and resource intensive.
- At the same time, it is absolutely necessary to calculate the research plan so that such an innovative product too is capable of further use, processing, recycling.
- The material innovation of the research project must again and at the same time respect the requirement for the so-called „product life extension model" – i.e. it must take this basic parameter into account in its agenda from the perspective of the technical solution and the material base.
- The technological innovation of the research project must respect the requirement to minimise energy consumption not only in the production itself, but also in the subsequent expected use of the output.

The above five principles will be considered as a basic guide for the design, assessment and evaluation of projects before they are proposed for inclusion in the Centre's research agenda.

What is the initial situation in the Czech Republic:

Circular economy / Circular Czechia 2040:

In December 2021, the Government of the Czech Republic approved a document entitled Circular Czechia 2040. It is a strategic document that was prepared within an inter-sectoral working group with the participation of other institutions, universities and industry representatives. The OECD Office in the Czech Republic guaranteed the preparation of this comprehensive document. This framework clearly and quantitatively defines the current state of play, while specifying the general objectives for each area so far, which are:

- Improving the protection of natural wealth and resources
- Reducing and improving waste management
- Increasing accountability at different levels
- Creating new jobs
- Technological innovations and approaches
- Innovative material approaches
- Introducing new practices, knowledge and perceptions of consumption
- Introducing non-toxic, safe and natural materials and practices
- Communal transfer of all acquired knowledge and expertise

The Circular Czechia 2040 strategy aims to maintain the value of products, materials and resources for as long as possible in the economic cycle and return those to the production cycle at the end of their use, while minimising waste. The strategy seeks primarily to reduce the generation of waste as such, improve waste management by

emphasising recycling (by promoting recycling technologies) and reuse, with improvements particularly in the areas of bio-waste, textile, construction and food waste, packaging and end-of-life electronics. The use of secondary raw materials is a priority for industry, construction and energy.

However, the strategy is a general (albeit specific) document, to which the MoE of CR will prepare action plans for individual periods. The first of these will be for 2022–2027. The circular economy will of course be significantly supported through grant schemes, with funding coming mainly from the National Recovery Plan and the new OPE. Overall, it can be defined that by implementing the set measures, Circular Czechia 2040 pursues, among other things, in the long-term:

- Improved waste management, including positive impacts on national climate and other environmental targets.
- Improved security of material supply and reduced dependence on material sources imported from outside the EU.
- Increased competitiveness of businesses.
- Reduced fossil fuel consumption.

1.2 Main objectives of the POLY-ENVI21 NCC

The POLY-ENVI21 project follows in its Strategic Research Agenda the strategies of the EU, the Czech Republic and especially the societal necessity to change the approach to the functioning of the economy and related development in the field of science and research.

From the perspective of the Tender Document of the 2nd competitive bidding procedure within the NCC Programme, this project plan and the Strategic Research Agenda of the Centre both correspond to the requirements as follows:

- The establishment of a nationwide stable and cooperating network of research institutes will lead to the emergence of a competence scheme for R&D, which will emphasize the quality and efficiency of research, especially from the perspective and with an emphasis on successful, meaningful and rapid transfer of the acquired knowledge; this will be achieved through the distribution of competencies based on the specialisation of R&D institutes and their focus on their own key skills and knowledge.

- Thanks to the participation of enterprises and clusters/associations of enterprises, the dissemination capability of the established Centre will be significantly improved, and thus the competitiveness of not only the enterprises themselves, but also of the industry as such must necessarily increase; the composition of the participants, their specialisation (meaning enterprises) and market focus all will allow a sufficiently broad portfolio for the implementation and commercialisation of the outputs of the individual sub-tasks and assignments.

- The direct link of the participating companies and their market position will also enable the dissemination of unique (yet specific) solutions developed during the project not only in terms of the current competitive position, but also in terms of the European perception of the results of applied research and development with a direct impact on industrial and social innovation.

- As mentioned above, on the part of research organisations there is a very strong representation in terms of the number of departments in each university; it is true that universities should also work in a certain

competitive environment, but on the other hand, the specialisation and excellence of the departments should be optimally used and a certain map and sequence of knowledge and skills should be created – in other words, the work and the way the Centre operates will also aim to set up this principle aimed at maximising the use of the excellence of the R&D departments at the individual ROs, to optimally exploit the specialisations of individual workplaces in the context of the requirements or orientation of industrial fields – this is mainly about the speed and turnaround of innovation, which is quite crucial in terms of the current state of (often undesirable) interconnectedness of the world economy and industry; the essential supervision of the functional and meaningful interconnection of the participating ROs will be carried out by the Centre's Board, which is staffed in such a way that the requirements for the effective functionalisation of the links between ROs are taken into account when deciding on partial project assignments, that the efficiency of knowledge transfer meets the qualitative and time requirements and that the link/effect for the final application is as feasible as possible and economically advantageous for enterprises.

- It should also be stressed that the project agenda of the Centre is closely and clearly linked to the existing (currently updated) National Research and Innovation Strategy (RIS3 2021–2027), both in terms of the sense of maximally exploiting the strengths and excellence of the position of research capacities and the economic-industrial background/position; secondly, the Centre's agenda will also reflect the territorial and regional strategies in its R&D activities, and to this end, sub-centres of excellence will be created for given areas, applications and disciplines in the course of the solution.

- The inter-disciplinarity and multi-disciplinarity of the project is ensured by the composition of the consortium; 4 clusters/associations will participate in the project: The Plastics Cluster as a transfer base and sponsor for a wide and sufficiently effective dissemination of the resulting knowledge; the Moravian-Silesian Automotive Cluster as a representative of the strongest industrial sector in the Czech Republic and mainly as a functioning mediator between industry strategies and research organisations; the Nanoprogress cluster as an association focused on applied and contract research for the broad field of use of functionalised nano-structures and their applications in industry, biomedicine and other fields; and, last but not least, the Creative Cluster focused on communicating perspectives and knowledge to the public, private, non-profit and educational sectors from various industries will also collaborate on the project.

- The circular economy cannot be understood as a separate economic field focused on a given segment or societal need; rather, it is a principled understanding of the overall environment of life, business and resource management, regardless of the size of the enterprise or the temporal uniqueness of the solution; all the more emphasis in this „philosophical" environment and understanding must be placed on the ability to be broadly applicable, in line with EU and Czech strategies for environmental and resource protection – and of course sub-projects/tasks/objectives cannot be taken out of the context of other aspects of society; again, in other words, the project plan as a whole and, of course, the sub-projects will be focused on complex (inter-disciplinary) mechanisms and will take into account the impacts of the outputs within the different disciplines and aspects of the behaviour of the economy, society and the system.

- The second public competitive bidding procedure of the NCC programme defines the research and application areas to which the submitted projects must declare compliance and correlate with; from this perspective, the POLY-ENVI21 project accentuates and tends to correlate with the requirements for the expected behaviour of the Czech Republic in the 21st century in terms of climate change and globalisation of the economy; it is clear

from the Centre's intention that the activities will take place in the field of new/advanced materials and nano-technologies, with an emphasis on the fact that society must and will deal with EOL products thus created.

- The link to the main strategic objectives of the world economy and EU policy in particular is described above and the Centre's aim will be to implement these often and increasingly general formulations in Sub-projects and solutions for individual sectors of numerous industries – automotive, petrochemical production and resources; consumer industry, textile industry, healthcare and chemistry as such – all while constantly taking into account the fact that „...an innovation or new product/service cannot be taken out of the context of its sourcing, consumption and subsequent use as an EOL solution..."

It is no coincidence that the terms of reference for the 2nd public competitive bidding procedure of the NCC programme were developed in parallel and in response to the national elaboration of the Strategic Framework Circular Czechia 2040, which in its approved version defines the following basic and initial assumptions and conditions:

„The Circular Czechia 2040 strategic framework was created based on the requirement for higher specification and concretisation of visions of priority areas of the Czech economy; it contextualises the creation of objectives within the approved Czech legislative framework, which includes the Strategic Framework 2030, the State Programme for Environmental Protection 2020–2030 with a view to 2050 and also the Principles of State Policy on Resource and Waste Management 2019–2022" – for the following areas:

1. *Materials and resources: Optimising the material and energy inputs of the national economy by 2040*
2. *Production and consumption: Primary materials will only be used for production in the Czech Republic when necessary and, on the contrary, inputs of secondary materials will be maximised*
3. *Waste management: All municipal and industrial waste will be reduced to the maximum extent possible and recycling for reuse will be maximised; energy recovery will only be possible in cases where recycling or reuse is not possible for technical or environmental reasons; landfilling will only take place in exceptional cases; by 2040 the Czech Republic will maximise recycling and reuse of waste so that the share of unused waste per capita continuously decreases accordingly; the Czech Republic undertakes to achieve a landfill rate better than the targets set*
4. *Research, innovation, digitisation: Enterprises focusing on activities and products with high added value and with an R&D share in their activities will be supported; state research organisations will direct their activities towards outputs applicable in the circular economy and the digitisation of industry and research will be fundamentally supported*
5. *Industry and competitiveness: By investing in the circular economy from both state and private sources, the aim will be to maximise resource independence and thus increase the competitiveness of Czech industry*
6. *Education and employment: The transition to a circular economy will create 50,000 new jobs in the Czech Republic by 2040; the education system will be expanded as a conceptual requirement to include education and training in circular principles of sustainable social and economic behaviour*

1.3 Target vision

1.3.1 *Connectedness of the R&D base and enterprises in relation to principles and objectives*

Members of the consortium are research organisations and their sites, the composition and definition of which is included in the project documentation and annexes.

Universities, industrial research organisations, cluster groups and companies are entering the project together, building on previous close cooperation, including experience with the Competence Centres from the call 1 and call 2. The activities of the individual Partners are interconnected so that it is possible to use the research capacities of the universities, transfer their findings to larger laboratory and semi-operational scales and, after optimisation, transfer them to industrial scale. The last phase of the transfer of R&D results can be carried out continuously using targeted requirements of companies as final implementers and the possibility to incorporate their requirements within the framework of semi-operational tests. In addition, the involvement of cluster organisations in the project allows for a wide dissemination of R&D results and a very broad involvement of companies participating in the process of implementation of project results. The whole team is designed so that after setting up forms of cooperation within the project, it can continue to function in the long term after the project is completed.

The project team is building on these previous activities:

- Alterbio Centre of Competence – Solutions for alternative antimicrobial systems will be taken to the next dimension to find its application in the wider field of polymer products.
- Centre of Competence – Centre for Advanced Polymer and Composite Materials – the issue of new directions of development in the field of polymer materials will be further developed in follow-up Sub-projects.
- Centre of Competence – Environmentally friendly nano-technologies and bio-technologies for water and soil purification – using nano-materials and new technological processes towards more energy and material friendly technologies.
- Centre of Competence –Surface Treatment Research Centre – the activity will further develop new types of functional surface treatments with higher stability and efficiency and using new materials that will be more compatible with the polymer matrix or better enable recycling of the polymer materials.

Tomas Bata University in Zlín acts as the Main Applicant and will also provide comprehensive administration of the project in relation to the Granting Authority and other participants in the Strategic Sub-project. The person acting for the Main Applicant is also the Project Manager and will be represented on the Centre's Board, which sets the concept and strategically manages the Centre and the project.

The project plans **three types of technical research areas (RAP)**, within which the involved **RO Partners** will carry out specialised and specific activities and engage as follows:

RAP II: Advanced materials

- UTB: Synthesis and testing of polymers; research in the field of natural fillers for plastics, additives and surface treatments; semi-operational validation and instrumental confirmation of achieved outputs – infrastructure available for simulation of all applicable processing processes; antibacterial and antiviral techniques and materials for waste treatment

- COC: Synthesis and upscaling of functional additives, especially for providing effective protection against organic and microbial pollutant deposition, for increasing barrier properties of polymer films and for surface treatment providing increased hydrophobicity, oleophobicity or conductive properties. The research will be carried out on a laboratory scale and the results will be transferred to a semi-operational scale on our own infrastructure with the aim of designing a validated production process.

VŠCHT: The assessment of the environmental impacts of the life cycles of plastics and plastic products (including by-products and recoverable waste) is related to the functional or declared unit to which each environmental impact is assigned. Any by-products generated must also be included in the analysis. In the context of life cycle environmental impact assessment of plastics and plastic products, there is a need to ensure that good quality data is collected to enable the assessor to reach a reliable result. The assumptions adopted for the assessment will be chosen to maintain the stated objectives and scope of the assessment.

Controlled preparation of polylactic acid foams and scaffolds by temperature-induced phase separation methods including preparation of gradient structures; use of scaffolds for rapid growth of microorganisms and drug testing; preparation of composite bio-scaffolds for tissue engineering. Optimisation of polymeric self-cleaning protective coatings for photovoltaic panels enabling tribo-charging of incident dust particles and their subsequent repulsion by periodic electro-dynamic pulse; optimisation of roughness, dielectric and surface properties for environments with different humidity; scale-up technology for preparation of coatings with controlled micro-roughness and controlled surface functionalisation.

- VUT: Use of bio-degradable PHA material produced from waste sources for development of slow-release fertilizer system controlled by soil biological activity, optimisation of preparation process and properties

- VŠB: Research in the field of polymer and polymer composite materials and nano-materials with antimicrobial properties, research in the field of polymer composite materials based on sustainable polymers including preparation and characterisation of materials, plus assessment of environmental impact and degradation possibilities.

- UPCE: Research in the field of thermally conductive polymer composites for 3D printing and other applications, research on the effect of selected fillers on thermal conductivity, research on the effect of composite conditioning settings on the final composite properties, characterisation of functional and mechanical properties of composites.

- ORLEN UniCRE: Synthesis of heterogeneous catalysts; characterisation of laboratory and commercial heterogeneous catalysts, chemical analysis of waste plastics – well-equipped infrastructure for solid, liquid and gas analysis and catalyst characterisation is available.

- UJEP: testing of advanced materials for catalytic conversion of products of chemical recycling of plastics into substances usable in the field of polymer products

- UPOL: Synthesis of polymers including synthesis of conducting polymers; synthesis, modification and functionalisation of nano-particle fillers and validation of their application as surface and bulk additives for plastics, preparation and functionalisation of nano-fibrous structures using synthesised additives; characterisation of the structure of polymeric materials.

RAP III: Environmental process engineering

-UTB: optimisation of processing procedures and design of polymer materials recycling; identification of polymers in the waste mix; optimisation of products and materials consumption; mechanical recycling processes and assessment of their efficiency and resource intensity; industrial basis for analysis and definition of input wastes; assessment of quality acceptability in relation to standards

-COC – cooperation in the design of the labelling process for polymer products, including upscaling of the preparation of labelling materials

-VŠCHT: Within the project, new technological processes and new materials will be designed. In order to evaluate their potential environmental impacts, they will be assessed in individual phases of the solution using the LCA method. The

aim of the environmental impact assessment will be to identify potential weaknesses from an environmental perspective and to identify possible courses of action.

Recycling, refining and fractionation of partially pre-sorted polyolefin wastes using non-toxic solvents; filtration, extraction and adsorption of unwanted pigments and additives; controlled dissolution and fractionation leading to upgrading of the properties of the resulting products and subsequent testing by NCC partners; solvent recycling; material, energy and economic optimisation of solvent-based recycling processes leading to value-added products. Scale-up technology and optimisation of sorting processes using tribo-electric charging – pigmented plastics can be sorted in this way, unlike spectroscopic methods; optimisation of the process to obtain high yield and purity of separated fractions; use of conductive polymer composites prepared in collaboration with NCC corporate partners as counter-materials for fast and selective tribo-charging.

The production, processing, use and disposal of plastics with the potential to create environmental burdens within industries. There are now increasing efforts to reduce these impacts by incorporating alternative production, recycling and disposal methods. The current need for a comprehensive assessment of environmental burdens requires an analytical tool capable of addressing the environmental impacts of energy production and energy by-products across their entire life cycle.

The assessment of the environmental impacts of the life cycles of plastics and plastic products (including by-products and recoverable waste) is related to the functional or declared unit to which each environmental impact is assigned. Any by-products generated must also be included in the analysis. In the context of life cycle environmental impact assessment of plastics and plastic products, there is a need to ensure that good quality data is collected to enable the assessor to reach a reliable result. The assumptions adopted for the assessment will be chosen to maintain the stated objectives and scope of the assessment.

-VUT: Optimisation of slow-release fertilizer production technology with regard to environmental impact, testing of fertilizers in real conditions (container and field tests) and monitoring of real impact on soil quality; cooperation in designing the procedure of marking polymer products by developing a mark and a way of reading the code.

-VŠB: Chemical recycling of waste polymers using catalysis, development and characterisation of catalysts including experimental data acquisition for scale-up. Study of degradation of antimicrobial polymers including degradation of 3D printing products

-UPCE: Research and optimisation of polymer composites with respect to their recyclability and separability of individual parts of composites.

- ORLEN UniCREcre: Laboratory pyrolysis of individual waste types, thermal pyrolysis of waste mixtures, comparison of laboratory thermal and catalytic pyrolysis in terms of yields and product composition, detailed characterisation of pyrolysis products

- UJEP: Cooperation on the development of technologies for chemical and thermal recycling of plastics in cooperation with NCC partners, characterisation of liquid and gaseous products of chemical and thermal recycling of plastics and synthetic fibres, design of separation of valuable chemicals (monomers, commodity substances...)

- UPOL: Functionalisation of polymeric filter materials with active substances for advanced water purification technologies; identification of polymers in waste mix; toxicity testing of nano-fillers used for polymeric nano-composites

RAP IV: Consumption in a circular environment

- TBU : Combined and mixed post-consumer waste and their processability/usability; reduction of material requirements of products – weight, wall thickness, etc.; use of side products from recycling technologies; technological solutions for processing recyclates

- COC: Synthesis and up-scaling of organic and hybrid nano-materials for functionalisation of polymer matrix or its surface; additives will allow to eliminate the production of mixed, difficult-to-recycle polymers and to increase the recycling efficiency of the whole process.

- VŠCHT: Within the project, new technological processes and new materials will be designed. In order to evaluate their potential environmental impacts, they will be assessed in individual phases of the solution using the LCA method. The aim of the environmental impact assessment will be to identify potential weaknesses from an environmental perspective and to identify possible courses of action. The production, processing, use and disposal of plastics with the potential to create environmental burdens within industries. There are now increasing efforts to reduce these impacts by incorporating alternative production, recycling and disposal methods. The current need for a comprehensive assessment of environmental burdens requires an analytical tool capable of addressing the environmental impacts of energy production and energy by-products across their entire life cycle.

The assessment of the environmental impacts of the life cycles of plastics and plastic products (including by-products and recoverable waste) is related to the functional or declared unit to which each environmental impact is assigned. Any by-products generated must also be included in the analysis. In the context of life cycle environmental impact assessment of plastics and plastic products, there is a need to ensure that good quality data is collected to enable the assessor to reach a reliable result. The assumptions adopted for the assessment will be chosen to maintain the stated objectives and scope of the assessment.

- VUT: Optimisation of the process of production of a bio-degradable PHA polymer from waste materials, in particular optimisation of the process of extraction of PHA from biomass in order to be used for coating in slow-release fertilizer systems, or in other applications; development and testing of application forms of identification marks for polymer products.

- VŠB: Use of recycled additive materials for 3D printing and modification of mechanical, surface and granulometric properties for improved use. Improving recyclability of polymer materials for additive technologies, efficiency of use in 3D printing through mechanical, chemical, surface treatments and optimisation of granulometric properties of powders for better utilisation

- UPCE: Optimisation of deposition procedures and properties of composites for target applications with the aim of their efficient use. Testing the reuse of recycled composites.

- ORLEN UniCREicre: Combined and mixed plastic wastes and their processability in semi-processing; use of products for chemical industry; assessment of catalytic x thermal pyrolysis of plastic waste – composition of products

- UJEP: Analytical support for the development of technological solutions for recyclates processing

- UPOL: Utilisation of products from recycling technologies; utilisation of pyrolysed plastic waste for preparation of carbon sorbents; application of pyrolysed plastic waste in electrochemistry as electrodes for supercapacitors.

Other participants and consortium members are of course enterprises. Depending on their sectoral classification and affiliation, the companies will work together to solve the individual Sub-projects in the context of the visions with which they enter the project. **In the three technical research areas, the companies** foresee their involvement mainly in the following activities and activities:

RAP II: Advanced materials

- Nanoprogress: Preparation, optimisation and functionalisation of advanced materials in the form of sophisticated nano-fibrous layers from tailor-made polymer solutions; analysis of polymer solutions and other input materials; analysis of the nano-fibrous structures developed; standardisation and scaling of advanced nano-fibrous structures.

- Moravian-Silesian Automotive Cluster: Facilitating the transfer of technical and technological knowledge from the research sphere to the field of designing and validation of moulded plastic products in the automotive accessories market, alignment of new material specifications with OEMs' definitions, validation of the use of materials with new properties, techno-economic evaluation

- Plastics Cluster – definition of needs for innovative solutions for processors in the Czech Republic – documents for partial assignments; provision of operational verification and capacities; creation of technological documents; provision of input materials and raw materials; cooperation with the ROs on pilot verification. Semi-operational validation of chemical and thermal recycling techniques; evaluation of products in terms of their sustainability; evaluation of economic aspects of the practices found

- Inotex: (Multi-)functional textiles by application of new (bio-)polymers; designing and validation of formulations for functional textile treatments; compatibility of refining systems; designing and validation of final treatments; evaluation of the effects achieved; validation of selected systems (pilot stage); techno-economic evaluation; material data sheets

- Fortemix Production: Additives for injection moulding technologies to optimise and unify product properties in the context of used plastic and construction waste; compatibilisation of used mixtures with impact on the possibility of extending the spectrum of used recyclates

- Teramed: Combined technologies for handling environmental damage; geomicrobiology as a technological tool for dealing with mixed wastes; advanced monitoring of contaminated mixed plastics

- Synpo: Applied research in the field of synthesis of (bio-)polymers, nano-structured polymers and functional nano-fillers. Up-cycling.

- ASIO TECH: Application of new/modified treatments of innovative materials for physical separation; pilot-scale testing; evaluation of efficiency and proposals for optimisation of materials and production processes; calculation of operating and investment costs, return on investment analysis

- Hella Autotechnik Nova: Application of the results of the development of new composite and coated plastic parts with the aim of reducing weight while maintaining functionality; testing the function of surface treatments; assessment of economic effects with regard to the principles of circularity

- Continental Corporation: Automotive applications especially in terms of input polymers used in their formulations – focus on bio-based and mineral fillers from renewable sources and local production; operational testing of outputs from individual sub-projects

- Ethanol Energy: Use of second-generation materials (2G materials) for the production of feedstock suitable for bio-plastics, sourcing of 2G materials.

- Simple Engineering: Collaboration and design of new forms of processing and new types of materials, including determination of real utility value for the end consumer; collaboration in designing structural and technological modifications of existing processes from the perspective of processing new materials; ensuring coherence between laboratory procedures and real process requirements of production.

- Zodpa: Validation of new (project-defined) principles and techniques for plastic waste labelling and efficiency in collection, separation and sorting; testing the effectiveness and reliability of these new practices

RAP III: Environmental process engineering

- Nanoprogress: Analysis of the environmental impact of processing and applicability of nano-fibrous structures; applicability of advanced nano-fibrous structures in the field of environment, their categorisation and testing in real conditions.

- Moravian-Silesian Automotive Cluster: Optimisation of the use of recyclates in the production of automotive accessories, improvement of technological procedures in the moulding of products from plastic granulates, reduction of the consumption of original material while maintaining the technical properties of the products, reduction of waste production, reduction of the weight of parts, reduction of energy consumption for the production of parts

- Plastics Cluster – sorting techniques and their applicability in real conditions; projection of recycling procedures; definition and categorisation of sorted plastic waste; mapping of the applicability of outputs across the post-consumer waste processing sector in the Czech Republic; preparation of project INPUTS for and together with commercialisation partners. Management of by-products of the recycling techniques found – seeking applicability in the context of sustainability and local solutions; environmental impact assessment of the different processes of production of plastics and plastic products by comparative methods that will analytically cover the entire life cycle of resources; consideration of different life cycle stages of energy operations

- Inotex: Finishing of textiles for recycling; cleaner production technologies; possibilities of separation of applied polymer layers and textile substrate; (bio-)polymer based treatments to reduce dependence on non-renewable resources; extension of textile functional effects; polymers for marking/identification of textile fibres

- Fortemix produkce: Implementation of recycling procedures and techniques; testing stage of research tasks; applicability for recycled products; optimisation of procedures for mixed and heterogeneous plastic recyclates/waste;

- Teramed: Research and development of up-to-date decontamination technologies aimed at monitoring and removing pollutants from plastic waste and process water used in recycling techniques.

- Synpo: Monitoring of circular principles and emphasis on by-product/waste product processing in the synthesis of bio-polymers, nano-structured polymers and SYNPO functional nano-fillers.

- ASIO TECH: Modification and functionalisation of water and air filters; development of materials and their testing in semi-operational scale; stress tests of materials – analysis of scaling, fouling and washing out of particles from filter materials; evaluation of efficiency, operating and investment costs and return on investment analysis

- Hella Autotechnik Nova: Design of process solution concepts within own plants; comparison with company's sustainability goals and related calculations; semi-operational tests and trials

- Continental Corporation: Technology validation tests under operating conditions and evaluation of final effects based on quantification of input raw materials and energy, including focus on operational efficiency in implementing these changes; overall evaluation of benefits and sustainability of the changes

- Ethanol Energy: Cooperation on the technical solution for the production of bio-plastics from 2G materials, cooperation in the transfer of laboratory results to a semi-operational unit, focus on the reusability of by-products in agriculture and, if appropriate, construction

- Simple Engineering: Design of laboratory and pilot units to ensure the transfer of theoretical procedures and their application in the field, basic design, structural and technological design for processing and recycling in terms of testing and real applicability

- Zodpa: Comprehensive support of the project in terms of verifying the outputs and conclusions achieved; communication of any emerging needs towards waste producers

RAP IV: Consumption in a circular environment

-Nanoprogress: Definition and categorisation of advanced nano-fibrous structures and their preparation in a circular environment; elaboration of procedures for preparation of nano-fibrous structures in a circular environment

- Moravian-Silesian Automotive Cluster: Linking circular production strategies from OEMs to Tier 1 to 2 suppliers, cooperation in reuse of secondary raw materials outside the automotive industry

- Plastics Cluster – defining validation applications, products and manufacturers – then evaluating the results achieved with balance sheets and quantification; inputs and contractual support for commercialisation – cooperation with the principal investigator, the ROs and other companies; inputs for the evaluation of the innovation life cycle and comparison with existing solutions. Analysis necessary to include by-products that may be generated; in the context of the assessment of environmental impacts of life cycles of plastics and plastic products, the need to ensure the collection of good quality data that will enable the assessor to reach a reliable result; the assumptions adopted for the assessment will be chosen in such a way that the stated objectives and scope of the assessment can be maintained.

- Inotex: Functional treatments of recycled fibres and textiles from emerging renewable sources; reduction of textile waste by using waste fibre materials as raw materials – re-/up-cycling; reuse of textile substrates as carriers of functions; functional recyclates; labelling for sorting mixed textile waste for recycling

- Fortemix produkce: Mapping of resources from the perspective of the waste management system in the Czech Republic – the principle for successful implementation and application involves the assurance and continuous availability of resources; cooperation with producers of post-consumer and post-industrial waste in technical requirements – management and sorting system

- Synpo: Inputs for life cycle assessment of bio- and nano-structured polymers and comparison with existing solutions

- ASIO TECH: Separation and recycling of economically valuable raw materials from wastewater and sludge and their subsequent reuse in production; bio-degradability of products in wastewater; pilot validation; evaluation of operating and investment costs and return on investment analysis

- Ethanol Energy: Cooperation in the modification of bio-plastics towards their self-degradability, applicability for agricultural production

- Simple Engineering: Designs and engineering of technological equipment and units to ensure the circular recovery and processing of used polymer materials, especially of the fibre type. Providing technological and structural designs of units necessary for verification of the proposed procedures

- Zodpa: Complete evaluation of the effect of the innovative practices and methods obtained by the project; relation to legislation and real-situation waste management at municipal level

An integral part of the project agenda is the **RAP-V**, which will fundamentally determine to what extent the outputs of the technical research areas will be widely and socially applicable and to what extent there will be general and professional awareness of the solutions achieved. This research area of **„Communication, dissemination, creativity“** will also work with and build on all legal and legislative measures related to the circular economy and measures to support it. In particular, the participants will participate in this RA as follows:

RAP V: Communication, dissemination, creativity

-UTB: coordination of dissemination activities towards the academic and implementation sphere; conceptual approaches and solutions for academic evaluation of results and outputs – coordination between the individual ROs within the consortium; promotional activities towards the Centre's Board and other entities and institutions; PR activities leading to maximum public awareness of the Centre, its activities and especially the applicability of its results within the region; international follow-up projects and cooperation in the context of the Centre's activities.

- SCHP ČR: coordination of R&D results with the legislative framework in the Czech Republic and the EU – dissemination and PR acitivities supported via SCHP members ; co-ordination of business models creation and commercialisation of the results ; international activities – via Cefic, Plastic Europe etc. ; communication with MPO and MŽP of the Czech republic ; competency of other platforms in Czech utilisation

- Plastics Cluster – dissemination and transfer of R&D results towards producers in the plastics industry; communication with potential foreign partners of the Centre not only for the field addressed within the project – it is necessary to search and define follow-up topics in order to ensure the sustainability of the outputs after the project is completed; preparation of documents for negotiations with state administration authorities – especially MoE, MIT, REACH Committee – and also coordination of commercialisation procedures with other associations – Czech Association of Circular Economy, Association of Towns and Municipalities of the Czech Republic, Ekokom, etc.

NANOPROGRESS – dissemination and transfer of R&D results in the field of producers and users of nano-materials in the Czech Republic and the EU

MSAC – dissemination of results among manufacturers for automotive applications

Creative Cluster – cooperation in the transfer of R&D results to the industrial sphere, both in terms of industrial design and towards the professional public; support for innovative activities between project participants and other partners of the creative industry, linking other associations and societies and strengthening links at regional, national and European level; the primary role is to increase the quality and expertise of the consortium, its members and employees, linking members in joint activities and projects, improving communication and information among members and outwards to other partners, cooperating entities and strengthening the promotion of the project.

1.3.2 *The inter-disciplinary principle of the POLY-ENVI21 NCC project*

Another viewing angle is the sectoral focus of the POLY-ENVI21 NCC project. From this perspective, the involvement and connectedness of the participants can be divided as follows:

Chemical industry:
The core sector in which the activities related to the approved sub-projects will be implemented. Within this sector, almost all of the assignments of all participating research organisations and the vast majority of participating companies will be carried out. With its sub-sectoral categories, Chemistry is a fundamental and supporting theme – chemical solutions in the field of materials directly touch on the applications and tasks of this project in the areas of innovation in polymer systems and additives, recycling processes and techniques and, last but not least, in the development of new polymers and polymer compositions. One of the main activities will be, for example, to address the recycling of polyolefins (the largest share in what is referred to as waste-bin municipal waste) with techniques that are innovative in the material, physical and technological sense. VSB-TU, UCT Prague, TBU Zlín, Fortemix produkce, Inotex, COC and Plastics Cluster will participate in solving this issue (in the form of sub-tasks). In addressing chemical recycling processes, emphasis will also need to be placed on the by-products that are generated, as a logical consequence, by the proposed and anticipated techniques – circularity and sustainability cannot be considered to be resolved if the process achieves insufficient conversion and the by-products are not further recoverable in the 'cycle' mode of operation. In other words, it can again be said that chemical processes are never isolated in terms of materials and energy and separable in relation to the life cycle of a product or process – indeed, all related/downstream/undesirable effects must always be defined, with the understanding that part of a meaningful solution must include finding a suitable (i.e. sustainable and meaningful) scheme for an efficient final balance.
An integral part of the project agenda will also be research and development of polymers produced from the available bio-base that Czech industry and agriculture has at its disposal. This area will focus on the mapping, characterisation and project planning of the chemical process for the production of non-synthetic polymers from raw materials that can be characterised as secondary or surplus in agricultural production. These solutions will partly build on the activities already implemented in this field and will be further contributed to by the participants in particular: Ethanol Energy, UCT, TBU Zlín, JEPU, COC, Synpo, Plastics Cluster, Nanoprogress, Simple Engineering, PUO and others.

Automotive:
In a sense, the automotive industry is a „component" industry – the final car manufacturer designs and guarantees the flawless and maximum quality function of thousands of parts that are subcontracted from other industries. The percentage of polymers and plastic products in components is increasing annually and over the long term, with manufacturers' current strategies being to maximise the use of post-industrial and post-consumer recyclates contained in these parts; while ensuring the downstream recyclability of these parts. However, the quality and performance requirements cannot be modified or changed in any way, making the eventual transformation to such materials all the more problematic and challenging. Nevertheless, most automotive groups have defined elements and components in their supply strategies for which the transition to a sustainable material source (i.e. recycled material) is not only expected but also required of sub-contractors.
Within the POLY-ENVI21 NCC project consortium, a group of participants has been formed to focus their research and verification activities primarily on selected components for automotive applications where this strategy is and will be

applied. These are mainly interior elements and parts made of plastics (especially injection moulding technology), textile woven and non-woven formations for interiors and some other car components where unique and specific properties are not required. This issue will be addressed in particular by the participants: Automotive Cluster, VSB-TU, PUO, Synpo, Hella Autotechnik and Continental Corp.

An important aspect and trend of innovation for the automotive industry is also the phenomenon of increasing the utility, user and functional properties of components – can also be defined as an effort to maximise the various durabilities, aesthetic properties and physical parameters of parts. Within the project and research agenda, sub-tasks are prepared for surface treatment and polymer base modification as well as for functionalisation of part behaviour (e.g. electrical properties, tribological behaviour, UV resistance, etc.) in order to continuously increase functionality, durability or aesthetics, but at the same time to avoid the development of solutions that would have a negative impact on the overall consumption of resources (materials) and/or on the recyclability of parts. Among other things, the solution will use advanced 3D additive technologies and materials for prototyping and verification purposes. This area will be addressed by Automotive Cluster, PUO, Synpo, Hella Autotechnik, Continental Corp., COC and Nanoprogress.

Textile industry:

The textile industry and the related fibre industry is again a sector that rather „services“ and sub-contracts to other sectors, from the furniture industry, through the classic textile consumer industry and agriculture, to the automotive industry again. Textiles are always preceded by the production of a fibre or other filament, the property of which in principle influences the final property of the textile (woven or non-woven) formation. Research here is again mainly in the application of chemical and physical principles of the basic polymer material and of course the additives used in the production of the fibre. A significant phenomenon here is the demand for conversion to bio-based polymers (see above chemical industry) and additives, dyes and auxiliaries that are generally environmentally friendly. This environmental friendliness can be implemented firstly in terms of raw materials and their sources, and secondly in terms of the recyclability of such materials without negatively impacting the collection, sorting and recycling system. Textile waste from synthetic fibres (originating in the clothing, furniture and automotive industries in particular) is as high as 20% of the polymer waste generated Europe-wide. It is therefore an essential part of the „plastic waste-bin“, which is also currently recycled at relatively low level.

The solutions to the sub-tasks will therefore involve the design and material modification of selected applications (uses) with the aim of applying bio-based polymers and additives and reflecting the requirement for trouble-free recyclability of EOL products. It will also include finding applications (see below for construction) in which selected textile recyclates can be sustainably and meaningfully „placed“ after their primary function has ended. Last but not least, the technological complexity of production plays a role here, with the research approach including the solution of envi-friendly procedures and techniques. The principle of the approach to the solution will be the development of such a raw material base and technological process in which the final implementer (company) will be able to achieve new and combined properties of fibre/textile with multifunctional effect and thus reducing the material intensity of the overall complex.

Inotex, COC, Synpo, PU, Nanoprogress, Automotive Cluster, JEPU, Fortemix produkce, Asio Tech, Teramed, Zodpa and others will participate in this sectoral area.

Construction:

From the perspective of one of the primary objectives of the project (development and introduction of materials and technologies for a circular and sustainable economy of the Czech Republic), it can be stated without exaggeration that the construction industry is the sector and industry with the greatest absorption capacity for the effective and

sustainable use of post-consumer plastic waste, which is qualitatively and continuously unacceptable in other sectors. In the past years, the participants of the proposed project have jointly implemented bilaterally or in groups several independent and specific R&D commercial projects in this area. The agenda of the POLY-ENVI21 project will enable a substantial expansion of this cooperation with an impact on many applications and implementations in the construction industry. In addition, it should be noted that the construction sector is also significantly influenced by the tendencies, directions and approaches of architects, designers and conservation – this area will also be affected in the course of the project, if only because the potential for the use of resources consumed by mankind (i.e. the waste produced) must also be explained, promoted and socially influenced in an appropriate way for the construction sector. The research organisations and enterprises involved are all active to at least some extent in a field(s) directly or indirectly related to construction production, the manufacture of components for the construction industry and/or auxiliary materials for the construction industry. Again, in the individual sub-projects, emphasis will be placed not only on the input materials and processing technologies, but also on defining, identifying and describing the processes affecting the handling of these elements/components at the end of their useful life. Close communication and cooperation with the Ministry of the Environment, the State Environmental Fund, Ekokom and other entities is assumed here in relation to the field. Creative individuals and designers will be heavily involved in the solution and will continuously prepare the strategy and procedures for the commercialisation of the outputs, their promotion and public awareness. Again, the solution is expected to involve research centres with innovative approaches, mainly in the field of technology, surface treatments, design solutions, etc.
One of the supporting arguments why numerous sub-assignments with target applications in the construction industry will be so frequent is, among other things, the fact that the construction industry is facing extensive changes in the availability of basic raw materials and their prices – see cement plants, mining licenses, gypsum from brown-coal power plants, etc. Therefore, a certain degree of cooperation with traditional manufacturers of building materials and components is expected – negotiations and participation in the solution and in the commercialisation of the outputs are already underway with many of them. Several previous projects have also already shown the way for the combined use of plastic and construction waste to produce components with new compositions and improved functional and performance properties.

The project therefore affects all key industries in the Czech Republic, with the issue of the circular economy itself being intertwined into the individual areas as outlined in the preceding text. Interdisciplinarity is therefore demonstrated by the project plan submitted and the participants agree on the achievability of the individual objectives in the given topics.

1.3.3 Research areas II to V – structure and description:

In addition to the management sub-task (RAP I), the research agenda throughout the duration of the project (in terms of research directions) will take place within Research Areas II to V. The individual sub-tasks will be designed to respect the objectives of the individual research areas and will be assessed from this perspective by the Centre Board. In order to effectively address the Sub-projects, their activities can be directed towards multiple themes. In particular, RAP V will be an umbrella activity that will be used primarily for the transfer of R&D results so that they are in line with the requirements of society, within the framework of legislative regulations and at the same time bring innovative solutions. The aim is to implement the results of the project in such a way that the Czech Republic will be among the key countries implementing technologies fully in line with the Green Deal strategy in the field of the use and processing of polymer materials.

The research areas of the POLY-ENVI21 NCC project are defined in its structure as follows:

RAP II : Advanced materials

- Synthesis of polymers
- Functional additives and (nano-)fillers
- Bio-based materials
- Structural analysis
- Implementation of green chemistry principles
- Materials vs. product design – automotive, textile, construction, medical, etc.
- Unification and condition of identification and data collection
- Marking and identification

RAP III : Environmental process engineering

- Processing flows
- Material recycling
- Chemical recycling / pyrolysis
- Balance analysis / circular principles
- Processing of by-products/waste products
- Separation, sorting and application possibilities
- Recycling flow designs by material
- Link to legislation, enforcement of proposed solutions
- Autonomous projects with interdisciplinary impact – automotive, textile, construction

RAP IV: Consumption in a circular environment

- Surface treatment and functionalisation, nano-
- Lightweighting/downgauging – product modelling
- Energy balances, LCA, CFP
- Use of side products
- Substitutes for traditional materials – assessing strategic arguments – mining etc.
- Sub-projects with balance – automotive, textile, construction, medical, etc.

RAP V : Communication, dissemination, creativity

- Legislation – OSS involvement, relationship to EU legislation
- Transfer activities – suggestions and recommendations in relation to market leaders in the automotive, textile, construction, medical, etc.
- Popularisation – creativity, involvement of the Ministry of Culture, Ministry of Education and Sports
- Awareness raising – website, information portal etc.
- Statistics – data collection in the Czech Republic, cooperation with Ekokom, Cenia, CWMA
- Interdisciplinary networking of the Centre – see structure of participants (clusters, associations), other bonds
- International related (past/future) projects

1.3.4 Method and source of defining the Sub-projects

The Sub-projects will be based on the current knowledge resources of research organisations on the one hand, and on the other hand on the needs defined by legislative changes, societal needs and strategic directions of the European Union and the Czech Republic. At the same time, the Sub-projects will be defined in such a way as to contribute to the creation of a stable and long-term base of applied research with a strong orientation towards the use of the results in practice.

The enterprises involved, including the clusters, provide a sufficiently broad resource base to define the needs of industrial/processing companies. At the same time, thanks to the involvement of associations (clusters) and the Chemical Industry Union, a relatively strong link has been established with those state administration bodies that are necessary for the project – in particular the Ministry of Environment and the Ministry of Industry and Trade. Here, the project can build on existing relationships and cooperation and can thus expect the technical design of the Sub-projects to be in line with the needs that are or will be determined by legislation. And thanks to this, it is logical to expect that the commercialisation of the outputs/results of the project will be realistically possible (through the consistency of research and needs) in a relatively wide dissemination spectrum.

However, the participating ROs in the project are expected to be able to define innovative and excellent approaches to solving the task within their long-term research directions and specialisations, and to achieve unique outputs with sufficiently strong and long-term market-competitive potential.

An essential aspect in defining the Sub-projects will be the assessment of the quality and degree of cooperation of the individual ROs among themselves and, of course, the links to their other research directions and international cooperation. The project involves the vast majority of technology universities in the Czech Republic, which often overlap in their R&D activities. The project is therefore expected, among other things, to find functional and working overlaps, define them and understand each other site's specific excellence.

The Sub-project proposal shall contain at least the following information:

- Project name and acronym
- Identification of the submitting member of the NCC-Polymers Project
- Identification of other members of the NCC-Polymers Project
- Name of principal investigator and research team members, incl. their FTEs
- Project objectives and subject matter
- Expected outputs under the rules of the NCC 2 call
- Timeline, start and end date of the Sub-project, project milestones
- Project budget, detailing - separately for each participant and as well as for the whole project - the following:
- Staff costs
- Sub-contracting costs
- Intellectual property costs
- Other direct costs
- Indirect costs
- The content and eligibility of the individual items, as well as the amount of co-financing based on the type of the NCC-Polymers Project member, all shall be defined by the Granting Authority's bidding dossier for the 2nd public call for proposals within the National Centres of Competence Programme.

The proposal shall be accompanied by the following information:

- Market research
- Patent search in the case of an anticipated patent

- Steps within the project and involvement of each partner

1.3.5 Coordination with state administration authorities and attitude to the public

As already mentioned in the text above, a significant influence on the successful implementation of the outputs (meaning commercialisation and dissemination) will be the influence of functioning coordination with ministries and other entities that co-create and transpose the principles of the circular economy into the real legislative environment of the Czech Republic. It is also not only about the creation of a functional link between the development, industry and the state, but also about targeted education in the field of „environmental principles and behaviour of the Czech population" – here it is unfortunately necessary to state that Czech society shows signs of great illiteracy in this direction and only a very small part of the population understands the individual necessity and the logical necessity of involvement.

These activities will take place mainly within the scope of the RAP-V and will involve (in addition to all other participants) in particular: Creative Cluster, Moravian-Silesian Automotive Cluster, Nanoprogress and Chemical Industry Union; active participation of the members of the Centre's Board is also expected. The following activities are primarily envisaged:

- Coordination and commenting on selected legislative measures in relation to European directives on waste management, single-use plastics, waste labelling and sorting systems, etc.
- Communication and unified approach to other professional and industry associations – AIU, Textile Cluster, Security Cluster, Circular Economy Association, Ekokom and others
- Preparation of documents and implementation documents for successful implementation of the Green Procurement System – already addressed in connection with the Ministry of Environment and the Ministry of Agriculture
- Educational and popularisation models for the general public
- Preparation of educational manuals for primary schools – in cooperation with the Ministry of Education

2. Current situation in the area/field with an emphasis on future development and trends

The leader in polymer production is China with 29.4%, followed by Europe with 18.5% and NAFTA countries with 17.7%. Commodity plastics dominate the production, namely polyethylene with 27%, followed by polypropylene with 19.3%, PVC with 13.0%, PET with 6.3% and polystyrene, including foam (EPS) with 5.7%. By 2025, experts at Plastics Europe forecast average annual growth of 3.7% for commodity plastics and 4.5% for engineering plastics.

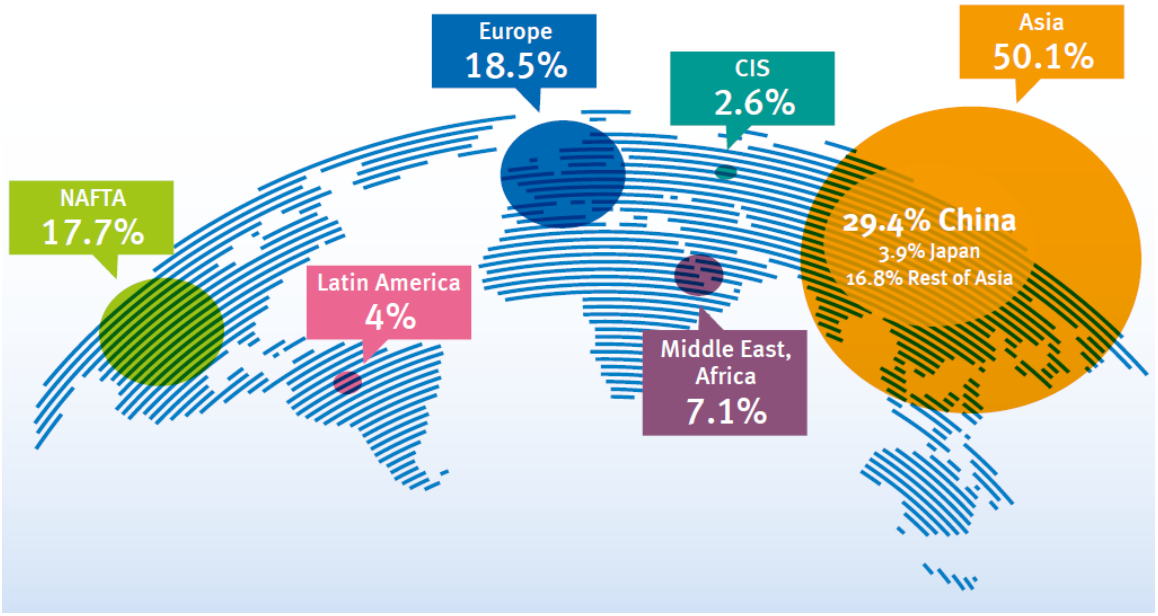


Fig. 1: Percentage of plastic consumption per region in 2019 (source: Plastics Europe Research Market Group & Conversio Market Strategy GmbH)

Polymer production and plastics processing cannot be seen as a stand-alone industry as we know from some statistical and economic assessments. In the Czech Republic, for example, plastics processing is still part of the chemical industry. In a way, plastics processing functions as a sub-supplier industry for all other industries as well as for e.g. agriculture and construction. From this perspective, the situation in Europe is roughly as follows:

Fig. 2: EU plastics processing volume as per application in 2019 (source: Plastics Europe Research Market Group & Conversio Market Strategy GmbH)

Key aspects of future developments are:

- Regardless of the upcoming restrictions, the plastics processing industry is both a dramatically growing market and, of course, a cross-cutting industry – it essentially sub-supplies all other market segments.

- The plastics industry has a clear objective for the next 30–40 years: To meet consumption, but at the same time to reduce the proportion of raw materials from non-renewable sources and, most importantly, to ensure the use of recyclates in final products and thus extend the lifetime of the polymer/plastic in its use.

- The new input materials (containing natural fillers and recyclates) require new ways of designing and assessing the final products as well – so a different approach is needed to assess the appearance, surface quality and safety of the product as a whole.

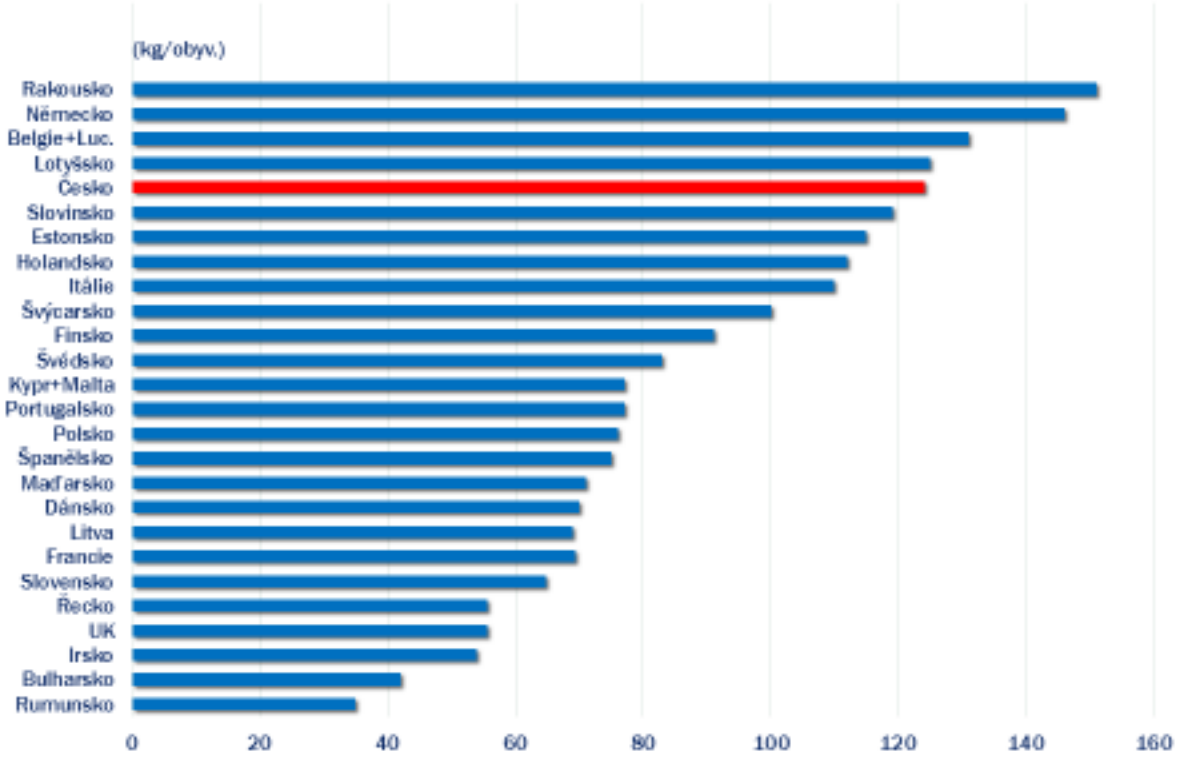


Fig.3 : The Czech Republic is one of the European countries with a very high level of plastic consumption per capita

The development and use of new plastics with tailor-made properties is an important driver of development in many industries. The need for future technologies translates directly into increasing demands for new specialty plastics and materials with the required properties, their preparation methods, production costs and their recyclability. It is also a way to bring compounding companies into the chain of large commodity plastics producers.

The quality requirements of the engineering, automotive and construction industries are increasing, and further applications of specialty plastics in the medical and electrical industries are developing. A long-standing problem that has been difficult to solve is the substitution of some chemicals still in use but restricted by REACH in terms of use. Solutions are being sought to reduce the flammability of plastics and to produce degradable plastics.

Further research and development focuses on bioplastics in conjunction with the selection of suitable raw materials, optimisation of production flows, development of more efficient bio-catalysts, and end-of-life processing of bio-plastics.

It is important to mention that the Czech Republic is also at the top of the EU in terms of plastic waste recycling:

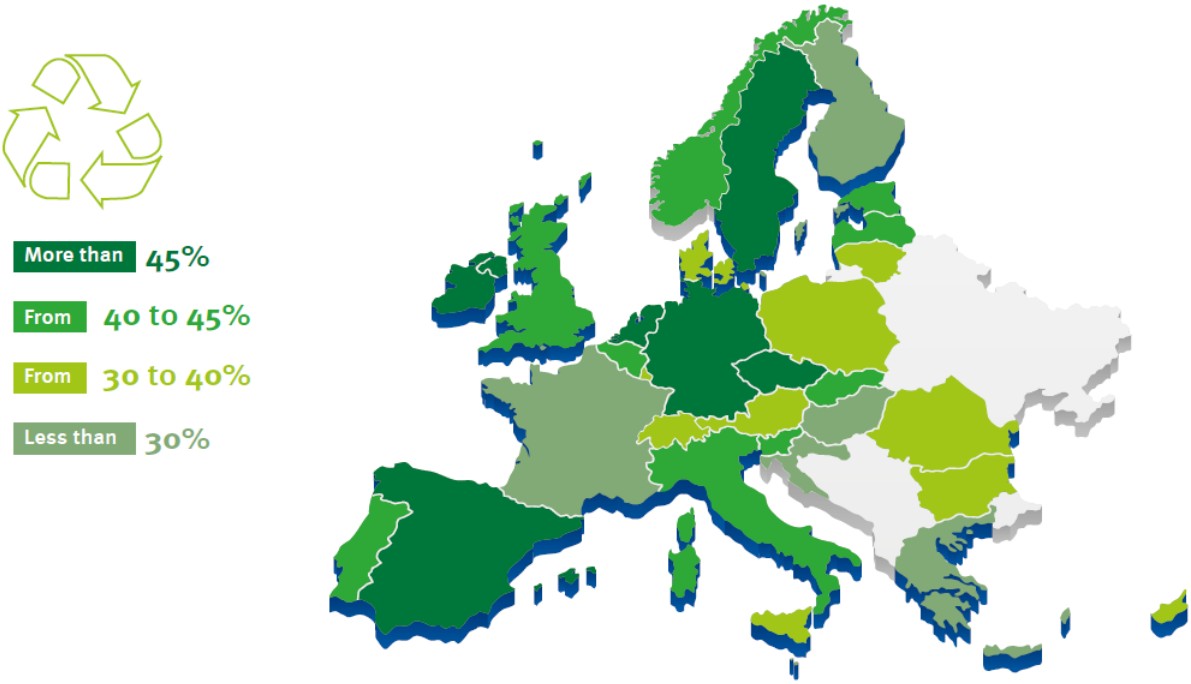


Fig.4: According to 2019 statistics, the Czech Republic had a high percentage of recycled plastic waste (source: Conversio Market Strategy GmbH)

The above-mentioned legislative framework and the strategic direction of the EU economy as a whole give a clear „green light" to the plastics processing industry, especially in terms of recycling techniques, methods and materials, but also in terms of basic polymer blends and their treatment/modifications. From this perspective, eco-innovations are expected mainly in the following research directions:

1. Utilisation of post-consumer recyclated plastics linked to increasing the yield of the collection and sorting system in the Czech Republic:

   This will primarily involve innovations and Sub-projects leading to the inclusion of recyclates (crushed materials, powders, regranulates) produced from sorted categories of plastics collected as municipal and post-industrial waste; specifically, it will involve activities aimed at secondary, fine-sorting processes, identification of polymers, identification of suitable compatibilisation systems necessary for reprocessing and reuse, as well as conceptual proposals for the processing of these materials in conventional facilities of plastics companies.

2. Optimisation of formulations (referred to as polymer compounds) used for production on the part of processing companies with emphasis on minimising the content of materials from non-renewable sources:

Here, the emphasis will be on the use of natural fillers ($CaCO_3$, talc, functional additives, etc.), which in many cases can not only reduce the need to use synthetic polymer (plastic made from oil or natural gas), but at the same time give products specific properties that extend the lifetime or improve performance.

3. Technological modifications and conceptual designs of treatment flows for processes specific to the conversion of post-consumer and post-industrial plastic waste:

   In this case, it will mainly be a semi-operational validation of processing principles, conditions and tools, with the output of the innovation being validated technologies and related technological regulations/conditions.

4. Product innovations:

   Nowadays, in many application areas, due to changes in the technical requirements for plastic products and developments in the field of legislative restrictions, a specific surface properties solution is required. Subsequently, upgraded products are expected to behave accordingly in terms of surface properties – resistance to physical or weathering effects, specific behaviour of the product surface when in contact with other products or modification of performance properties with regard to product durability.

   Existing available technological solutions are focused either on economically disadvantageous alternatives based on modification of the entire mass of the plastic product, i.e. on modification of the used polymer material or on the production of polymers with the required properties, or on inefficient variants of solutions in the form of application of additional heterogeneous structures on the surface of final products in downstream technological operations (painting, printing, etc.). In this context, current conventional methods either fail to provide money for value (expensive raw materials and their high consumption), are investment-intensive (complicated technologies) or ultimately produce products with a significantly heterogeneous structure, which significantly limits their recovery (recycling) at the end of their life cycle.

5. 3D+ additive technological innovations:

   3D printing technology itself has become relatively commonplace. The anticipated print solution within this innovation area is expected to be quite substantial. Currently, filament/string (FDM printing) or polymer solution (SLA printing) is used for printing. In the near future, it will be possible to use individual types of polymers directly for printing in primary form (powder or granules). Some attempts to design direct-printing devices already exist, but they are still untested and operate not very well. A great potential is also expected in the field of additive technologies and treatment of materials that will be modified in their basis for the given purpose – electromagnetically shielding / conductive/antimicrobial materials, etc.

3. Key objectives in terms of technologies and knowledge that are achievable within 3 years, and at the end of the project

Objectives for the 2023–2025 project period

- Surface treatment of plastic products – solution of hydrophobicity, oleophobicity
- Semi-operational testing of recycling processes for polyolefins combining thermal, chemical and solvent principles
- Self-cleaning properties of plastic products – photoactive systems
- Reducing the permeability of flexible plastic products – especially in the packaging industry
- Conductive systems – modification of polymers with conductive polymers for dissipative systems
- Modification of PUR polymer to incorporate a dopant into the PUR structure and subsequent *in situ* polymerisation of conducting polymers on the prepared (nano-) fibres.
- Textile matrices – functional surface treatments; antistatic, dissipative treatments; modifications for sensing and electronic applications
- Circular economy – selective PES/BA labelling for recycling – dispersion of NIR-visible indicator additives that simultaneously yield photo activity
- Polymeric materials and nano-materials for environmental applications
- Functional surface treatment with a focus on increasing levels of circular economy and reducing dependence on non-renewable resources
- Polymer nano-composites with advanced functional properties
- System for identifying polymer types in the recycling chain
- New types of thermally conductive composites

Objectives for the 2026–2028 project period

- Modifications of polymer filter materials with active substances for advanced water purification technologies.
- Pyrolytic processing of waste polymeric materials for the preparation of carbon sorbents for use in wastewater or gaseous waste treatment technologies.
- Polymeric materials with advanced functional properties (magnetic, electrical, thermal, etc.) thanks to additives based on nano-particles of metals, metal oxides and carbon.
- Catalytic pyrolysis – recovery of BTX from waste polyolefins
- Systems and procedures for triboelectric sorting of plastics
- Innovative technology for waste gas and water treatment using catalytic and non-catalytic processes
- Mastering the process of thermal depolymerisation and catalytic pyrolysis of waste polymers.
- Preparation and characterisation of catalysts by TPD, TPR, BET, XRD, XRF or FTIR
- Solvent recycling, cleaning and sorting of waste plastics – non-toxic base
- Modified nonwovens with specific properties

3.1 Research directions/areas – definition and distribution:

The project activities will be directed towards three main research areas and one overarching dissemination activity, „RAP V: Communication, dissemination, creativity“. The objectives of each activity can be defined as follows:

RAP II: Advanced materials – the focus will be on simplifying and unifying the polymer materials used so that they can be recycled more efficiently. Blended polymer materials will be eliminated and functional properties such as

permeability, oleophobicity, hydrophobicity or stability of surfaces against deposition of organic and microbial pollutants will be addressed by additivation. Additives will be designed to be fixed to the polymer matrix to prevent their migration. Nano-materials will also be used, where the issue of fixation will be handled very carefully to avoid burdening the environment with these materials, whose effect on human health is not well described. LCA analyses of the use of individual polymer materials, including bio-based materials, will be performed to assess the actual environmental impact and to design materials with a minimal carbon footprint for individual applications, maximising the use of all available recycling processes. For the effective use of automation elements in the sorting of polymeric materials, a method of marking such materials will be designed to enable automatic sorting of at least 80% of plastic waste.

RAP III: Environmental process engineering – models will be developed of the sorting process of individual polymeric materials with regard to their material composition. Recommendations will be made as to which polymer blends are unsuitable from the point of view of material recycling and can be replaced by the technologies developed in RAP II. The assessment of individual recycling processes will be developed with regard to long-term flows in the field of plastics production and processing, including the energy intensity of individual processes. A waste treatment process will also be proposed in areas such as the textile and automotive industries, where the recovery of used polymer materials is very problematic. The proposed processing procedures for polymer materials for which it will be impossible to use standard recycling processes will use the principles of circular economy. A procedure will be elaborated for using most of the materials in other areas of human activity, especially construction. It can be expected that in the near future the construction industry will face an acute shortage of fillers and one of the options to address these changes will be the proposal to incorporate unusable waste into a form suitable for these purposes.

RAP IV: Consumption in a circular environment – the processing of polymer materials for key areas of industry, both in the production and downstream stages, will receive increased attention. In cooperation with individual industrial entities and their cluster institutions, a strategy for a gradual change of approach to polymer materials will be proposed, which will simultaneously reflect the results of R&D activities in RAP II and RAP III. Individual proposals will be supported by data from detailed LCA and CFP analysis as well as detailed energy balance. At the same time, consideration will be given to the long-term vision for the extraction of raw materials and the long-term availability of the raw materials currently used. The changed design of polymeric materials will also be based on current knowledge in the development of the automotive industry, which is moving towards lightweight recyclable materials suitable for electro mobility; in the textile industry, where functional, comfortable materials are preferred; as well as in the construction sector, as described above. The results will be implemented in pilot industrial outputs, which will be gradually transferred into common practice after the project is completed. This output is expected to support RAP V activities. In addition to extensive dissemination activities towards the professional public, close interaction with the public administration bodies and detailed knowledge of legislative changes in the EU will be necessary. The effort will be not only to harmonise the outputs with current European trends, but also to include the Czech Republic as a major industrial producer among the key partners that make up this process.

3.2 Definition of objectives in terms of TRL, relevance and uniqueness:

Most of the activities planned under the project have already been addressed by the consortium members in the past. Input on innovations in polymer materials for both functionalisation and surface modification is at TRL 3 to 5. The project is expected to harmonise the approaches of individual research teams with the real needs of industrial enterprises. At the same time, it will be necessary to reflect the long-term vision of the Green Deal and to orient the further development of industrial partners in this direction. The alignment and optimisation of these processes is expected to

be the goal of the first three years of the project so that the state of knowledge reaches TRL 5 to 6 and the processes studied can be studied at a semi-operational scale. On the one hand, this will allow the technological processes to be fine-tuned before they are transferred to operational scale and, on the other hand, it will allow a sufficient volume of material to be prepared for testing them in real conditions.
The project activities will then be directed so that they are at TRL 7 level and ready for industrial scale deployment upon completion of the project. Some outputs will be implemented on a pilot industrial scale.

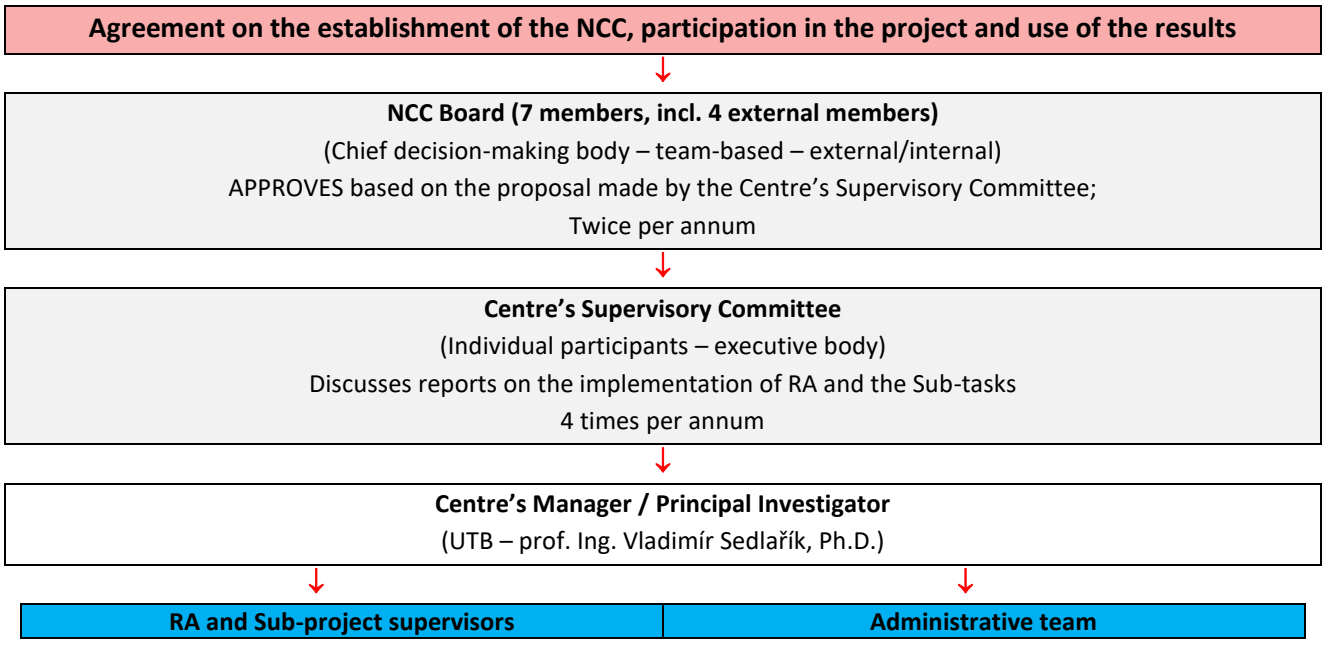
3.3 Achievability in terms of commercialisation:

The companies involved in the project, including in the form of cluster organisations, expect to be able to participate in the implementation of new technologies on a production scale and thus increase the technical level of their production. Dynamic changes are taking place in the production and application of polymer materials, especially for automotive applications, with significant changes in the approach of end users to the materials used and the potential for recycling. The members of management of the companies involved are aware of the fact that without significant investment in innovation in the near future it will not be possible to succeed in the long term in dynamically changing markets. The companies will actively participate in formulating the research objectives, especially in the optimisation and up-scaling phase of the researched processes. Subsequently, there will be close cooperation in the dissemination of R&D results with the possibility of increasing the implementation potential of the activities under investigation.
The overall objective from the perspective of the industrial partners is to be able to incorporate innovative technologies into the production cycle of processing and application of polymer materials, taking into account the need to use recyclable materials with a minimal carbon footprint as well as the vision of the Green Deal call. This approach will simultaneously engage the integrated companies in cutting-edge technologies at the European level, which will contribute to the transition of domestic production capacities to the making of products with higher added value.

NCC Board, Centre´s Supervisory Committee and RA and Sub-project supervisors will strictly managed (and will manage other persons involved in the project execution) in sense of the approaching max commercial effects and business models settings – this all will be taken into account just already within the process of definition and individual projects work solutions. It will be also specified as a part of the project account card definition and will be supervised by the Sub-project supervisors. Status of commercialisation will be continuously negotiated with the accent on business models ways and methods, business opportunities as well as NCC´s accessible financial effects quantification.

4. Description of strategic project management and principles for the composition and proceedings of the Centre's Board

NCC management scheme :



5. Method for evaluating the implementation of the strategic agenda - evaluation plan

The fulfilment of the set objectives of the project will be achieved through individual research sub-projects. Each Sub-project will be approved only on the pre-condition of a precise research plan and specification of the outputs of the applied research. The head of the research project will be the person to oversee how these outputs are delivered. Already during the preparation of the project, the Partners agreed on the structure and heads of the Sub-projects. This structure serves simultaneously as the basis for the funding plan and the plan for the implementation of R&D results linked to the activities of industrial partners. If the project is accepted, each Sub-project head will provide the necessary supporting documents and submit them to the Centre's Board for consideration. The aim is to create the pre-conditions for the project, including its subparts, to be started as soon as possible after its approval.

The fulfilment of the set objectives of the Strategic Research Agenda will be monitored at several stages:

- The Sub-projects will be managed by Sub-project heads who will coordinate all planned activities. Within the framework of the Sub-projects, 3 to 4 technical meetings are planned per year to check the progress of the solution and to review and revise the research activities so that the planned activities are completed on time.
- The project manager will be kept informed about the progress of the Sub-projects and, in case of deviations from the project schedule, the General Assembly of the Centre or the Centre's Board will be notified. In the event of significant deviations, these bodies will decide on the further resolution of the situation or the termination of the Sub-project and the launch of a new Sub-project.
- The General Assembly of the Centre will meet twice per year to review the progress of the Sub-projects. The heads of these projects will be required to provide concise and accurate progress reports. In addition to the technical implementation of the Sub-projects, the General Assembly of the Centre will monitor the progress of the commercialisation of the project outputs, revise the direction of the Centre on the basis of current developments in the field and provide the Centre's Board with documents for the announcement and approval of new Sub-projects.
- The Centre's Board will monitor the overall direction of the project. It will be informed about the progress of the approved Sub-projects. It will assess whether the technical direction of the Sub-projects is in line with the project plan and current trends in the field. The Centre's Board will check whether the matter addressed meets the long-term requirements for commercialisation of the results obtained. The progress of technology transfer and implementation of the project results will be monitored not only in terms of the Sub-project schedule, but also in terms of follow-up and parallel activities. The Centre's Board will ensure that a functional system capable of perceiving developments in the field of new electronic systems is created within the Centre so that it is continuously incorporated into the course of the Sub-projects and subsequently implemented through commercialisation and technology transfer.
- The formal implementation of the project progress and dissemination activities will be continuously monitored by the administrative team set up by the Lead Beneficiary. The administrative team shall report directly to the Centre's Manager, who shall also be responsible for informing the Centre's General Assembly and Board of any deviations without delay. If the deviations cannot be resolved by electronic communication, a special meeting of these bodies will be convened to propose a solution to the situation.
- Each Partner will be responsible for the monitoring and review and correct use of the funds. At the same time, it will be obliged to inform the project financial manager about the progress of the spending in due time; the financial manager will then be responsible for communication with the Granting Authority and for checking the use of financial support according to the rules of the call. The Lead Beneficiary shall have the right to carry out random checks on the progress of the use of grant funds by individual Partners and to request that any deviations from the rules be amended. The financial manager will be responsible for inspecting the funds obtained through the commercialisation of R&D results submitted by the individual research organisations. This activity will be carried out on an ongoing basis to ensure that the consortium is able to present sufficient commercialisation revenues in relation to the grant disbursed.