THE SCIENCE AND TECHNOLOGY FORESIGHT PROJECT

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EXTERNAL EXPERT SERVICES FOR THE IMPLEMENTATION OF MAPPING AND FORESIGHT AS PART OF THE SCIENCE AND TECHNOLOGY FORESIGHT PROJECT

ANALYTICAL REPORT ON THE CONDUCTED SCIENTIFIC AND TECHNOLOGICAL MAPPING

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Content

Foreword

Based on the Contract (CLASS: 406-01/20-01/00053, file no.: 533-03-21-0040), the Ministry of Science and Education engaged a consortium consisting of the Institute for Development and International Relations and the Institute of Economics, Zagreb, to implement the mapping and foresight activities as part of the Science and Technology Foresight project (KK.01.1.1.03.0001). Find out more about the project at: https://mzo.gov.hr/istaknute-teme/eu-fondovi/operativni-program-konkurentnost-i-kohezija-2014-2020/strateski-projekt-znanstveno-i-tehnologijsko-predvidjanje/851.

Mapping and foresight activities within this project refer to the analysis of the research sector which is connected to the Energy and sustainable environment TPA, as it is defined in the Smart Specialisation Strategy of the Republic of Croatia for the period from 2016 to 2020 (hereinafter: S3). The mapping and foresight activities are carried out in three stages: (1) Scientific and technological mapping;[1] (2) Science and technology foresight pilot exercise; (3) Education on the importance of planning and implementing mapping and foresight activities. The goal of this report[2] is to present the results of the first part of this comprehensive project, i.e., the results of scientific and technological mapping.

1 Introduction

The Smart Specialisation Strategy (S3) may be considered an approach of smart diversification of the activities of organisations/institutions within the national/regional economy, with a focus on finding a balance between their existing competencies and identifying hidden opportunities relevant to these organisations/institutions. This strategy is mandatory for all European Union (EU) countries. It is the prerequisite for spending funds from the European Structural and Investment Funds (ESIF) for the thematic goal *Research, development and innovation*. In addition, some countries are implementing the S3 strategy at a national level, e.g., the Republic of Croatia (RH), while other countries are implementing it at a regional level (e.g., Poland). By implementing the programme of this strategy, new competencies of the participants (business entities, institutions from the research sector) can be developed within the national economy or parts of the economy through ensuring that these institutions/companies participate in activities of higher added value (cf. Panori et al., 2021, Asheim et al., 2017) when compared to the level of added value that the institutions/companies had reached before the implementation of this strategy. This refers to the fact that these programmes enable a significant increase in investments in research and development activities both in research institutions and in companies (EC, 2021). In the context of research institutions, participation in activities of higher added value requires the existence of internationally recognised research excellence in those institutions. For this reason, it is important to be familiar with the research excellence of the researchers and research groups in the analysed institutions, which is one of the topics of this report.

To implement the Smart Specialisation Strategy (S3) in the Republic of Croatia, the ministries responsible for the implementation have defined the vision, mission and goals and designed the

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programmes to help achieve the strategy goals. The implementation of this ambitious strategy began in 2016 and presented a challenge for public policy authorities, who were tasked with increasing the rate of use of EU funds and at the same time ensuring the planned S3 goals are achieved. Balancing these two goals requires the S3 authorities responsible for designing and implementing public policy apply additional effort to advance the activities related to this strategy, including scientific and technological mapping.

The mapping and foresight activities are carried out as part of the *Science and technology foresight* project, which has the general goal of creating a coherent and comprehensive system of determining the priorities of research and development policies and innovations in the Croatian research field. The project consists of three main elements: (1) drafting of a proposal for a legal framework for handling data on Croatian scientific activity; (2) creating the Croatian Research Information System (CroRIS); and (3) implementing the scientific and technological mapping and foresight.

The goal of scientific and technological mapping is the establishing of a comprehensive database of research competencies and capacities of the public scientific organisations of the Republic of Croatia operating in the ***Energy and sustainable environment*** TPA of the Smart Specialisation Strategy (S3). Mapping helps increase the visibility of the results of the research carried out in these organisations/institutions, increases the performance of the sector, facilitates the identification of the strengths of the research sector in a specific area, and generates recommendations for the development of guidelines for conducting a science and technology foresight exercise (pilot) at a national level.

The Energy and sustainable environment TPA is divided into two sub-thematic priority areas (STPAs): (1) ***Energy technologies, systems and equipment (STPA 1)*** and (2) ***Environmentally friendly technologies, equipment and advanced materials (STPA 2)***. STPA 1 focuses on the development and application of modern energy technologies and the manufacturing of equipment that is expected to be efficient, remotely controlled and monitored, compatible with smart grids, environmentally friendly, and recyclable at the end of its lifetime. This requires the introduction of new optimised technical solutions and advanced materials, as well as the application of different functionality and condition monitoring sensors based on solutions related to information and communication technologies (ICT).

STPA 2 focuses primarily on addressing climate change challenges and developing a reduced CO_2 emission economy in Croatia. The EU Renewable Energy Sources (RES) Directive establishes targets for increasing the average share of RES in final energy consumption (Government of the Republic of Croatia, 2016). The geostrategic position of Croatia allows the use of different forms of environmentally friendly technologies, such as solar energy, water energy and wind energy. This represents a strong incentive and a direction for future research initiatives in this area, with the support from the appropriate government measures and the industry stakeholders able to invest in research and development who are connected to those initiatives and measures.

Scientific and technological mapping was used to collect data on the science and technology system connected to this TPA. Data analysis established a link between the participation of public scientific organisations as part of different projects and the research results of the researchers from these institutions. By comparing this data, **the points with the greatest concentration of excellence, researchers, and research groups have been identified**. **This concentration of excellence was mostly analysed in the areas of article publishing, project participation, and collaboration.** This report has contributed to the building of a database of researchers in connection with the activities related to this

TPA. It has also contributed to the classification of the researchers based on affiliation with the *Energy and sustainable environment* TPA within that database. Thanks to this report, a link between scientific research and the *Energy and sustainable environment* TPA was established. In addition, a clear distinction was made between the STPAs within this TPA. STPA1 (***Energy technologies, systems and equipment***) is described as ‘engineering‘, whereas STPA2 (***Environmentally friendly technologies, equipment and advanced materials***) is described using fields, parts of engineering, natural and agricultural sciences. Finally, to the authors’ knowledge, this is the first report that covers the STPAs within the *Energy and sustainable environment* TPA.

This report comprises five parts. The first section describes the methods of data collection and the process of building a database of researchers whose activities are related to the analysed TPA to varying degrees. The second section provides an overview of secondary data, i.e., the programmes involving Croatian researchers as part of the analysed TPA. This programme overview includes an analysis of the participation of Croatian researchers in the Smart Specialisation Strategy programme that is being implemented using the *S3 Policy Delivery Instruments* and *the S3 Policy Additional Instruments*. In addition, the overview of projects/programmes in this report goes beyond the projects/programmes analysis of the S3 strategy. In addition to the two *policy instruments* groups, this report investigates the selected EU programmes involving Croatian researchers connected with the *Energy and sustainable environment* TPA. The third report section presents the basic findings from the survey conducted about researchers associated with the analysed TPA. Here, findings are given on analysis scope, data and sample structure. In addition, the third section provides findings on project and research excellence, research infrastructure use, and knowledge dissemination. This report section also analyses the performance and the potential of researchers in this thematic area. The fourth report section presents the SWOT analysis results. The fifth and last report section presents the conclusions and recommendations for follow-up activities.

1.1. Basic terms in the report

The **Field of Science and Technology (FOS) classification** is a classification system for branches of scientific and technical fields. This classification was published by the Organization for Economic Cooperation and Development (OECD). The revised version of the classification from 2007 is currently in use. The major fields within this classification are: *Natural sciences*, *Engineering and technologies*, *Medical sciences*, *Agricultural sciences*, *Social sciences,* and *Humanities*. The major fields are sub-categorised into 2-digit levels. One exception is the *Engineering and technologies* field which is sub-categorised into 3-digit levels (more details are given in OECD, 2007). The users of this classification are primarily participants in the government and public sector, and the purpose is to monitor, evaluate and analyse the financing of specific fields of science.

Researchers within the **Energy and sustainable environment** TPA are all those who identified themselves as belonging to one of the two STPAs (*Energy technologies, systems and equipment* STPA or *Environmentally friendly technologies, equipment and advanced materials STPA*) in the survey. The analysis in this report showed that, in the Republic of Croatia, slightly more than three hundred researchers belong to STPA1, while slightly more than five hundred researchers are, to a greater or lesser extent, connected to STPA2. Interestingly, only slightly less than 30% of the researchers surveyed in the third report section stated that their work can belong to both STPAs (explanations of the TPA and the related STPAs are given in the last paragraph of this subsection and in Annex 1 of the Survey Questionnaire).

Researchers in institutions were evaluated by analysing three types of indicators: (1) publications (number of Web of Science /WoS/ articles, number of WoS citations, number of Scopus articles); (2) different forms of collaboration in the field of articles and projects; and (3) project participation. A combination of factor analysis and cluster analysis was used to evaluate the performance of the research groups. This approach produced three groups of researchers: researchers demonstrating outstanding research excellence (excellent researchers), project-oriented researchers, and researchers with a smaller scientific contribution.

In the context of this project and in this report, **mapping** involves the identification of researchers and research groups in the *Energy and sustainable environment* thematic area on the basis of analysing the intensity of their activities such as: (1) participation in different projects as part of the *S3 Policy Delivery Instruments*, *S3 Policy Additional Instruments,* as well as in selected EU programmes; (2) number of published scientific papers (indexed in the WoS and Scopus databases); (3) collaboration with other institutions; (4) research results commercialisation; and (5) use of equipment that supports the work of researchers.

Projects. The subject of interest of this report is the participation of Croatian researchers in projects of a part of the S3 programmes as well as their participation in projects of a part of EU programmes (e.g., EU's Framework Programme for Research and Innovation—Horizon 2020) related to the topics of energy and environmental protection that are not included in the programs of the Smart Specialisation Strategy.

Smart Specialisation Strategy (S3) of the Republic of Croatia was adopted in 2016 with the aim of using the structural funds from certain EU grants. In order to use these funds, the Republic of Croatia has adopted the following specific strategic goals as part of this strategy: (1) Increasing the capacity of the research organisations to carry out cutting-edge research that meets the needs of the economy; (2) Overcoming the fragmentation of the innovation value chain and bridging the gap between the research organisations and the business sector; (3) Modernising and diversifying Croatian economy through business sector investments in research, development and innovation; (4) Upgrading the global value chain and encouraging the internationalisation of Croatian economy; (5) Engaging in partnership work for solving societal challenges; (6) Developing smart skills—improving the qualifications of the existing and new workforce for smart specialisation. The thematic areas of this strategy are: (1) Health and quality of life; (2) Energy and sustainable environment; (3) Transport and mobility; (4) Security; and (5) Food and biotechnology. The S3 Strategy is composed of 42 programmes. These programmes are divided into two groups. The first group of programmes are the *S3 Policy Delivery Instruments*, where each project is part of at least one TPA. The other group are the *S3 Policy Additional Instruments,* which contribute to the goals of the Smart Specialisation Strategy.

The **Energy and sustainable environment TPA** is one of five TPAs within the Croatian Smart Specialisation Strategy. The selected thematic areas determined the priority areas within the S3 Strategy. Previously, this TPA has shown to be significant in the context of financing S3 projects because a substantial part of the financed instruments was in this area. This thematic area is further divided into two sub-thematic priority areas (STPAs), (Government of the Republic of Croatia 2016: 101). The STPA1, *Energy technologies, systems and equipment*, focuses on the development and application of modern energy technologies and the manufacturing of equipment that is expected to be efficient, remotely controlled and monitored, compatible with smart grids, environmentally friendly, and that may be recycled at the end of its lifetime. The STPA2, *Environmentally friendly technologies, equipment and advanced materials*, is aimed at addressing the challenges of climate change and economic development with reduced carbon dioxide (CO_2) emissions in the Republic of Croatia (Government of the Republic of Croatia, 2016: 105).

Topics of energy and environmental protection. In contrast to the preceding term, which is connected to the participation of researchers in the *S3 Policy Delivery Instruments*, where every project is a part of at least one thematic area, the **topics of energy and environmental protection** also include the researchers who evidently cover this topic and who have participated in projects of certain EU programmes within the *energy and environmental protection* topic.

Web of Science (WoS) categories. The Web of science categories are features appearing in every journal and book included in the *Web of Science Core Collection* citation database. The number of WoS categories is subject to annual revision and it is constantly rising. At the time of drafting this report, there were 252 WoS categories classified into five thematic areas: Arts & Humanities, Life Sciences & Biomedicine, Physical Sciences, Social Sciences, and Technology.

1.2 Mapping methodology

The first step of mapping covered the building of the database, i.e., the classification of researchers into the databases. To classify the researchers from the *Energy and sustainable environment* TPA in the database, researchers were selected by their institution and/or they were identified through the projects that the employees of the Ministry of Science and Education (MZO), the Ministry of Economy and Sustainable Development (MINGOR), and the Croatian Agency for SMEs, Innovation and Investments (HAMAG BICRO) categorised as belonging to this thematic area. These are projects that are a part of the *S3 Policy Delivery Instruments.* A little over a thousand researchers considered to relate to this TPA to a greater or lesser extent were identified this way.

Thanks to the efforts of the employees of MZO, MINGOR, HAMAG BICRO, Agency for Mobility and EU Programmes (AMPEU), University of Zagreb, Centre for Research, Development and Technology Transfer (CIRTT), State Intellectual Property Office (DZIV), and the Croatian Science Foundation (HRZZ), data was obtained on the participation of Croatian researchers in different projects within the different programme groups listed. MZO employees collected data on programmes/projects within the structural funds and data on the use of EU programmes. Thanks to the employees of MINGOR and HAMAG BICRO, information was collected on the use of funds within the following programmes: Unity Through Knowledge (UKF), Research and Development Programme (IRCRO), Development of Knowledge-Based Companies (RAZUM), *Proof of Concept* (PoC), and the Programme of encouraging research and development activities in the field of climate change. HRZZ employees provided information on projects financed from different programmes implemented by the Croatian Science Foundation. CIRTT employees, themselves participants of EIT RawMaterials, provided data on the participation of Croatian researchers in programmes financed by the European Institute of Technology (EIT). DZIV employees provided data on patent applications and granted patents according to the International Patent Classification (IPC).

A survey was also conducted for the purposes of mapping. The questionnaire was created based on a literature review and then developed further based on conversations with experts in the researched area as part of a pilot research. The questionnaire comprised seven parts: (1) basic information about the researcher; (2) published scientific papers; (3) research and development projects; (4) collaboration; (5) patents and research commercialisation; (6) research infrastructure; and (7) knowledge dissemination.

Given that the initial database included more than a thousand researchers, a sampling process was carried out to conduct the survey, i.e., send the questionnaire. This sampling was used to select a representative number of researchers in this TPA who will be sent the questionnaire. The sample was stratified according to two criteria: (1) whether or not the researcher was selected by their institution to answer the questionnaire, with all nominees being included in the sample; (2) the number of projects within the *S3 Policy Delivery Instruments* related to the *Energy and sustainable environment* TPA in which the researcher participated, where the number of projects can belong to one of three categories (no projects, one project, two or more projects). Five strata[3] were obtained this way. The sample was selected in such a way that the probability of including those selected by their institutions into the sample was set to 1, while the size of the subsample in each of the remaining three strata (where the non-nominated were) was calculated by setting the maximum error in each stratum to 10% and assuming a 50% response. Researchers in each of the three strata with the non-nominated researchers were selected randomly. Three other potential stratification criteria were also considered: (1) the first year of publication of the article entered in the WoS citation database; (2) the number of papers in the WoS database; and (3) the researcher's field of activity depending on field of science, according to the FOS classification. However, it turned out that selecting the sample according to the first two criteria resulted in a sample that was sufficiently balanced in relation to the other three criteria with respect to the population, and it was agreed that it is not necessary to add additional stratification criteria.

A total of 515 researchers were sampled in this way. It was later determined that five of the sampled researchers have retired. A final sample of 510 researchers was finally obtained. The questionnaire was implemented from 7 October to 21 November, 2021. The survey was originally intended to end at the end of October, but after sending two reminders and extending the survey, an interviewer was finally hired in November to urge the researchers to fill out the questionnaire. Almost half of the sampled researchers (253, i.e., 49.6%) answered the questionnaire.

One survey question asked *In which STPA as they are defined in the Smart Specialisation Strategy of the Republic of Croatia (S3) is your research dominant?* and this helped obtain more precise information about how the researchers perceive themselves, whether as belonging to the *Energy technologies, systems and equipment* STPA or as focusing more on the *Environmentally friendly technologies, equipment and advanced materials* STPA. The approximate number of researchers in Croatia who are associated with both STPAs was also obtained this way. Finally, based on the survey and the weighting of the results for the entire population of a little over 1200 researchers, an estimate was made that around 300 researchers participate in activities related to the *Energy technologies, systems and equipment* STPA, whereas 500 researchers *participate in activities related to the Environmentally friendly technologies, equipment and advanced materials* STPA*.*

The comparative collection of secondary data and the primary data from the survey contributed to a better understanding of the researchers and research groups within the *Energy and sustainable environment* TPA. However, participating in projects within programmes—which was established for slightly over a thousand researchers recorded in the ways described above—is not a guarantee that the researcher considers themself a part of this TPA. As an illustration, slightly over thirty percent of respondents (31%) in the survey said that they do not belong to any of the analysed STPAs.

The programmes used to implement the Smart Specialisation Strategy of the Republic of Croatia involve experts in information and communication technologies (ICT) and experts in key enabling technologies (KET), which are both cross-cutting themes within the S3 strategy. These experts are a mandatory part of every project in the programme of the S3 strategy, meaning they can be a part of any TPA and may even consider themselves as not personally belonging to any TPA. In addition, some projects (especially those with larger financial sums) cover several thematic areas simultaneously.

[3] There were no nominees with 0 projects, so the final number of strata is 5 and not 6.

Centres of research excellence are a prime example of this. This means that a subsequent analysis of the classification of projects into this TPA was indirectly carried out through the survey, which can help decision makers in the S3 area to better understand the activities of researchers in the scope of the S3 programmes.

In this report, the publication category of research articles is linked to the field in which the researcher (author of the article) is professionally active. The publication of research articles is analysed using WoS categories, as opposed to scientific activity, which is analysed using FOS areas according to the OECD classification (OECD, 2007). The linking of WoS categories and FOS areas in this report was made thanks to an analytical tool that allows articles from the WoS categories to be transferred directly into FOS areas (Kutlača, 2021). Considering that researchers who have been engaged in research work for a longer period may have published their papers in several WoS categories during their careers, for the purpose of creating a database of researchers, the value of the WoS category in which the author publishes most often was entered into the database. This value was obtained by counting the WoS categories of each article of a specific researcher on the WoS website.

Linking these categories is particularly important for STPA2 *Environmentally friendly technologies, equipment and advanced materials.* Fitting into a particular area can be understood broadly and it is not always clear which profiles of researchers can be involved with specific projects or even which profiles of researchers can work in the same STPA. Thanks to the research conducted and the data collected about each researcher and their WoS category, along with the researcher's statement of belonging to one of the two STPAs, a better understanding on how to describe these two STPAs in the context of research was gained. Researchers from the STPA1 *Energy technologies, systems and equipment* are engineering-oriented and carry out research in the following FOS classification fields: 2.2, 2.3 and 2.7 (OECD, 2007). On the other hand, according to the analysed sample, researchers from the STPA2 *Environmentally friendly technologies, equipment and advanced materials* predominantly carry out research in the following FOS classification fields: 1.4, 1.5, 2.5, 2.11, and 4.1.

The analysis of patents was carried out using the International Patent Classification, applied under the international Patent Cooperation Treaty (PCT), which ensures the proper procedure for filing patent applications for the purpose of protecting inventions, standardised in more than 100 countries.

2. Analysis of programmes related to the *Energy and sustainable environment* TPA

Energy and sustainable environment TPA stands out as an important area of specialisation in Croatia (Government of the Republic of Croatia, 2016). This TPA is even more important considering there is a possibility of contributing significantly not only to national, but also regional and global challenges concerning safe, clean and efficient energy, climate change, and efficient use of resources. When investing this TPA, the following stand out as the most significant advantages of Croatia: (1) the existence of significant industrial capacities related to electrical equipment for electric power systems and supporting industries for constructing large metal and concrete structures; (2) a long tradition and broad experience in design and construction of energy plants, transmission lines, substations and control systems with export potential; (3) the presence of natural resources suitable for producing energy from renewable energy sources (RES) such as solar energy, wind energy, hydro-energy, biomass; and (4) a certain number of public and private scientific organisations with proven capabilities that can support and boost industry competitiveness through research and development.

2.1. *Energy and sustainable environment* TPA as part of the Smart Specialisation Strategy of the Republic of Croatia (S3)

The Smart Specialisation Strategy of the Republic of Croatia for the period from 2016 to 2020[4] is a set of policies for the transformation of the economy towards creativity and innovation in the six specific strategic goals listed in part 1.1 of this report. In the context of this report, projects oriented towards the *Increasing the capacity of the research organisations to carry out cutting-edge research that meets the needs of the economy* (SSG1) and *Overcoming the fragmentation of the innovation value chain and bridging the gap between the research organisations and the business sector* (SSG2) goals are the most important.[5] These projects are important because the research institutions which are the subject of this report take part in them.

The goals listed in section 1.1 are being realised through 42 delivery instruments with a total allocation of HRK 8.3 billion. Alongside MZO, the delivery instruments[6] are under the jurisdiction of: MINGOR, Ministry of Labour, Pension System, Family and Social Policy (MROSP), HRZZ, and HAMAG-BICRO. These instruments are divided into two groups: (1) the first group are the *S3 Policy Delivery Instruments*, where each project is part of at least one TPA; (2) the second group are the *S3 Policy Additional Instruments,* which contribute to the goals of the Smart Specialisation Strategy, where a connection to a particular TPA is not a precondition of project financing. There are 19 programmes in the first group, and 23 programmes in the second one.

According to the most recent report by HAMAG-BICRO (HAMAG-BICRO, 2021) on the implementation of S3 in Croatia, in the period from 2016 to 2019, 78.5% of the Smart Specialisation Strategy delivery instruments were in progress (33 out of 42), 9.5% were in planning (4 out of 42), and 12% have finished

[4] A new S3 strategy for the period from 2021 to 2027 is currently in development.
[5] Public scientific organisations can contribute to the goals with their activities.
[6] Additional seven instruments of a total allocation of HRK 0.5 billion contribute to the strengthening of scientific and research activities and innovations in the field of fisheries and agriculture and in the private sector, and these are under the jurisdiction of: (1) the Ministry of Agriculture; (2) the Ministry of Regional Development and EU Funds; and (3) the Ministry of Economy and Sustainable Development.

implementation phase (5 out of 42). By the end of 2019, 59% of the allocation was contracted (HRK 4.9 billion out of the HRK 8.3 billion allocated), and of that, 26% of the contracted funds were paid (HRK 1.3 billion out of HRK 4.9 billion), i.e., 16% of the allocated funds. The *Energy and sustainable environment* TPA takes the lead in terms of the number of projects by TIC with a positive assessment by the IIC (94 projects out of a total of 210 or 44.8%, with a total value of project ideas of around HRK 1.6 billion). The presence of the *Energy and sustainable environment* TPA (37%) compared to other TPAs is significant for the science and research sector. On the other hand, according to the distribution of the number of contracted projects by TPA for the business sector (calls for RDI phase 1 and PoC for private users), most projects fall into the *Energy and sustainable environment* TPA (31% and 38%, respectively).

Moreover, the European Commission (EC, 2021) states that engineering and ICT related fields are the most frequently addressed topics in different projects within the EU S3 strategies. This data shows that over 90% of all S3 strategies (168 out of 185; 91%) explicitly reference the societal challenge 'Climate Action/Resources' and 72% reference the sub-thematic area 'Energy'.

2.2. An overview of the participation of Croatian researchers in the Smart Specialisation Strategy policy programme

The S3 policy instruments are divided into *S3 Policy Delivery Instruments* (section 2.2.1) and *S3 Policy Additional Instruments* (section 2.2.2). Delivery instruments are more significant in terms of their scope, and each of the projects within these instruments belongs to one TPA. On the other hand, additional policy instruments are not dedicated to a specific theme nor to a specific TPA, so HRZZ projects are included in them. Projects that belong to this TPA are also subjects of interest, whether they were classified into this topic by the employees of certain ministries, or whether the surveyed researchers declared that they belong to this thematic area. The projects combine activities and address specific needs in *Energy and sustainable environment* TPA, which is why they are analysed in this report.[7] This is different from the results of the survey, where the results are presented at the level of the STPAs (section 3.3.2). This report analyses the projects implemented between January 1st 2011 to June 30th 2021. The implementation of some projects began in 2017, with greater portion of the projects being implemented later. Nevertheless, a larger number of programmes in this report section will end in 2023. Hence, it is possible that the programmes of two consecutive Smart Specialisation Strategies will be implemented in parallel.[8] It is important to note that the aid intensity (percentage of aid for each individual project) is not the same for each programme. Some programmes have aid intensity of 100%, while other programmes have 85%, meaning the project beneficiaries themselves must, to some extent, co-finance the project in which they plan to participate.

[7] For the projects in Figures 2.1 and 2.2, thematic monitoring is difficult because the projects are mainly infrastructure projects and the activities in such projects can be related to different thematic areas. That is why, when specifying TPAs within the projects of the SIIF, INFRA, TWINN ZCI, STRIP, HR ZOO and CALT programmes, these projects are listed as relating to several TPAs.

[8] The Smart Specialisation Strategy this report is based on was adopted in 2016 and is valid until 2020. At the moment, the new Smart Specialisation Strategy for the period from 2021 to 2027 is being drafted.

2.2.1 S3 Policy delivery instruments

In this section, reported policy delivery instruments are either a programme or a project.[9] Figure 2.1 shows the first group of selected S3 policy instruments, i.e., projects within the analysed *Energy and sustainable environment* TPA. Projects in the listed programmes incorporate many activities and one project often covers several thematic areas of S3. The criterion for the analysis of projects in this report was that the project had to be registered in the *Energy and sustainable environment* TPA. Data presented for each programme includes the number of projects in the programme, the estimated number of researchers involved in the programme[10], the period of project implementation, and the project aid intensity. The acronyms for all public scientific institutions that participated in these programmes and those that filled out survey questionnaire (section 3) are available in Annex 5**.** When analysing the number of projects in individual research institutions, it should be taken into account that the number shown here is the number of institutions participating in each project.[11] Likewise, when analysing the total value of a project, considering we only have data on *the total value of the project* and that there is no data on *the amount of funds each institution received in a particular project* (when several institutions participate in one project), the figures showing the total value of the project present the total value of an individual project received by an individual institution, and not how much of the total project value went to each individual institution.

The **Science and Innovation Investment Fund (SIIF)** is aimed exclusively at higher education institutions and public scientific organisations in the Republic of Croatia. The duration of the SIIF programme is from 2019 to 2023, and the aid intensity ranged from 67% to 85%. The purpose of the grant programmes is to build the capacity of higher education institutions and public scientific organisations in technology transfer and research results commercialisation, with the aim of advancing sustainable regional development and the competitiveness of the high value-added industrial sector. A total of sixteen projects related to this TPA are being implemented as part of this programme. Between two and five institutions participate in each project. As for the number of projects related to the analysed TPA which are awarded to different research institutions, FSB is takes the front as the project leader in two projects (total value HRK 13.8 million). Regarding the number of different project participations, FKIT leads with three projects. It is estimated that over two hundred researchers are participating in the projects of this programme related to the *Energy and sustainable environment* TPA.

The strategic goal of the **Strengthening the economy by applying research and innovation (STRIP)** programme is to encourage innovation and excellence in research through building the capacity of public universities and public scientific organisations for technology transfer, a better cooperation with the economy, and encouraging the commercialisation of research results, innovation and excellence. The duration of the STRIP programme is from 2020 to 2023, and the aid intensity ranged from 60% to 83%. Twenty projects are being implemented, where project applicants are research institutions and project partners are private firms. FER and FSB stand out as the leaders in this programme, with 6 and 5 awarded projects respectively, with a total value of HRK 40.5 million and HRK 43.5 million. It is

[9] Thus, in the CALT and O-ZIP projects, one project constitutes this policy delivery instrument. In this case, project is synonymous with programme. In the case of programmes such as SIIF or STRIP, several projects form the same policy delivery instrument, and in that case the term ‘programme‘ is different from the term ‘project‘.

[10] The data was provided by the experts of the ministries responsible for the implementation of individual programmes that are the subject of the report's analysis. The values are only estimates because it is possible that other researchers participated in the implementation itself or that the researchers listed by ministry experts did not participate.

[11] In some cases, several institutions are involved in one project, so that project gets assigned to each individual institution participating in it.

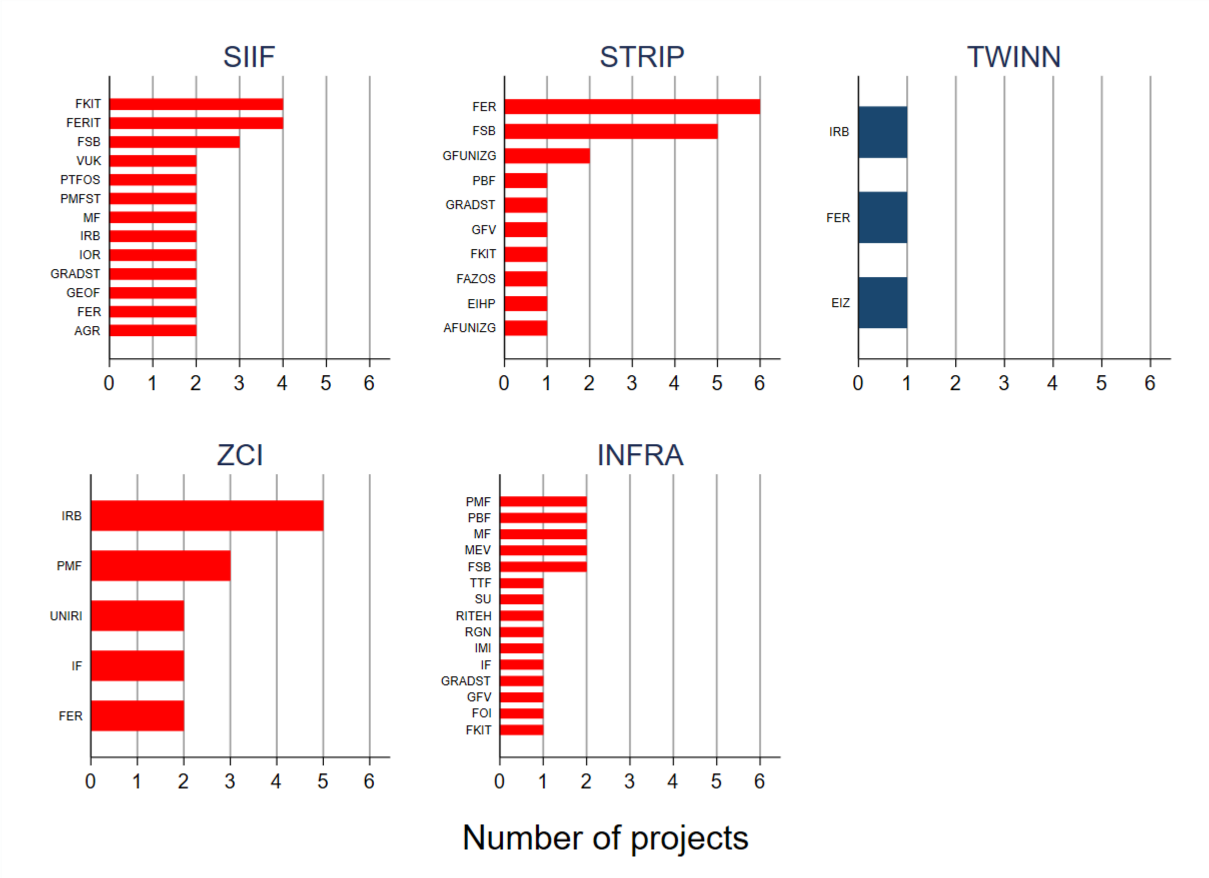
estimated that over 150 researchers are participating in the projects of this programme related to the Energy and sustainable environment TPA.

The **Centres of research excellence (ZCI)** programme has the mission of pushing the boundaries of research, knowledge and society in general through research and all its potential applications, thereby increasing and advancing the international visibility and recognition of the Croatian research community and contributing to the development of economy and society as a whole. The duration of the ZCI programme is from 2017 to 2022, and the aid intensity in each project within this programme ranged from 67% to 100%. A total of five projects related to the analysed TPA are being implemented as part of this programme. It is important to note that projects in ZCI programme cover several thematic areas besides the *Energy and sustainable environment* TPA and it is impossible to break up each project according to individual STPA. In terms of the number of awarded ZCI projects, IRB and PMF stand out, with 5 and 3 awarded projects, respectively. Out of these, IRB is the project applicant/leader in two projects (HRK 74.9 million) and PMF is the project applicant/leader in one project (HRK 36.9 million). Much like in the STRIP programme, it is estimated that over 150 researchers participated in the ZCI projects related to analysed TPA.

Programme **Infrastructure – Investing in organisational reform and infrastructure in the research, development and innovation sectors (INFRA)** offers capacity building for research, development and innovation (RDI) by providing support for organisational reform/changes and development of RDI infrastructure of research organisations, with the aim of improving the quality, scope and relevance of their research activities and their transformation into internationally competitive research institutions that create new research, societal and economic value. The duration of INFRA programme is from 2018 to 2022 and the aid intensity for each project within this programme ranged from 67% to 100%. At the moment, fourteen projects are being implemented as part of INFRA programme. With two projects each, this list of institutions is headed by PMF, PBF, MF, MEV and FSB — each institution is the project applicant in one project, and a project participant/partners in the other. It is interesting to note that some of the projects have no project participant/partners (hence, only project partners), while others have several partner institutions. The range of eligible costs within these projects is between HRK 7.03 million (applicant FSB) and HRK 232.6 million (applicant IMI). It is estimated that over 100 researchers are participating in the projects of this programme related to the *Energy and sustainable environment* TPA.

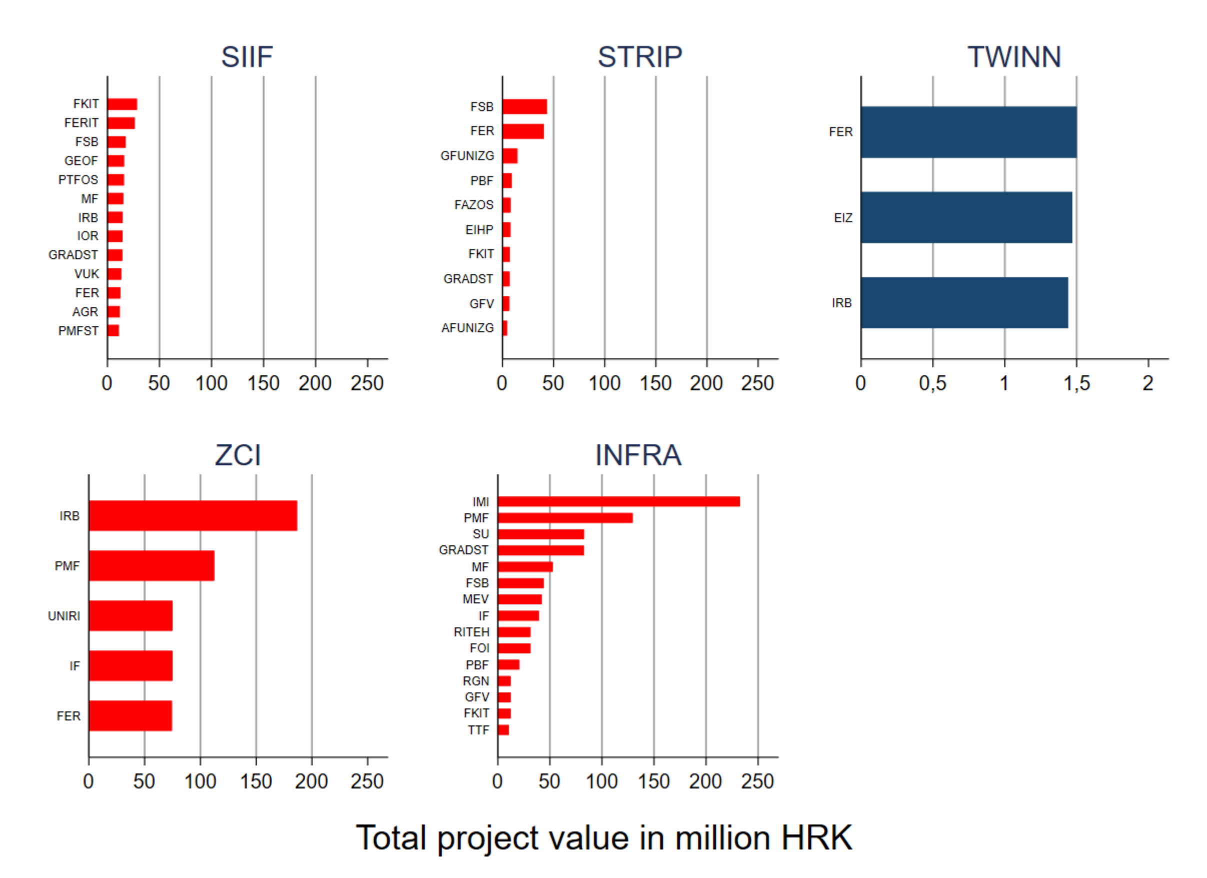
The **Developing and strengthening of synergies with horizontal activities of the HORIZON 2020 programme: Twinning and ERA Chairs (TWINN)** programme stimulates the interaction of European programmes with the cohesion policy, i.e., the structural funds as part of the Smart Specialisation Strategy. This programme is aimed at capacity building, sustainability and excellence of the research and development activities of the research sector in the Republic of Croatia. The duration of TWINN programme is from 2018 to 2021, and all projects within this program have ended. FER, EIZ and IRB were awarded one TWINNING project each, with a total value of HRK 1.5 million, and each project had 100% aid intensity. Compared to the previous programmes, the projects within this programme were smaller, with about 10 researchers engaged.

Figure 2.1 Number of SIIF, STRIP, TWINN, ZCI and INFRA projects by institution



Note: For SIIF projects, the following institutions have one project each: GFOS, SFSB, KEMUNOS, FBF, EF, MATUNOS, TTF, PMF, GRADRI, FESB, FŠDT, KRS, PTF, FAZOS, PBF. For ZCI projects, the following institutions have one project each: PTFOS, PMFST, GRADRI, FERIT, MEF, MedILS, SU, MF, TTF, PBF, GFUNIZG, FPZ, KTFST, FESB, UNICATH, UNIDU, RITEH, FSB, BIOTECHUNRI, CNRM. These institutions were not shown on the graph due to presentation limitations. Columns in blue indicate completed programmes; red columns indicate active programmes.

Figure 2.2 Total value of SIIF, STRIP, ZCI, INFRA and TWINN projects by institution



Note: For SIIF projects, the following institutions have one project each: GFOS, SFSB, KEMUNOS, FBF, EF, MATUNOS, TTF, PMF, GRADRI, FESB, FŠDT, KRS, PTF, FAZOS, PBF. For ZCI projects, the following institutions have one project each: PTFOS, PMFST, GRADRI, FERIT, MEF, MedILS, SU, MF, TTF, PBF, GFUNIZG, FPZ, KTFST, FESB, UNICATH, UNIDU, RITEH, FSB, BIOTECHUNRI, CNRM. These institutions were not shown due to presentation limitations. Columns in blue indicate completed programmes; red columns indicate active programmes. *The measurement scale on the abscissa for TWINN projects is different compared to the other programmes.*

In addition to the programmes presented above which include several projects, there are three programmes that have only one project each **(HR-ZOO, O-ZIP,** and **CALT)**.

The main goal of the **Croatian Scientific and Educational Cloud (HR-ZOO)** project, with a total value of HRK 196.8 million, is the construction of a computing and data cloud that will be the fundamental component of the national research and innovation e-infrastructure. The implementation period of this project is from 2017 to 2023. Since this is the only project within this programme, it can be considered a "project programme". HR-ZOO was designed as a shared infrastructure for the purposes of modern education and internationally relevant research and as an instrument of integration into the European research area and the European area of higher education. The leader of this project is SRCE, and the project participants/partners are UNOS, UNIRI, SU, IRB, and CARNET. Like in the case of the TWINN programme, it is estimated that about 10 researchers are involved with the implementation of this project. The aid intensity for this project is 100%.

The **Open Scientific Infrastructural Platforms for Innovative Applications in Economy and Society (O-ZIP)** project, with a total value of HRK 547.2 million and a 100% aid intensity, where IRB is the project leader, covers the improvement of existing and the construction of new IRB facilities for the implementation of cutting-edge research. The implementation period of this project is from 2018 to 2023. The project will result in establishment of four multidisciplinary research platforms and the implementation of an organisational reform of IRB, which will help them reach new levels of research excellence, especially in the priority areas as defined by the Smart Specialisation Strategy of the Republic of Croatia. The implementation of the O-ZIP project will create the preconditions for increasing the scope, quality and performance of research aimed at solving societal challenges, implementing cutting-edge collaborative research, and promoting the importance of research results commercialisation, thus contributing to the development of innovative and competitive entrepreneurship.

The main goal of the **Centre for Advanced Laser Techniques (CALT)** project, with a total value of HRK 121.3 million and a 100% aid intensity, where IF is the project leader, is to improve the existing and develop new research infrastructure based on advanced laser techniques at IF. For this purpose, the building of the first wing of the institute will be completely renovated and adapted to the requirements of contemporary research work and then equipped with the most sophisticated research equipment based on advanced laser and optical systems. The implementation period of this project is from 2017 to 2022.

If we compare the S3 delivery instruments within this TPA, we can see that one research institution usually participates in only one programme. Figure 2.2 shows the financial structure of individual programmes. The projects of programmes ZCI, INFRA and HR-ZOO have the most substantial financing. It is interesting to note that even though IMI has only one INFRA project, this project has the most substantial financing, with an amount of around HRK 240 million. There are only a few institutions, such as FER as part of the STRIP programme or IRB as part of the ZCI programme, with their activities present in several projects in the scope of one programme. One good thing is that the programmes shown in this figure include many institutions located outside of Zagreb.

Figure 2.3 shows the second group of selected S3 policy instruments, i.e., programmes within the analysed *Energy and sustainable environment* TPA. These instruments are financially less substantial (Figure 2.4) compared to the projects shown in Figure 2.2.

The programme aimed at strengthening research and development activities related to climate change within the Smart Specialisation Strategy is called the **Programme for encouraging research and development activities in the field of climate change** (for the purposes of this analysis, this programme is abbreviated **R&D Climate**), and most projects in the programme are carried out by IRB, AGR and PMF. These institutions are both applicants/leaders and partners in projects related to this programme. The programme was developed with the aim of reducing the impact of climate change, which is why different institutions, such as AGR are involved, as opposed to the ones we usually expect to find in programmes in this area, like FER and FSB. Given its profile as a research institute and its size, IRB participates in different projects within this thematic area. 25 projects them from this programme started their implementation in 2020.[12] The aid intensity for these projects is 85%. It is estimated that over 80 researchers are participating in various projects of this programme.

Research and development projects IRI 1 and IRI 2 (phase 1 and phase 2) are under the authority of MINGOR, and grants are awarded through the Operational Programme Competitiveness and Cohesion 2014–2020 from the European Regional Development Fund. The duration of the IRI 1 programme is

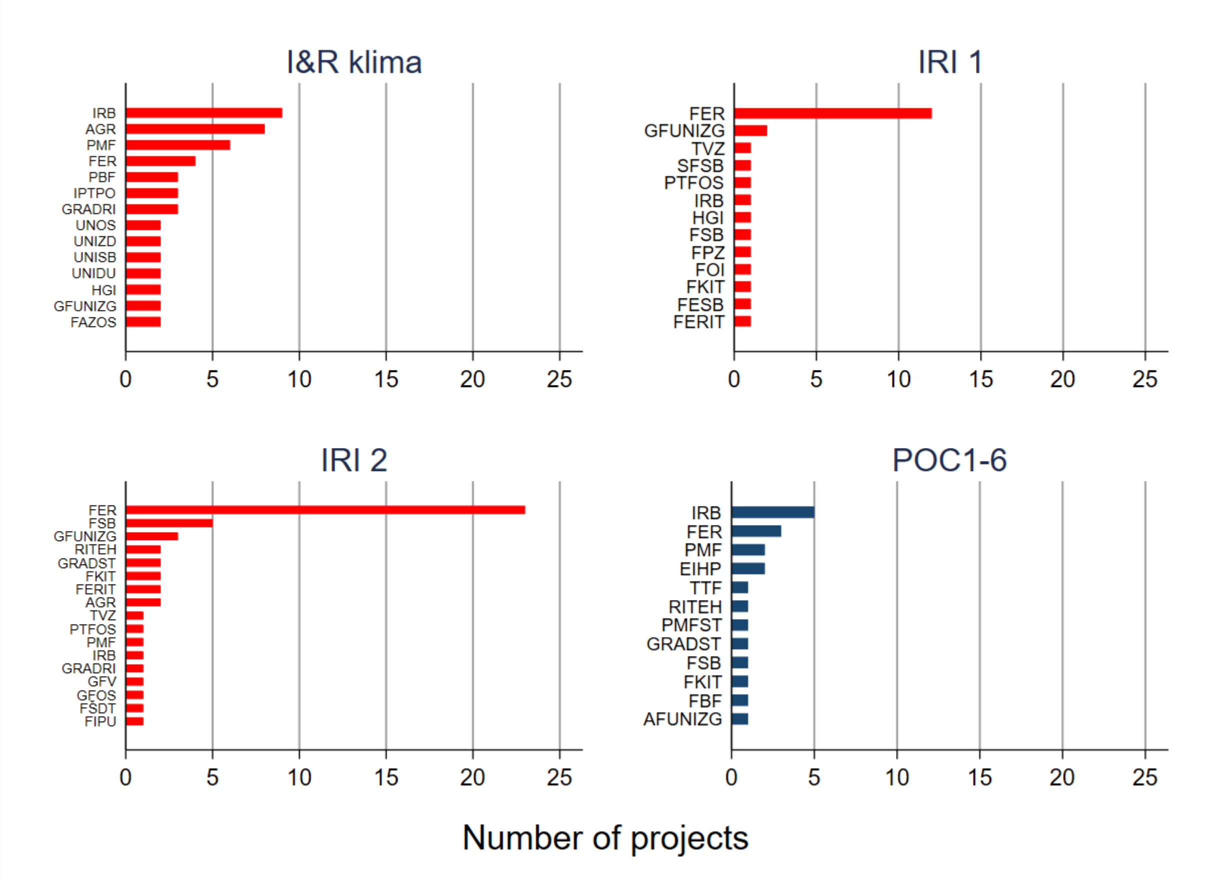
[12] Unfortunately, no information was received from MINGOR employees about the planned completion of the projects.

from 2016 to 2023 and the duration of the IRI 2 programme is from 2020 to 2023. The aid intensity for IRI 1 projects ranges from 25.4% to 77.4%. For IRI 2 projects, the aid intensity ranges from 29.5% to 78%. Within the IRI 1 programme, research institutions take part in 25 projects, whereas within the IRI 2 programme, research institutions take part in 51 projects. Through these programmes, the institutions develop new products in the scope of one or more selected RDI topics within the priority thematic and sub-thematic areas of S3. The programme is aimed at strengthening the capacities for research, development and innovation and improving cooperation with other research institutions. Two scenarios are possible with these projects – either only private firms participate in them, or research institutions and private firms participate in the projects together. Given that this report focuses on research institutions, only IRI projects with research institutions participating in them are considered below. In both phases of IRI programme, FER, GFUNIZG and FSB lead in terms of number of projects and absorption of funds (Figure 2.3 and Figure 2.4). Over 100 researchers are involved in the IRI 1 projects, whereas over 300 researchers are currently involved in IRI 2 projects.

The **Proof of Concept (PoC)** projects were under the authority of HAMAG-BICRO, and the data presented here refers to programmes from the first six project cycles (2010–2016) in these programmes, the PoC 1-6, aimed at research institutions (**PoC Public**). In terms of fund absorption (Figure 2.3 and Figure 2.4) two lead institutions are IRB (total value HRK 1.6 million) and FER (total value HRK 1.1 million) million). In total, 69 projects in which Croatian researchers participate in six project cycles were financed. It is estimated that over 70 researchers participated in these projects.[13]

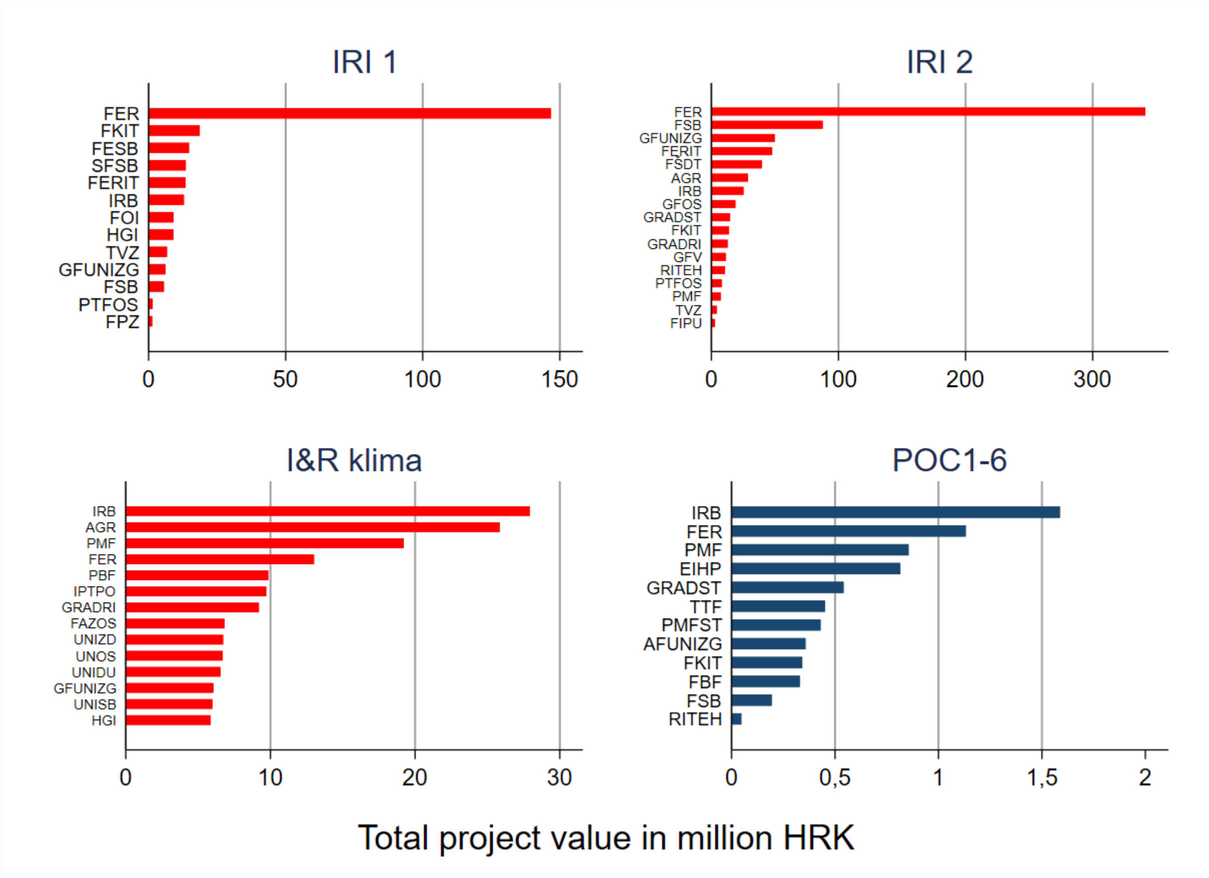
[13] The applications contain information about the applicant, but no information about the project teams. It is likely that these are individual projects, but we should not ignore the possibility that there were projects where teams were involved.

Figure 2.3 Number of R&D Climate, IRI 1, IRI 2, and PoC projects by institution



Note: For R&D projects, the following institutions have one project each: PFRI, MEDRI, IMP, RGN, TTF, FBF, FSB, UNIPU, IV, RITEH, KRS, IF, EFOS, FŠDT, GEOF, GRADST. These institutions were not shown due to presentation limitations. Columns in blue indicate completed programmes; red columns indicate active programmes.

Figure 2.4 Total value of awarded R&D Climate, IRI 1, IRI 2, and PoC projects by institution



Note: In the case of the R&D Climate programme, the following institutions have smaller financing compared to the above: PFRI, MEDRI, IMP, RGN, TTF, FBF, FSB, UNIPU, IV, RITEH, KRS, IF, EFOS, FŠDT, GEOF, GRADST. These institutions were not shown due to presentation limitations. Columns in blue indicate completed programmes; red columns indicate active programmes. The measurement scale on the abscissa is different for all programmes.

2.2.2 S3 Policy additional instruments contributing to the goals of the Smart specialisation strategy

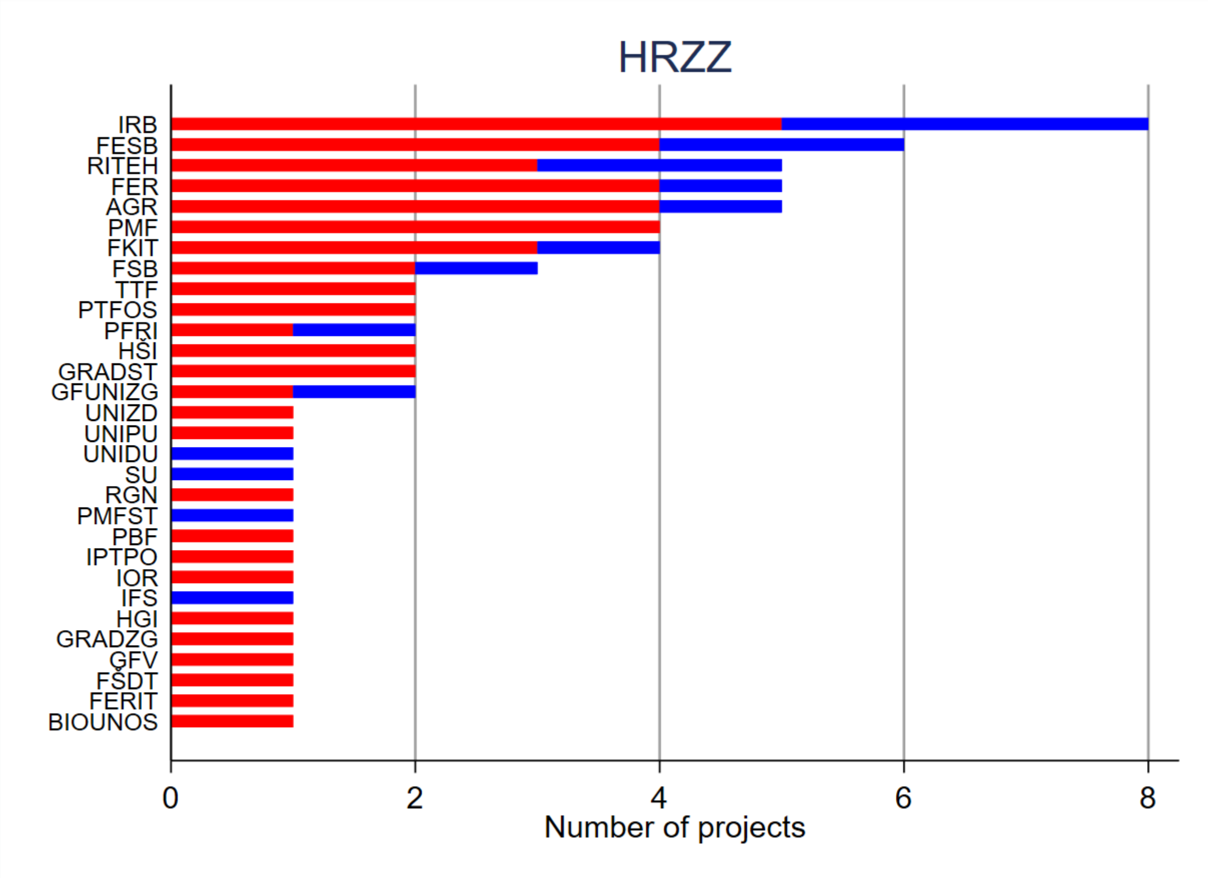
As in the previous section, this section analyses the projects at the *Energy and sustainable environment* TPA level. This group of policy instruments includes programmes that are not directly connected to a specific TPA. Programmes in this group are considered to contribute to the Smart Specialisation Strategy. However, not all projects in which Croatian research institutions under the Croatian Science Foundation participated were considered, only those that address the issue of energy and environmental protection. By including this group of projects, as well as projects financed by EU programmes (section 2.3 of the report), we can reach those researchers and groups of researchers who address the topics of energy and environmental protection in their work but who, due to the particularities of the S3 strategy, are not a part of *S3 Policy Delivery Instruments* related to analysed TPA.

HRZZ employees have selected the projects in this section based on information about the projects in the *Energy and sustainable environment* area. In addition, a survey questionnaire[14] was used to obtain information on the additional participation of researchers in these programme schemes. Finally, the information about HRZZ projects obtained through the survey questionnaire was added to the information obtained from HRZZ employees.

HRZZ projects refer to research and installation projects of the **Croatian Science Foundation**. The analysed projects were implemented from January 1st 2011 to June 30th 2021. Both completed and ongoing projects were considered. Research projects are used to finance fundamental research in a specific area that generates new knowledge and improves existing knowledge and that is aimed at facilitating a better understanding of the research subject matter. They are also used to finance applied research carried out with clear technological, economic or societal goals. In terms of the number and the total value of HRZZ projects related to the topics of energy and environmental protection (Figure 2.5 and Figure 2.6), IRB is in the lead with 8 projects, followed by FESB with 6 projects, then RITEH, FER and AGR with 5 projects each. It is estimated that over 300 researchers were engaged in the implementation of these projects. As for the total value of the projects in the analysed period, the order is somewhat different. IRB is in the lead with a total project value of HRK 8.8 million, followed by FER (HRK 7.7 million) and AGR (HRK 7.25 million).

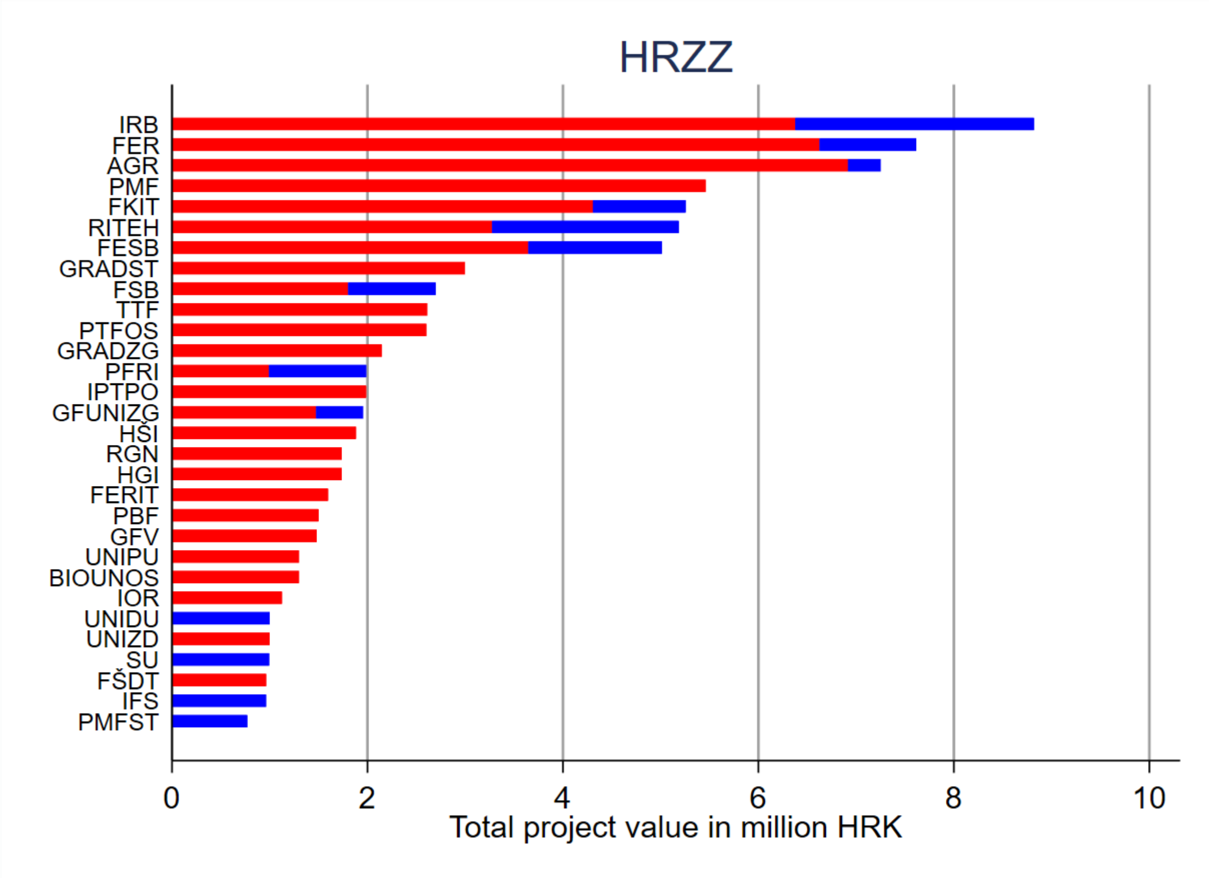
[14] The results of the survey questionnaire are presented in the third report section.

Figure 2.5 Number of HRZZ projects implemented by institution, 2011–2021



Note: Columns in blue indicate completed projects; red columns indicate active projects.

Figure 2.6 Total value of awarded HRZZ projects by institution, 2011–2021



Note: Columns in blue indicate completed programmes; red columns indicate active programmes.

2.3 An overview of the participation of Croatian researchers in selected EU programmes related to the topics of energy and environmental protection

This section provides information on the participation of Croatian researchers connected to the topic of energy and environmental protection in European programmes. Much like with the HRZZ projects, these projects involve researchers who are part of the STPAs, but also involve research groups who work within this topic but who are not registered in the projects of a part of the S3 delivery programmes, meaning their projects do not belong to any of the S3 thematic areas. Furthermore, this section also lists two other EU programmes: COST and EIT. However, it should be noted that there are other forms of EU programmes established by the European Commission that are not the subject of this report, such as ERASMUS, INTERREG etc, just as there are programmes by UNESCO as well as different bilateral projects (e.g., between Croatia and Hungary).[15] The selection criteria for the programmes were financing, the number of participants, the number of projects in each programme, networking with other research institutions, as well as the inclusion of participants from different sectors.

As for the selection of projects in this report section, it was carried out in the same way as with the HRZZ projects. Information on projects from the FP7 and H2020 areas that can be linked to the topic

[15] The other programmes are listed below Table 3.2 in this report.

of energy and environmental protection was requested and provided by MZO. Only the programmes considered to be related to the topics of energy and environmental protection in the context of this report were analysed. For FP7, projects in the environment and nanomaterials subprogrammes were analysed. For H2020, projects covering energy, environment and other projects were analysed.[16] The period covered by analysis is identical to the periods in the previous sections of this report. In addition, a survey questionnaire was used to collect information about the participation of researchers in these programmes. Finally, the information about projects within the EU programmes was added to the information obtained from MZO employees.[17]

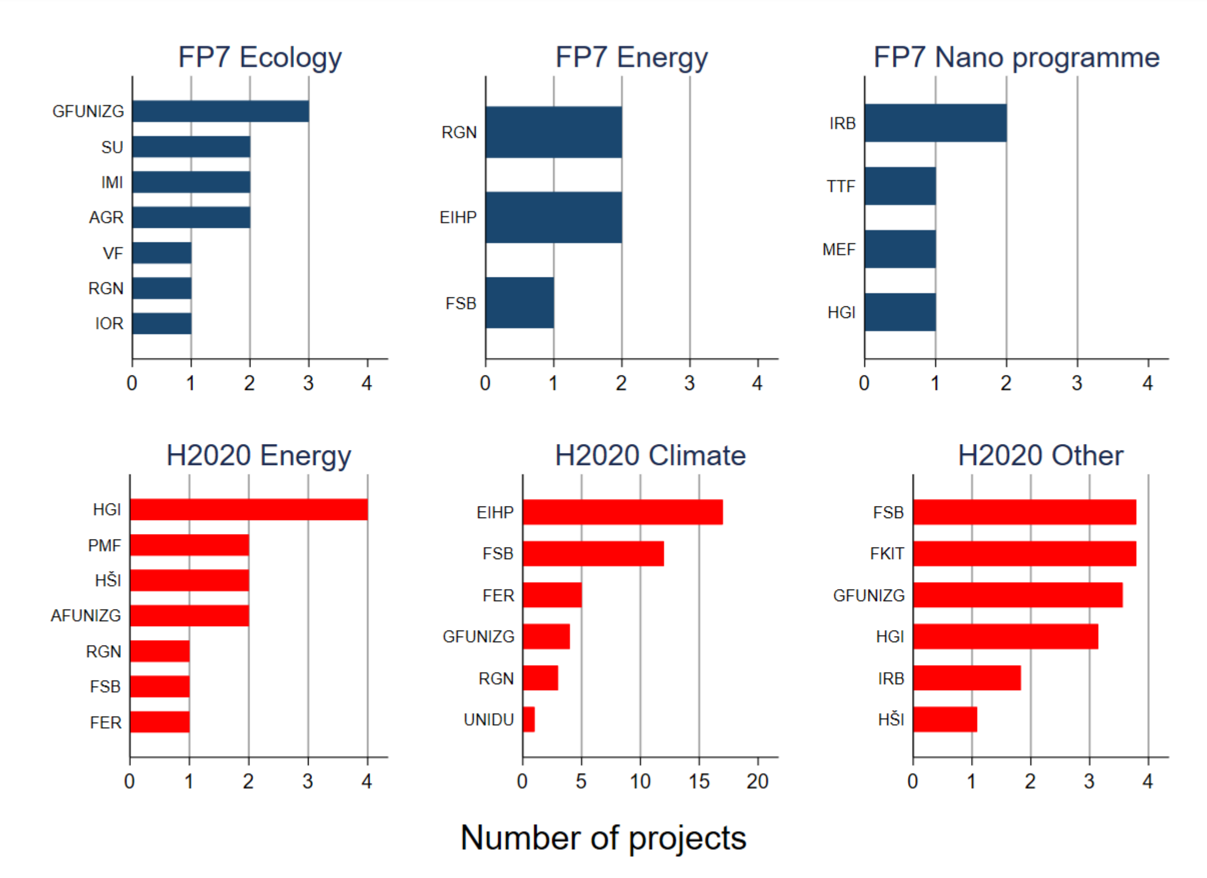
Seventh Framework Programme (FP7) was the EU's main instrument for financing research and development. The 7th framework programme lasted for seven years, from the beginning of 2007 to the end of 2013. The programme was aimed at organising cooperation between universities, research centres and the industry and providing financial aid for their joint projects. With the FP7 programme and similar programmes (H2020), in many cases the projects resulted in the development of new technologies, innovations or other original applicable results. Out of the FP7 programmes related to the topic of energy and environmental protection, SU and GFUNIZG had three projects each, while RGN, AGR, FER, EIHP and IMI had two projects each (Figure 2.7).

Regarding the participation of research institutions in the **Horizon 2020 (H2020)** programme, which is the successor of FP7, EIHP, FSB, FER and HGI lead in terms of the number of projects (Figure 2.7). The results can be interpreted through a change in the focus of the programmes, where interdisciplinary topics are very prominent, and these also feature societal challenges such as the climate.

[16] 'H2020 other' in Figure 2.7 refers to projects the surveyed researchers stated they participated in, where these projects can be connected either to the topic of energy or the topic of environmental protection.

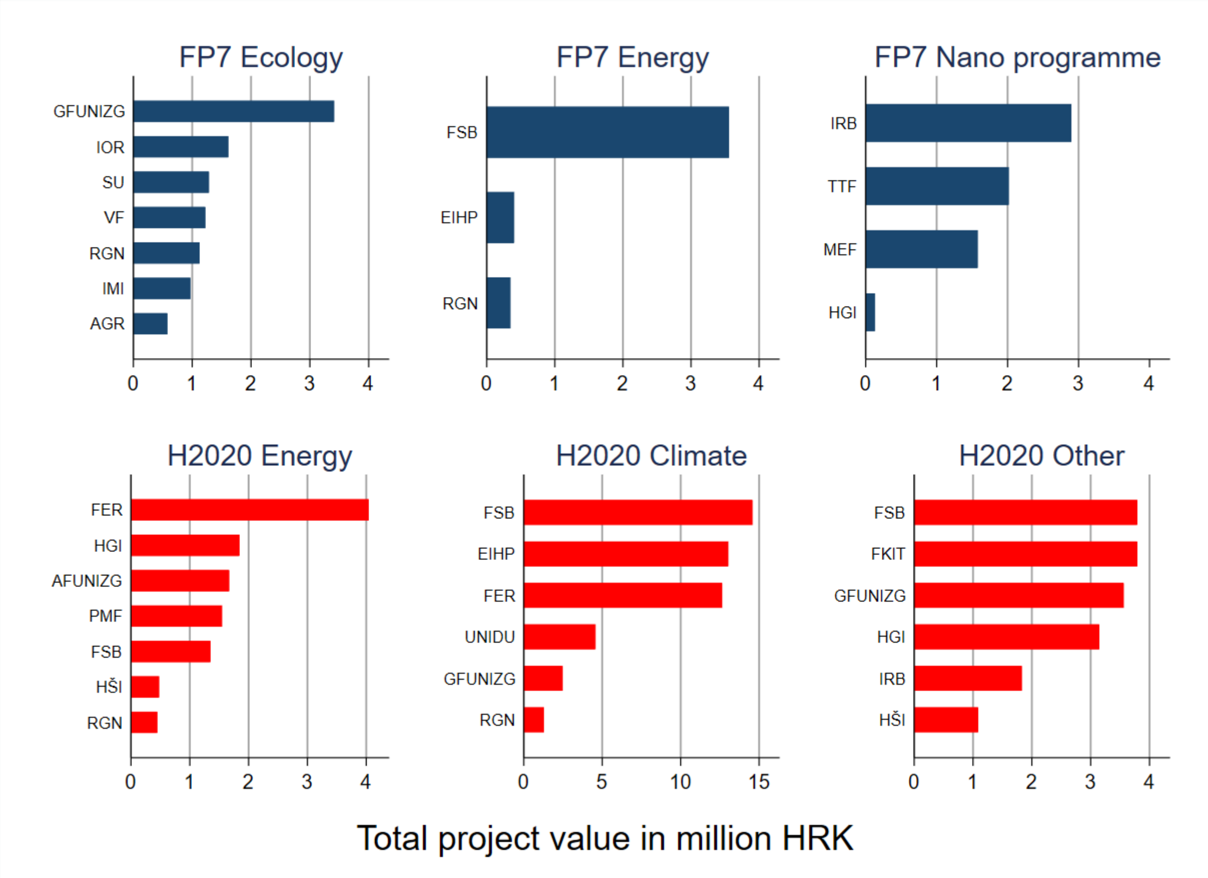
[17] Unfortunately, information on the financial value of the projects for the Croatian participants and information on teams was not collected for all the projects in the FP7 and H2020 programmes, so only the number of projects and their duration are shown.

Figure 2.7 Number of FP7 and H2020 projects by institution



Note: Columns in blue indicate completed programmes; red columns indicate active programmes. ‘H2020 other’ refers to researchers who have registered themselves as belonging to one TPA and the projects can be linked to the topics of the report analysis. The ‘FP7 Nano programme’ was considered because it is often associated with the materials that are part of this TPA. *The measurement scale on the abscissa for the ‘H2020 Climate‘ projects is different compared to the other programmes*.

Figure 2.8 Total value of awarded FP7 and H2020 projects by institution



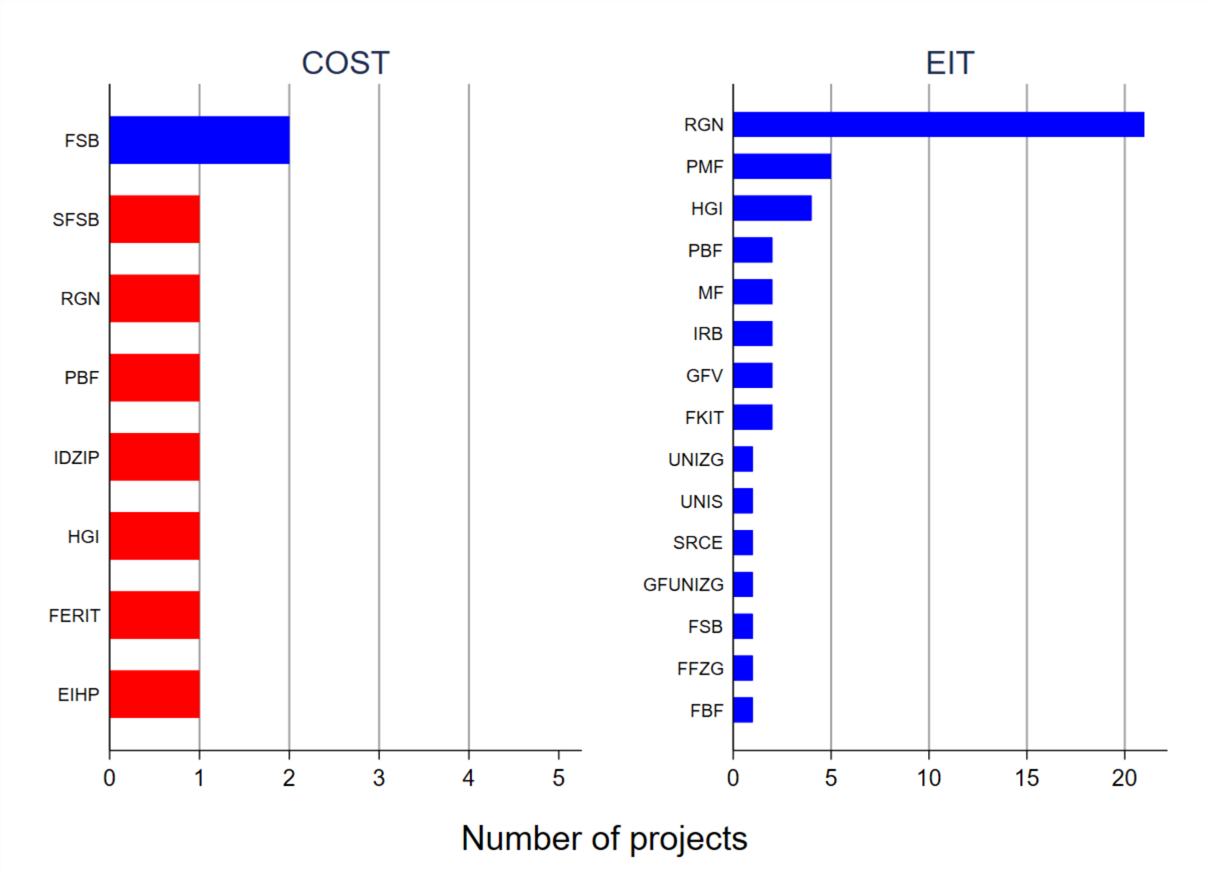
Note: Columns in blue indicate completed programmes; red columns indicate active programmes. 'H2020 other' refers to researchers who have registered themselves as belonging to one TPA and the projects can be linked to the topics of the report analysis. The 'FP7 Nano programme' was considered because it is often associated with the materials that are part of this TPA. *The measurement scale on the abscissa for the 'H2020 Climate' projects is different compared to the other programmes*.

European Cooperation in Science and Technology (COST) is the oldest European programme established in 1971. The programme promotes collaboration among researchers, development of new ideas and initiatives, and establishment of networks between researchers, but also non-governmental organisations and SMEs. In Croatia, the coordination of these programs is carried out by the MZO. The mission of the COST programme is to provide networking opportunities for researchers and innovators with the aim of strengthening the European perspective for solving scientific, technological and societal challenges. In terms of the number of COST programmes from the Energy and sustainable environment TPA, FSB leads with 2 such projects, while 4 other institutions have one each (Figure 2.9). Four projects are active and two have ended.

The role of **European Institute of Innovation and Technology (EIT)** programme is to strengthen Europe's ability to innovate by driving solutions to pressing global challenges and by supporting entrepreneurial talent for the creation of sustainable growth and qualified employment in Europe. The EIT is an EU body that is an integral part of Horizon 2020, the EU's umbrella program for research and innovation. The EIT supports the development of dynamic pan-European partnerships – the EIT's

Knowledge and Innovation Communities – between leading companies, research laboratories and universities. EIT is a complex programme covering several topics,[18]some of which are covered by the **EIT RawMaterials** programme. The results for the EIT RawMaterials are presented below. The goals of *EIT Raw Materials* programme are ensuring sustainable competitiveness of the European mineral, metal and materials sector along the whole of the value chain by encouraging innovation, education and entrepreneurship. In Croatia, a significant number of research institutions take part in the *EIT Raw Materials* programme, compared to other EIT programmes where researchers covered by the analysis reported much smaller numbers of projects[19] or no participation at all. Among these projects, RGN is in the lead with over 20 EIT projects, followed by PMF and HGI with 5 and 4 projects, respectively (Figure 2.9).

Figure 2.9 Number of COST and EIT (RawMaterials) projects by institution



Note: Columns in blue indicate completed programmes; red columns indicate active programmes.

[18] The programmes within the EIT: EIT Climate KIC Croatia Hub, Hub Croatia by InnoEnergy, EIT Raw Materials, EIT Manufacturing Hub, and EIT Health Hub Croatia. The role of the research sector is different in every programme; for example, in EIT Raw Materials, the research sector plays an active role, while in Hub Croatia by InnoEnergy it plays no part. For this reason, the subject of interest of this report section is the EIT Raw Materials.

[19] In the EIT Climate KIC Croatia Hub, two projects in which researchers from AGR took part were reported.

2.4 Analysis of patents related to the Energy and sustainable environment TPA and their relationship with specific industries

As was pointed out earlier, the analysis of patents in this report section was carried out using the International Patent Classification (IPC). Even though the subject of interest here are the activities of researchers from January 1st 2011 to June 30th 2021, in this report section patents are analysed over a period of 20 years. This is because patents are usually analysed over a period of twenty years or longer. In patent analysis, it is important to keep track of the changing technology categories the granted patents fall into and of the determinants causing those changes.

In accordance with the IPC, patents are classified into the following sections: A: *Human Necessities*; B: *Performing Operations*; *Transporting*; C: *Chemistry*; *Metallurgy*; D: *Textiles*; *Paper*; E: *Fixed Constructions*; F: *Mechanical Engineering*; *Lighting*; *Heating*; *Weapons*; *Blasting*; G: *Physics*; and H: *Electricity*.

These sections were used to identify the patent sections relevant to the *Energy and sustainable environment* TPA. This report section assumes that the patents covered by sections F: *Mechanical Engineering*; *Lighting*; *Heating*; *Weapons*; *Blasting*, and H: *Electricity* are related to the *Energy and sustainable environment* TPA. It is possible that the real scope of patents is even larger and that it includes patents from sections C and G. However, no clearly defined mechanism exists which could have been used to isolate the patents related to the socio-economic activities within the *energy and environmental protection* topic from the patents related to other economic activities that may or may not be part of other S3 TPAs in Croatia (see section 1.1 of the report).

When analysing the significance of sections F and H, all classes of section H were included, but the section F classes related to weapons and ammunition (F41, F42, F99Z) were excluded. The combined share of granted patents covered by sections F and H that can be linked to the *Energy and sustainable environment* TPA for the period from 2001 to 2021 is 7.44%. The share of consensual patents[20] for the same classes and the same period is 17.44%. With 239 granted patents, natural persons protected considerably more of their inventions than legal persons (118) in the analysed period. In section F, the following classes cover the most patents: F16 *Engineering elements or units*; *general measures for producing and maintaining effective functioning of machines or installations; thermal insulation in general* (29), F02 *Combustion engines; hot-gas or combustion-product engine plants* (8), F24 *Heating; ranges; ventilating* (7), and F03 *Machines and engines for liquids; wind, spring or weight motors; producing mechanical power or a reactive propulsive thrust, not otherwise provided for* (4). The number of consensual patents is slightly higher compared to patent applications—37 consensual patents in subclass F24, 24 consensual patents in subclass F03, 23 consensual patents in subclass F16, and 9 consensual patents in subclass F02. For section H, class H02 *Generation, conversion, or distribution of electric power* takes first place, with eight granted patents and 47 consensual patents from 2001 to 2021. Other section H classes and subclasses cover significantly smaller numbers of patents. To illustrate, in subclass H04B *Transmission* there are four granted patents, and in subclasses H01R *Electrically-conductive connections; structural associations of a plurality of mutually-insulated electrical connecting elements; coupling devices; current collectors* and H01H *Electric switches; relays; selectors; emergency protective devices* there are three granted patents in each.

[20] These are patents that are granted without substantive examination, i.e., based on an agreement (consensus) of the public. A consensual patent can last for a maximum of 10 years. The process of protecting an invention by consensual patent is faster and cheaper than the process of obtaining a classical patent.

In economic analyses, when added values are presented, the values of sub-sectors of individual industries within the entire industry sector are analysed. For the previous patent analysis, the analysis of technology categories was used, which is why it is not possible to directly translate the values of technology categories into the values of the industrial sub-sectors. Therefore, it is necessary to use concordance, an instrument which enables us to compare the number of patents in technology categories and the concentration of patents in industrial sub-sectors. To compare the IPC values and the statistical classification of economic activities (NACE) values, the NACE Rev.2 was used, a concordance developed for Eurostat. Currently, two versions of NACE Rev.2 concordance (EUROSTAT, 2015) exist, and the second one was used to create this report (Annex 7). With this concordance, the number of patents classified using the IPC was directly transferred into the number of patents in specific industries which have been classified into one of the 65 NACE Rev.2 divisions. Out of a total of 1475 patents granted from 2001 to 2021, 820 of them (55.59%) could be classified in one of the 65 industry categories classified in NACE Rev.2 groups with three digits. The concordance helped identify the industries which correspond to the patents granted in the classes and subclasses of sections F and H. Patents were identified for some of the industries, while for some industries there were no identified patents; to illustrate: *Manufacture of consumer electronics* (39) and *Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus* (44). Overall, patents are present in a little over half of the industries, 33, as opposed to 32 industries where no patent values are present in the specified period. As for the patent granting dynamics, a decline can be noticed in the period from 2010 to 2019 when compared to the period from 2001 to 2009—patents have over 50% less value than the patents in the period from 2010 to 2019 for all lines except line 27.3 (*Manufacture of wiring and wiring devices*).

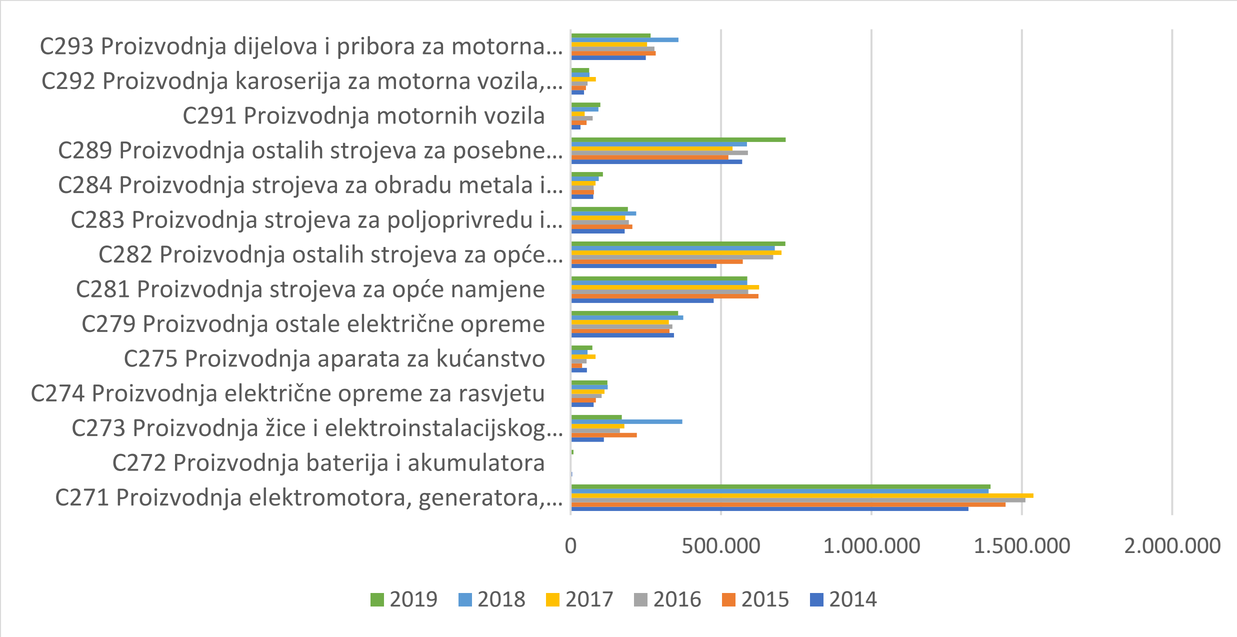
Table 2.1 Number of patents in industries related to the Energy and sustainable environment thematic area

NACE Rev.2 codes	NACE Rev.2 categories related to IPC classes and subclasses in sections F and H	Number of patents granted from 2001 to 2009	Number of patents granted from 2010 to 2019
28.2	Manufacture of other general-purpose machinery	18	13
27.3	Manufacture of wiring and wiring devices	6	7
28.1	Manufacture of general-purpose machinery	9	0
29.1	Manufacture of motor vehicles	2	1
27.2	Manufacture of batteries and accumulators	1	0
27.4	Manufacture of electric lighting equipment	1	0

Source: DZIV data used.

When the data in Table 2.1 is compared with the data in Figure 2.10, which shows the added value amounts in thousands of HRK for the industries *Manufacture of electrical equipment, Manufacture of machinery and equipment*, and *Manufacture of motor vehicles, trailers and semi-trailers* analysed using NACE Rev.2, we can see that the highest concentration of patents from the previous table can be found in the industries that are in the third (28.2), seventh (27.3), and fourth (28.1) place based on their added value expressed in thousands HRK in 2019.

Figure 2.10 Added value (in HRK thousands) of selected industries for the period from 2014 to 2019



Source: DZS data used.

3. Researcher and research group excellence analysis

3.1 About the survey

A survey was used to collect data on scientific productivity and capacities in the **Energy and sustainable environment** TPA defined in the Smart Specialisation Strategy of the Republic of Croatia. The **aim of the analysis** was to determine what part of the analysed area holds the greatest concentration of research and innovation excellence of the researchers and research groups. The analysis should present the performance, capacities and potentials of this TPA.

To collect primary data that would provide insight into the state of the Energy and sustainable environment TPA, a **questionnaire** was created based on a literature review and discussions with experts. The questionnaire included questions concerning basic information about the researchers, published scientific papers in the WoS and Scopus databases, competitive science and research projects, financing sources, projects with the economy, collaboration on projects, innovation activities, protection of industrial property rights, commercialisation of research results, research infrastructure and knowledge dissemination. The data covers the period from 01.01.2011 to 30.06.2021. The questionnaire is attached to this study (*Annex 1*).

The **pilot research** was conducted in August and September of 2021 on a sample of five researchers (*Annex 2*). The aim of the pilot research was to collect comments from the researchers and to discuss the structure and the comprehensibility of the questions in the questionnaire. Both experts and MZO commented on the questionnaire. Their comments were accepted built into the improved questionnaire.

For the next phase, an agency was hired—**IPSOS**, a global agency for market research and public opinion polling,[21] chosen for their experience and expertise. The role of the agency was to create an online version of the questionnaire with a user-friendly interface and easy to fill out. The online questionnaire was sent to the researchers from the sample in the analysed thematic area. The initial data collection lasted from October 7th to November 21st, 2021. To increase the response rate, two reminders were sent, and the data collection time was extended. In November 2021, a professional interviewer was hired to contact the researchers who did not respond to the questionnaire by phone and remind them to complete it, which increased the response rate significantly.

A total of 510 researchers who are potentially active in the analysed TPA were identified and were sent the questionnaire. Out of those, 253 researchers (49.6%) filled out the questionnaire and stated they were active in the analysed TPA, whereas 257 (50.4%) of the researchers never answered the questionnaire. Out of the researchers who never answered the questionnaire, 12.1% have up to 5 years work experience, 12.1% have between 5 and 10 years work experience, 44.0% have between 10 and 20 years work experience, and 31.9% have between 21 and 50 years work experience. The average length of service of the researchers who never answered the questionnaire is 16.5 years (researchers in sample 13.2 years), their average total number of WoS papers regardless of field is 33.3 (researchers in sample 20.3), and the number of their WoS citations is 558.7 (researchers in sample 462.2). Nine of the researchers who never answered the questionnaire have over 100 WoS papers. When we consider

[21] https://www.ipsos.com/hr-hr

this data, our sample is somewhat underestimated. However, if we consider the possibility that some of the researchers who never answered the questionnaire do not belong to this TPA,[22] the collected sample may be considered satisfactory for further analysis and conclusion.

To identify the areas with significant research capacities, a **comparison** was made between:

- two sub-thematic priority areas (STPAs) defined within S3: 1) Energy technologies, systems and equipment (STPA 1), and 2) Environmentally friendly technologies, equipment and advanced materials (STPA 2);
- public scientific organisations (n=39) and the counties they operate in;
- FOS1 and FOS2 areas (OECD, 2007); and
- group of researchers by scientific activity.

For this chapter, the data source is the questionnaire. The data in the questionnaire was **analysed** using descriptive statistics, frequency distribution analysis, mean values, ANOVA (analysis of variance), factor analysis, and cluster analysis. If statistically relevant differences between the analysed groups of researchers and the indicators have been identified, this is stated in the text.

This kind of analysis was carried out for the first time in the Energy and sustainable environment TPA. It should be borne in mind that, if specific STPAs or groups of researchers are analysed, these produce smaller samples, which makes the analysis more difficult and reduces the statistical significance of some of the indicators. Given that there are big differences between the researchers, the standard deviation is significant. **Nevertheless, the results are indicative and may be used to analyse the state of the Energy and sustainable environment TPA.**

Following an introduction to the survey, basic information about the sample is given. Next is the analysis of the results about researchers in relation to the number of published scientific papers, projects and collaboration on projects. This is followed by an analysis of innovation activities and commercialisation and an overview of research infrastructure and knowledge dissemination. This chapter closes with an analysis of the performance of the groups of researchers.

3.2 Basic information about the sample

253 researchers filled out the questionnaire. Out of those, 185 have stated that their research is related primarily to the Energy and sustainable environment TPA, whereas 68 researchers stated that they mainly work in research in other areas, which are not necessarily part of S3.[23] In keeping with the task of this research, the subject of analysis here were the **185 researchers** whose research work is related primarily to STPA1 (119 researchers) and STPA2 (66 researchers). This is the **final sample** and all the results in this report section refer to those researchers and their public scientific organisations.

[22] During the survey, a fairly large number of researchers stated that they do not belong to the TPA being analysed, so they chose not to fill out the questionnaire.
[23] This research may be a part of some other S3 area or it may belong to a cross-cutting theme such as, for example, robotics, key enabling technologies (KET), or information and communications technologies (ICT).

In the final sample, 66 researchers (35.7%) belong to STPA1 and 119 researchers (64.3%) belong to STPA2. The sample is dominated by men (62.7%), with only 37.3% researchers being women. Both areas feature more men than women, especially STPA1, and these differences are statistically relevant.

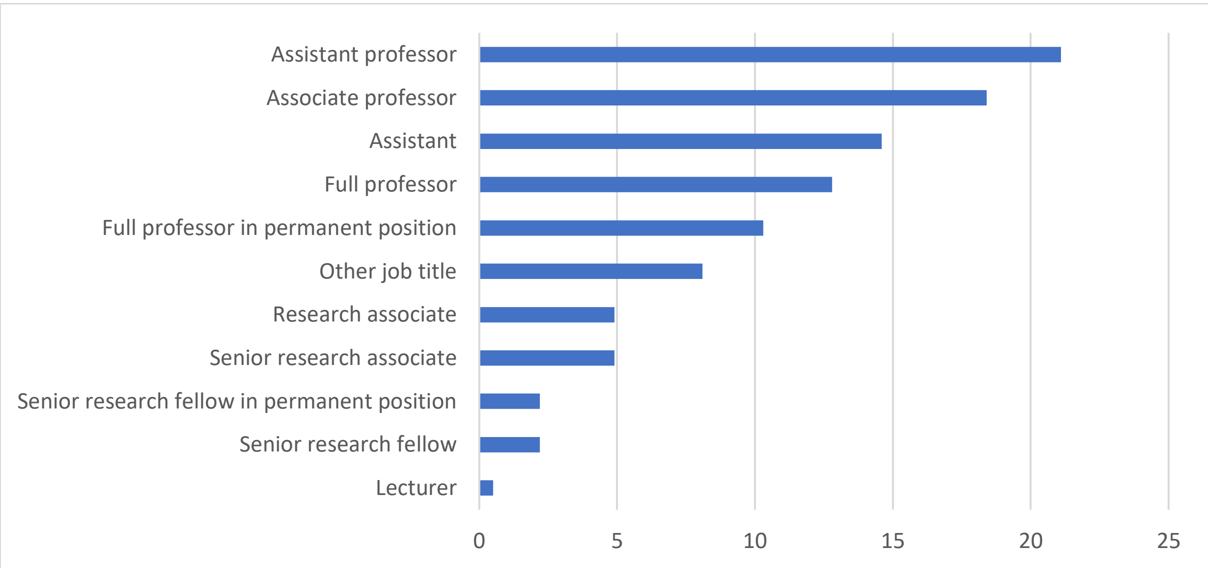
Regarding the type of employment contract, researchers with indefinite-duration employment contracts are dominant (76.8%), with only 23.2% of researchers having fixed-term employment contracts. A similar structure can be observed in both areas and the differences are not statistically relevant.

All categories of researchers according to job title classification are present in the sample, from teaching assistants to assistant professors and full professors in permanent position, both in faculties and in institutions, considering the equivalent of scientific rank and job title. There are 15.1% researchers with lower scientific rank and job title (teaching assistants and lecturers), assistant professors and research associates make up 25.9% of the sample, associate professors and senior research associates make up 23.4% of the sample, while senior research associates, full professors and full professors in permanent positions make up 27.6% of the sample (Figure 3.1). Other job titles are also present, such as researchers on a project, expert associates, or heads of centres. The differences between STPA1 and STPA2 are not statistically relevant.

On average, the researchers have 13.2 years of experience in research within the thematic area. Researchers in the STPA1 have slightly more experience compared to researchers in the STPA2 (14.6 years in STPA1 compared to 12.5 years in STPA2). These differences are statistically relevant.

On average, the researchers spent 40.9% of their time a month on implementation of research within the Energy and sustainable environment TPA—37.5% in STPA1 and 42.7% in STPA2. Although these differences are not statistically relevant, these results indicate that the researchers in STPA1 invest less time into research compared to the researchers in STPA2.

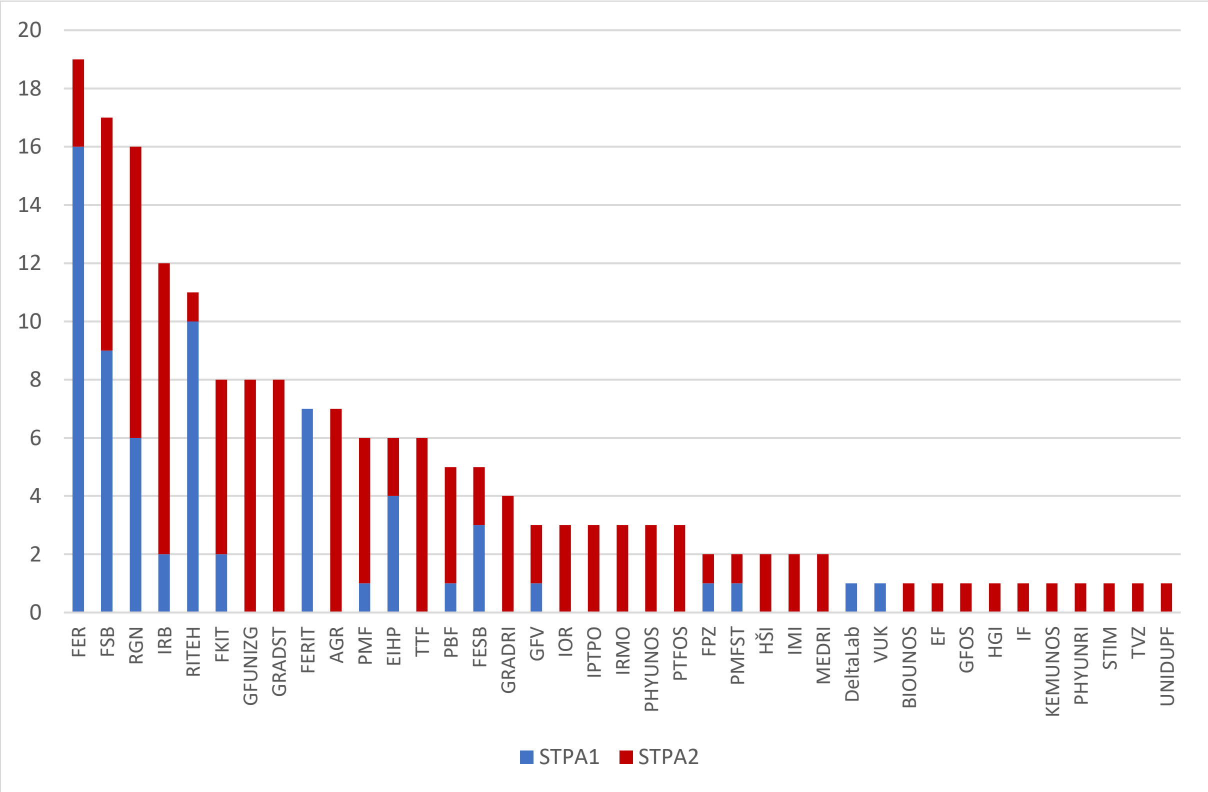
Figure 3.1 Sample structure by job title, in %, n=185



Note: 'Other job title 'refers to a position not related to the job title. This is the position of a researcher on a project, expert associate, or centre head.

The sample structure regarding field and institution is shown in Figure 3.2. Researchers from **39 institutions** participated in the survey. Out of these, 13 institutions have research in both areas. The results show that there is a large concentration of research in the analysed area regarding institutions. **There are 75 researchers who are associated with five institutions, which makes for 40.5% of all surveyed researchers.** Significantly more institutions are involved in STPA2 than in STPA1. In the sample, most researchers in STPA1 come from FER[24] (16), RITEH (10) and FSB (9), whereas the most represented institutions in STPA2 are IRB (10), RGN (10) and FSB (8).

Figure 3.2 Number of researchers by STPA and institution, n=185



The activities of the researchers have also been analysed according to **region** regarding the county in which the institution operates. In the sample, **65.4% of researchers come from the City of Zagreb,** and 9% come from Primorje-Gorski Kotar County, Osijek-Baranja County, and Split-Dalmatia County each. The rest of the researchers come from Varaždin County (2.2%), Istria County (2.2%), Zagreb County (1%), Karlovac County (0.5%), and Dubrovnik-Neretva County (0.5%). A high concentration of researchers can be found in the City of Zagreb. In STPA1 there are 65.2% researchers from the City of

[24] The list of acronyms of all analysed institutions can be found in *Annex 5*.

Zagreb, and in STPA2 there are 65.6% researchers from the City of Zagreb, which makes it evident that there are researchers who consider themselves as belonging to both STPA1 and STPA2.

3.3 Analysis of excellence

3.3.1 Published scientific papers

Published scientific papers are the most important indicator of scientific productivity. In the science and education system of the Republic of Croatia, they are an important criterion for the evaluation and promotion of researchers. That is why university employees are highly motivated to do research and publish scientific papers, which in turn determine the work tasks of the researchers.

The results of the questionnaire show that, over the last ten years, the researchers in the Energy and sustainable environment TPA have published 3,757 papers in the WoS database (20.3 papers per researcher) and 3,856 papers in the Scopus database (20.8 papers per researcher) (Table 3.1). Over the last ten years, the researchers have on average published two papers a year in the WoS database. On average, more papers were published in the WoS database in STPA2 than in STPA1, and the differences are statistically relevant. It should be noted that some papers are indexed in both the WoS and the Scopus database, so the comparison of the number of papers in these two databases should be interpreted with caution.

Citation of papers is an important indicator of the quality of a scientific paper and the international recognition of the paper (Abbott et al., 2004). A great number of citations means that the journal in which the scientific paper is published is often cited, making it more recognizable in the scientific community (Abbott et al., 2004). According to this indicator, the number of citations is greater in STPA2 than in STPA1 both in total and on average per researcher. If we look at the sum of the number of papers and citations in the WoS database—an indicator that represents the contribution of researchers (Abbott et al., 2004) and the reputation of researchers (Gonzales-Brambila and Veloso, 2007)—we can see that greater average values were recorded in STPA2 compared to STPA1.

Table 3.1 Published scientific papers and citation, 2011–2021

Published papers	STPA1 (n=66)	STPA2 (n=119)	Sample (n=185)
Number of published scientific papers in the thematic area			
Total number of papers in the WoS database*	1,200	2,557	3,757
Average number of published papers in the WoS database*	18.2	21.5	20.3
Total number of published papers in the SCOPUS database	1,358	2,498	3,856
Average number of published papers in the SCOPUS database	20.6	20.9	20.8
Citations and reputation of researchers	STPA1 (n=65)	STPA2 (n=117)	Sample (n=182)
Citations of papers in the WoS database			
Total number of WoS paper citations**	23,974	60,147	84,121
Average number of WoS paper citations**	368.8	514.1	462.2
Reputation of researchers (average per researcher)**	387.2	535.8	482.7

Note: The differences between STPA1 and STPA2 are statistically relevant at the levels of *0.1; **0.05; ***0.01. The reputation of a researcher is calculated as the average of the sum of WoS papers and the number of citations per researcher.

Moreover, the analysis shows **there are significant differences between researchers**. The number of WoS papers in the analysed 10-year period ranges from 0 to 286 per researcher[25] (0–159 in STPA1 and 0–286 in STPA2). The differences in the numbers of published papers in the WoS database between the researchers are smaller in STPA1 than in STPA2. There are 15 researchers in the sample who have never published a scientific paper in the WoS database in this area. These are teaching assistants who have just started their careers. Differences between researchers exist where the number of WoS paper citations is concerned as well. The number of citations ranges from 0 to 6,226 in STPA1 and from 0 to 10,926 in STPA2. There are 11 researchers in the sample who have no paper citations in the WoS database. These are also researchers with lower scientific rank.

An analysis of **Pearson's correlation coefficients** has shown that the researchers who have a great number of papers in the WoS database also have a great number of papers in the Scopus database (the linear correlation coefficient is r=0.958) and a greater number of citations (r=0.818) as well. There is also a positive linear correlation between the number of papers in the WoS database and work experience (r=0.355). Correlations are statistically relevant at the level of 0.01. Citation depends not only on the quality of the journal (papers in the WoS database), but also on the number of papers in the WoS database. As work experience grows, so does the number of citations. Considering it is important for researchers in higher positions to have quality papers with a greater number of citations and for their work to be internationally recognised, it can be expected that their papers will cumulatively generate even more citations in the future (Gonzales-Brambila and Veloso, 2007).

When we look at the number of **scientific papers in the WoS database by institution**, we can see that there is a concentration of the number of scientific papers in a smaller number of institutions. Figure 3.3 shows an overview of published papers in the WoS database by institution. In terms of the total number of WoS papers, FSB and IRB stand out, accounting for 27.9% of all WoS papers in the sample. In terms of the total number of papers, STPA1 is dominated by FSB (51.3 WoS papers per researcher active in STPA1), IRB (57 papers per researcher active in STPA1), and FER (14.8 papers per researcher active in STPA1). Put together, these three institutions account for 67.8% of the total number of papers in the WoS database in STPA1. In STPA2, with regard to the total number of WoS papers, the following institutions stand out: IRB (35.5 papers per researcher active in STPA2), STIM (n=1, one researcher was analysed; 286 papers per researcher active in STPA2), AGR (37.4 papers per researcher active in STPA2), and PBF (63.3 papers per researcher active in STPA2). Put together, these institutions account for 45.3% of the total number of papers in that STPA.

[25] The number of papers also depends on the method of counting and the number of authors of the papers.

Figure 3.3 Number of papers in the WoS database by STPA and institution, 2011–2021, n=185

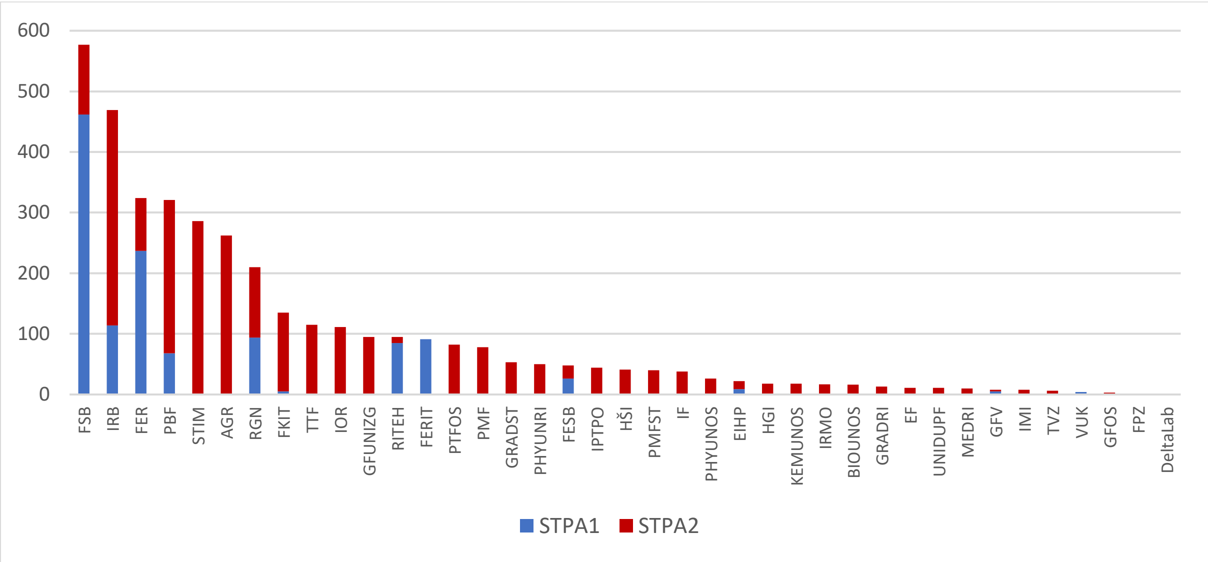
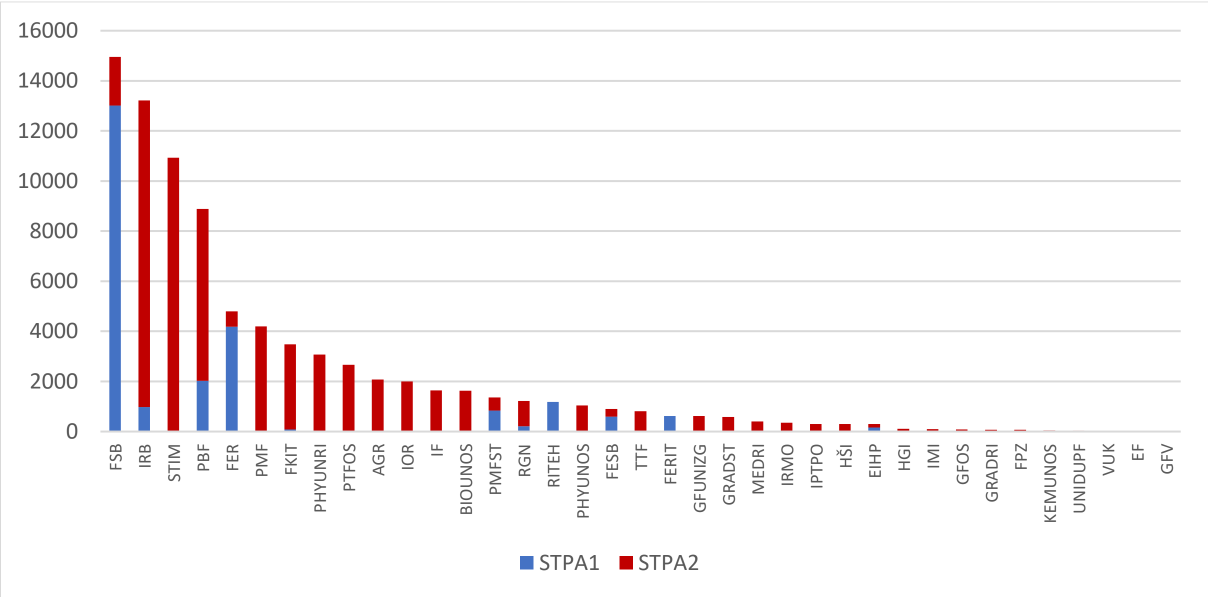


Figure 3.4 shows an overview of **paper citations in the WoS database by institution.** In terms of the total number of WoS citations, FSB, IRB and STIM stand out, accounting for 46.5% of all citations in the analysed TPA. In STPA1, with regard to the number of citations, the following institutions stand out: FSB (1,446 citations per researcher active in STPA2), FER (261 citations per researcher active in STPA1), PBF (2,027 citations per researcher active in STPA1), RITEH (118 citations per researcher active in STPA1), and IRB (491.5 citations per researcher active in STPA1). Put together, these institutions account for 89.2% of citations. In STPA2, the following institutions stand out: IRB (1,223 citations per researcher active in STPA2), STIM (n=1, one researcher was analysed, 10,926 citations), PBF (1,716 citations per researcher active in STPA2), and PMF (836.6 citations per researcher active in STPA2). Put together, these institutions account for 59.9% of citations.

Figure 3.4 Number of paper citations in the WoS database by STPA and institution, 2011–2021, n=185



Regarding published papers in the WoS database, overall, the **greatest number of papers was published by researchers from institutions from the City of Zagreb (2,722)**, followed by Split-Dalmatia County (517), Osijek-Baranja County (239), and Primorsko-Goranska County (165). Per researcher, the greatest number of papers was published in Split-Dalmatia County (28.7) and the City of Zagreb (22.5).

An analysis of papers in the WoS database and citations according to **FOS1 and FOS2 classifications** (OECD, 2007) follows. According to the FOS1 classification, the greatest number of papers in the WoS database belonging to *STPA1* refer to the *Engineering and technology* (1,110) area, whereas for STPA2 the most productive areas are *Natural sciences* (1.141) and *Engineering and technology* (1.103). The number of papers in the WoS database according to the FOS2 classification is shown in Figure 3.5 for *STPA1* and in Figure 3.6 for STPA2.

Figure 3.5 Number of papers in the WoS database according to FOS2 classification, 2011–2021 in STPA1, n=66

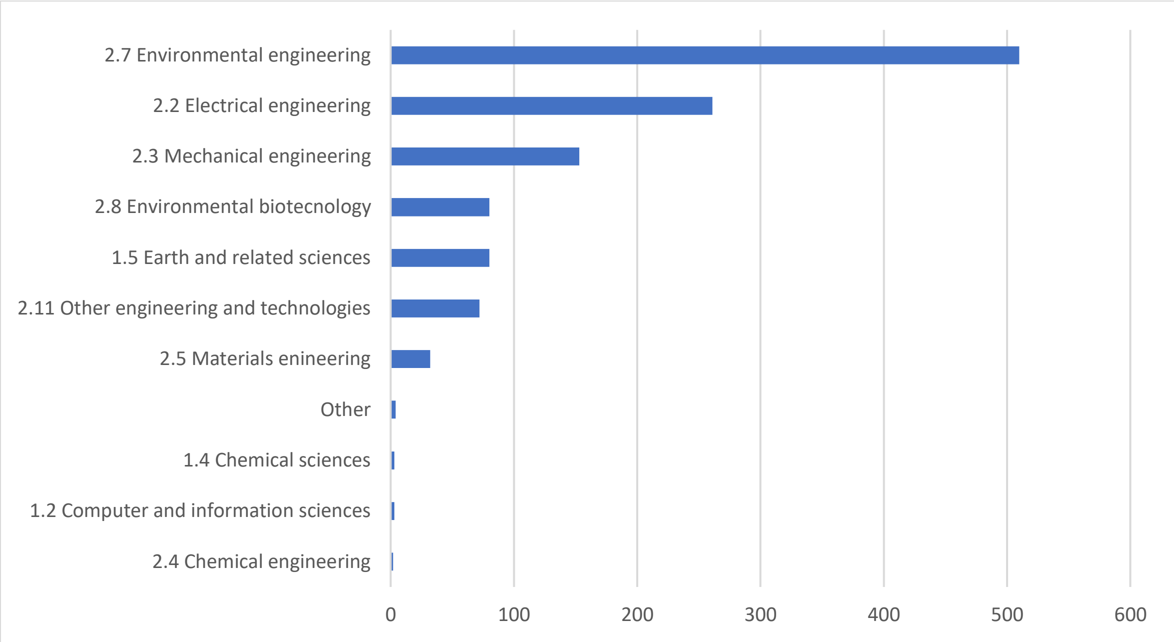
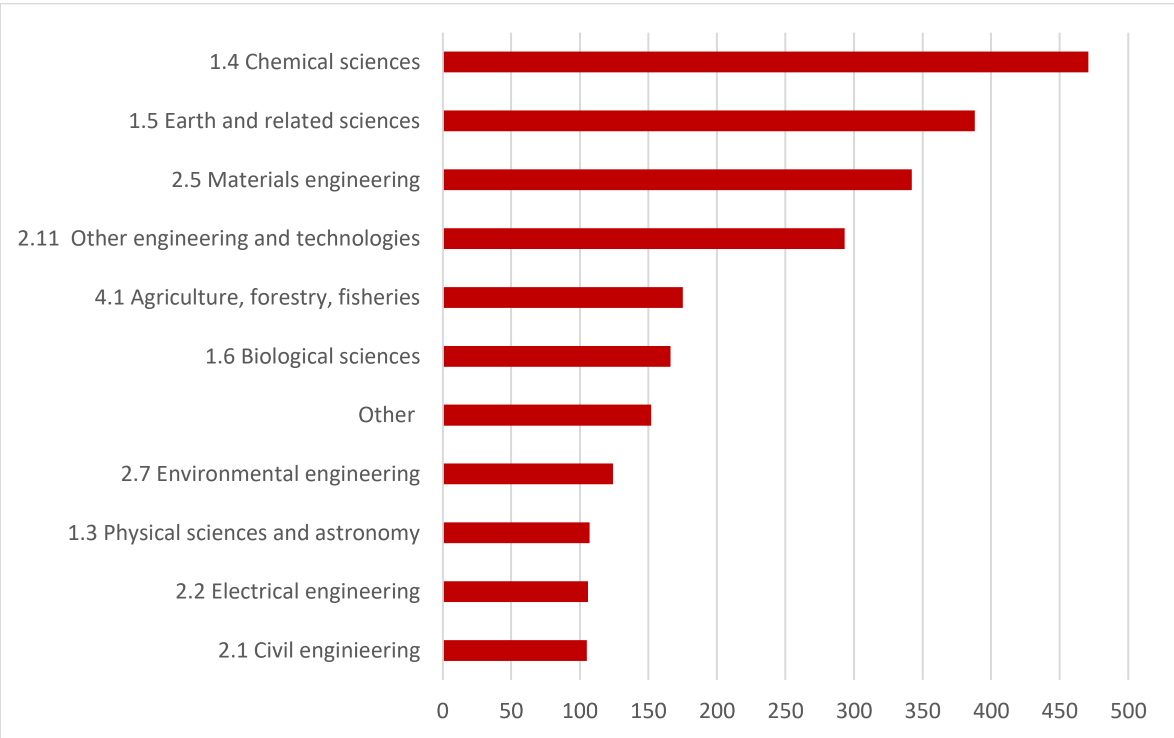


Figure 3.6 Number of papers in the WoS database according to FOS2 classification, 2011–2021 in STPA2, n=119



Note: There are 128 unclassified papers (N/A).

STPA1 has the greatest number of papers in areas 2.7, 2.2, and 2.3, whereas STPA2 has the greatest number of WoS papers in areas 1.4, 1.5, and 2.5. Both areas (STPA1 and STPA2) feature the same areas, but with different intensities (e.g., areas 2.2 *Electrical engineering*, 2.7 *Environmental engineering*, 2.11 *Other engineering and technologies*).

These results are somewhat surprising considering it was expected that *Environmental Engineering* will dominate STPA2 and not STPA1.[26] However, if we look at engineering areas 2.1–2.11, these are dominant in STPA1. We could say that the activities of the researchers in STPA1 are clustered in three FOS2 areas—2.7 *Environmental engineering*, 2.2 *Electrical engineering*, and 2.3 *Mechanical engineering*—where researchers have published over 100 WoS papers. In *STPA2* this scope is more complex and includes parts of natural sciences (1.4 *Chemical sciences*, 1.5 *Earth and related sciences*, 1.6 *Biological sciences*), technical sciences (2.5 *Materials engineering*, 2.11 *Engineering and technologies*, 2.2 *Electrical engineering*, and 2.1 *Civil engineering*) and 4.1 *Agriculture, forestry and fisheries*.

We asked the researchers in the questionnaire to list some **interesting topics for research** related to the Energy and sustainable environment thematic area regarding the possibility of publication in scientific journals in the next 5 to 10 years. Some interesting topics were entered, mostly related to the research of advanced technologies and materials (23 researchers), sustainable materials and sustainable management (16 researchers), circular economy (22 researchers), alternative fuels and energy sources (15 researchers), energy transition (13 researchers), and energy storage (13 researchers). Topics related to digital transformation, digitisation and optimisation (9 researchers), renewable energy sources (9 researchers), and energy efficiency (8 researchers) were also listed. Other topics included artificial intelligence and energy systems management.

3.3.2 Research and development projects

Projects are an important source of financing for the research community. Research grants are competitive science and research projects and represent external financing secured by a research institution or individual researchers. Research grants are often used in literature as an indicator of the market value of specific research that is the result of research work (Abbott et al., 2004). In the questionnaire, the researchers were asked to enter the number of international competitive science and research projects and projects in cooperation with the business sector they were involved in over the last 10 years in the Energy and sustainable environment TPA. Three categories of projects were analysed—completed projects, ongoing projects, and planned projects. For the analysis, it was considered that a researcher could be a leader or a collaborator on a project. Data on amounts and sources of project financing was also collected. Out of the sample of 185 researchers, 146 researchers (78.9%) stated that they had participated in a competitive science and research project as project leader or collaborator, of which 52 were in STPA1 and 94 in STPA2.

In the role of **leader on a competitive science and research project** which has been completed or is ongoing, there were 81 researchers (55.5% of researchers who have participated in a project), of which 25 were in STPA1 and 56 were in STPA2. There were a total of 397 such projects. If we look at the total

[26] One possible explanation is that the researchers decided on a particular *STPA* themselves and so there is some subjectivity in these categories.

number of projects, STPA2 has more science and research projects, but also more researchers who were project leaders (Table 3.2). However, if the number of research projects per leader is analysed, the situation is somewhat different and the differences are statistically relevant. The average number of these projects was 7.4 in STPA1 and 3.8 in STPA2 (p=0.04). **It can be concluded that in *STPA2* there were more science and research projects in total, whereas in *STPA1* there were more science and research projects on average per researcher.**

Table 3.2 Analysed projects by project leader, 2011–2021, n=81

Project leader	STPA1 (n=25)				STPA2 (n=56)			
	Implemented projects	Ongoing projects	Total	By researcher	Implemented projects	Ongoing projects	Total	By researcher
EU grants	16	16	**32**	**1.3**	46	17	**63**	**1.1**
Structural funds	16	32	**48**	**1.9**	13	19	**32**	**0.6**
UKF	0	0	**0**	**0.0**	4	0	**4**	**0.1**
PoC	2	1	**3**	**0.1**	9	0	**9**	**0.2**
IRCRO&RAZUM	0	0	**0**	**0.0**	0	0	**0**	**0.0**
HRZZ	10	13	**23**	**0.9**	20	24	**44**	**0.8**
Other projects	70	9	**79**	**3.2**	44	16	**60**	**1.1**
Total	**114**	**71**	**185**	**7.4**	**136**	**76**	**212**	**3.8**

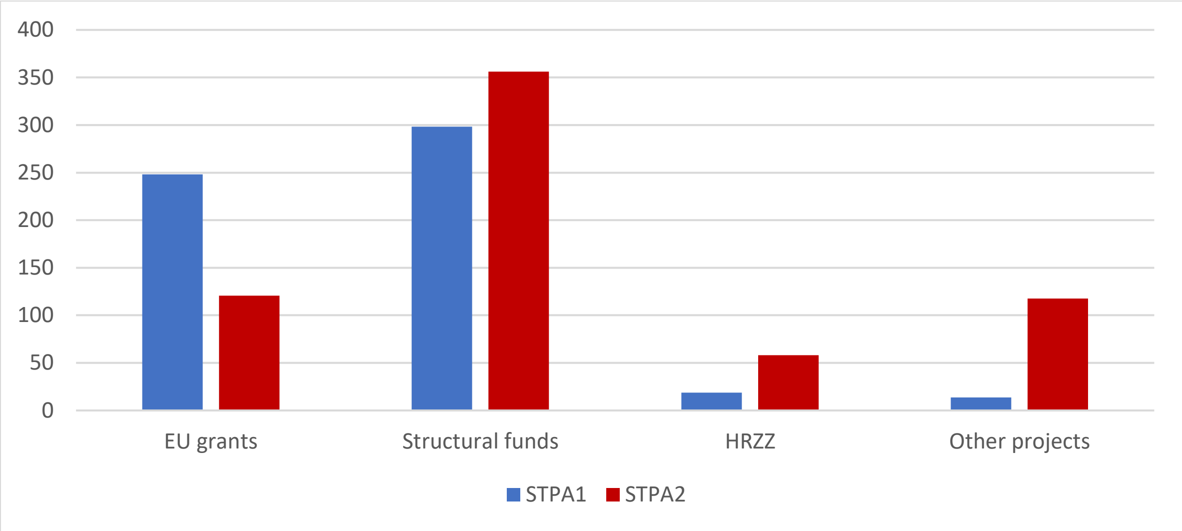
Note: EU grants include projects within EU programmes such as FP7, Horizon 2020, COST programme, and EIT projects. Structural funds refer to ERDF projects, e.g., IRI I, IRI II, SIIF. UKF is the Unity Through Knowledge Fund, and PoC is the programme for testing an innovative concept. HRZZ projects are projects of the Croatian Science Foundation. Other projects include ERASMUS, UNESCO, KlimaDigital projects, projects financed by the Croatian Agency for the Environment and Nature, VIF institutional projects, bilateral projects, scientific and technological cooperation projects of Croatia with other countries, Interreg V-A Hungary-Croatia Co-operation Programme 2014–2020, university grants, internal projects of institutions, and IPA projects.

Regarding the structure of the research projects, STPA2 had more EU projects (such as FP7 and Horizon 2020) and HRZZ projects, whereas in STPA1 there were more projects related to structural funds (such as IRI and SIIF). In terms of the number of projects, in both areas the category 'other projects' stands out, making up 42.7% of the total number of implemented and ongoing projects in STPA1 and 28.3% in STPA2. If the average number of projects per researcher is analysed, STPA1 had slightly more EU grants, structural funds, HRZZ projects and other projects per researcher.

Amounts of financing according to sources are listed in Figure 3.7. Over the last ten years, the most important source of project financing for both areas were structural funds, EU grants and other projects. STPA1 had a greater amount of EU grants, while the amount of structural funds, HRZZ projects and other projects was greater in STPA2 compared to STPA1.

The total amounts are greater in STPA2 compared to STPA1 due to the greater number of researchers. However, when analysing the amounts of implemented projects and ongoing projects by leader, the situation is somewhat different. On average, the researchers in STPA1 secured greater amounts than researchers in STPA2, i.e., HRK 23.1 million compared to HRK 11.6 million. **Compared to STPA2, it can be concluded that, with regard to the average per leader, STPA1 has—with its smaller number of researchers—secured more projects which also had greater value according to project.**

Figure 3.7 Structure of financing sources of the analysed projects by project leader, 2011–2021, in HRK million, n=81



In the sample, 130 researchers were in the role of **collaborator on a competitive science and research project** which has been implemented or is still ongoing, of which 49 researchers are in STPA1 and 81 researchers are in STPA2. Overall, there are more research projects in STPA2 than in STPA1 (Table 3.3). However, when looking at the average per collaborator, there were 5.5 projects per researcher in STPA1 compared to 4.6 projects per researcher in STPA2, and the differences are statistically relevant (p=0.005). Researchers in STPA1 have on average slightly more EU grants, structural funds and other projects, whereas researchers in STPA2 have more HRZZ projects.

Table 3.3 Analysed projects by project collaborator, 2011–2021, n=130

Project collaborator	*STPA1* (n=49)				*STPA2* (n=81)			
	Implemented projects	Ongoing projects	**Total**	**By researcher**	Implemented projects	Ongoing projects	**Total**	**By researcher**
EU grants	67	28	**95**	**1.9**	70	44	**114**	**1.4**
Structural funds	23	39	**62**	**1.3**	27	70	**97**	**1.2**
UKF	0	0	**0**	**0.0**	6	0	**6**	**0.1**
PoC	7	0	**7**	**0.1**	6	0	**6**	**0.1**
IRCRO&RAZUM	1	0	**1**	**0.0**	0	0	**0**	**0.0**
HRZZ	32	14	**46**	**0.9**	54	52	**106**	**1.3**
Other	45	13	**58**	**1.2**	32	14	**46**	**0.6**
Total	**175**	**94**	**269**	**5.5**	**195**	**180**	**375**	**4.6**

Correlation coefficients show that there is a positive correlation between the number of papers in the WoS database and the number of research projects where the researchers were leaders (r=0.182) and collaborators (r=0.183) and the amount of financing for the projects where they were leaders (r=0.390) and collaborators (r=0.199). This means that more research projects also means more papers in the WoS database. This has also been written about in scientific literature (Auranen and Nieminen, 2010, Gush et al., 2018). Researchers with more financial resources also publish better scientific papers with more citations (Gonzales-Brambila and Veloso, 2007). The researchers who become recognisable produce quality papers, have more citations, and have the resources to finance their research activities, and ultimately, they are more likely to be successful in the future as well, unlike less productive researchers (Gonzales-Brambila and Veloso, 2007).

Projects with the business sector are the next important source of financing and an important form of cooperation between the research community and the economy. **The correlation coefficients show that a greater number of projects with the economy does not necessarily mean a greater number of scientific papers**, because the coefficients are not statistically relevant.

In the analysed sample of 185 researchers, 50 of them were project leaders on projects with the business sector (26 of them in STPA1 and 24 in STPA2). There were 62 researchers who were collaborators on projects with the business sector (29 researchers in STPA1 and 33 researchers in STPA2). In total, there were 335 projects with the business sector where the researchers were leaders, and 372 projects where they were project collaborators.

Table 3.4 shows the number of implemented projects with the business sector. In total and per researcher, STPA1 had more projects than STPA2, both in the leader and the project collaborator category. Per leader researcher, STPA1 had 10.2 projects and STPA2 had 2.9. Per project collaborator researcher, STPA1 had 10.4 projects and STPA2 had 2.1. These differences are statistically relevant (p=0.000). These are mostly projects with contracting authorities from Croatia.

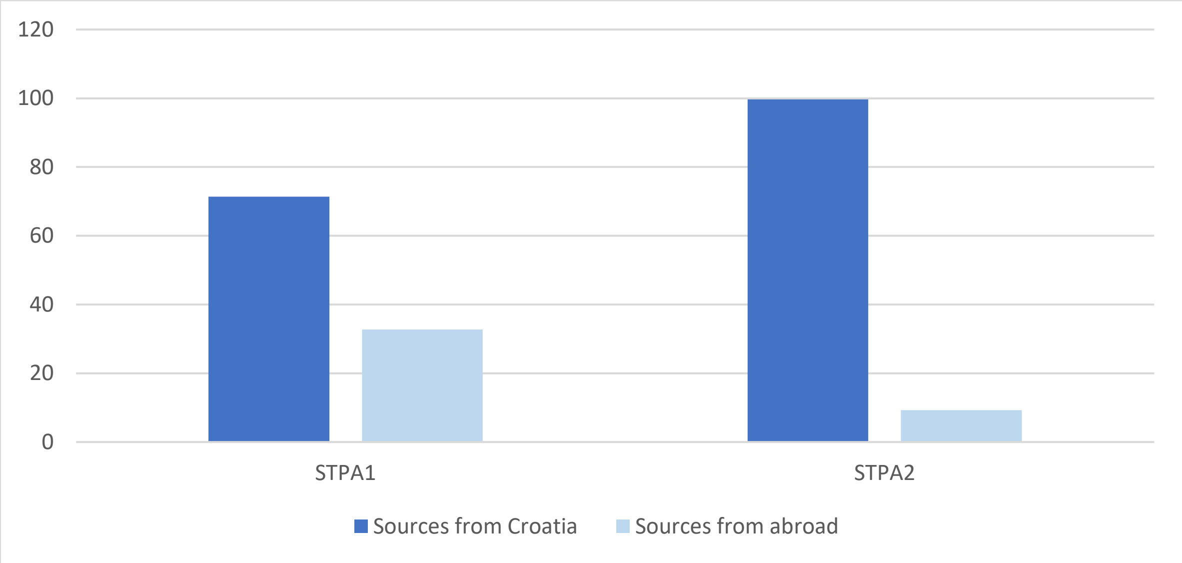
Table 3.4 Projects with the business sector, 2011–2021, n=119

	STPA1 (n=26)				**STPA2 (n=24)**			
Project leader	**Implemented projects**	**Ongoing projects**	**Total**	**By researcher**	**Implemented projects**	**Ongoing projects**	**Total**	**By researcher**
Contracting authorities in the Republic of Croatia	207	22	229	**8.8**	51	9	60	2.5
Contracting authorities outside the Republic of Croatia	30	6	36	**1.4**	7	3	10	0.4
Total	**237**	**28**	**265**	**10.2**	**58**	**12**	**70**	**2.9**
	STPA1 (n=29)				**STPA2 (n=33)**			
Project collaborator	**Implemented projects**	**Ongoing projects**	**Total**	**By researcher**	**Implemented projects**	**Ongoing projects**	**Total**	**By researcher**
Contracting authorities in the Republic of Croatia	246	16	262	**9.0**	48	16	64	**1.9**
Contracting authorities outside the Republic of Croatia	36	4	40	**1.4**	5	1	6	**0.2**
Total	**282**	**20**	**302**	**10.4**	**53**	**17**	**70**	**2.1**

Note: Project leaders and collaborators were included.

Figure 3.8 gives an overview of the **sources of financing for the projects with the business sector by STPA and type of contracting authority.** In the analysed period, STPA2 had HRK 109 million of projects in total with the economy, whereas STPA1 had HRK 104 million. **The number of projects with contracting authorities outside of the Republic of Croatia is relatively small.** In the financing structure, they are represented by a smaller share in both areas (31.4% in STPA1 and 8.5% in STPA2). Per leader researcher, the differences are not statistically relevant: HRK 4.0 million in STPA1 as opposed to HRK 4.5 million STPA2.

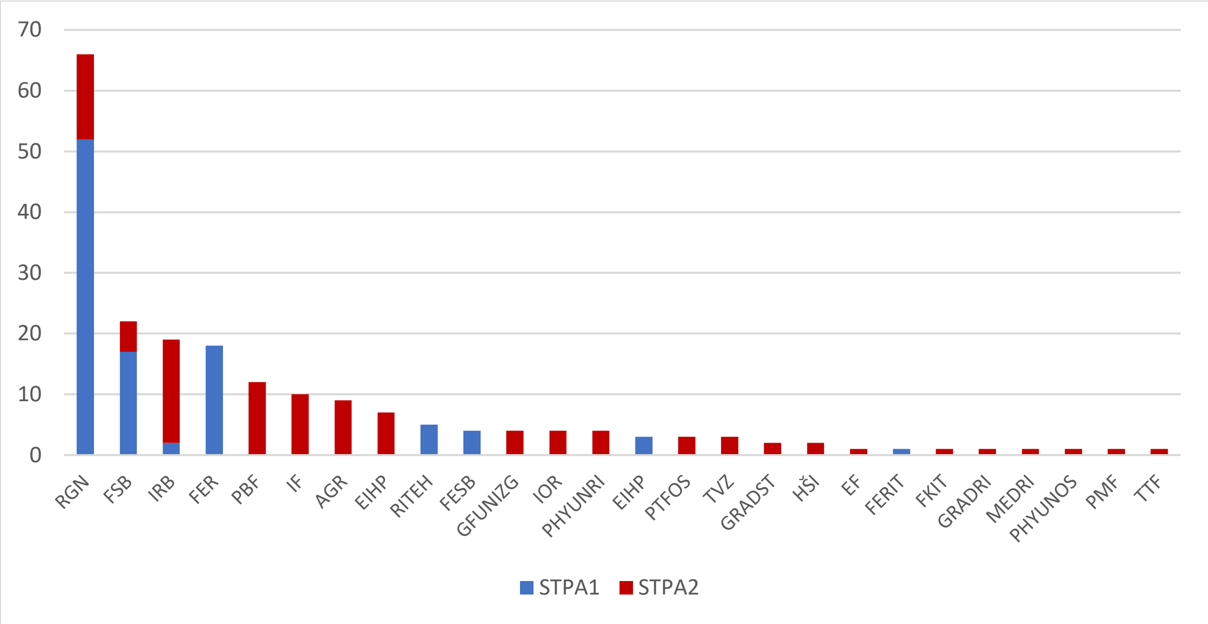
Figure 3.8 Sources of financing for projects with the economy by STPA and type of contracting authority, 2011–2021, in HRK million



Note: Project leaders and collaborators were included.

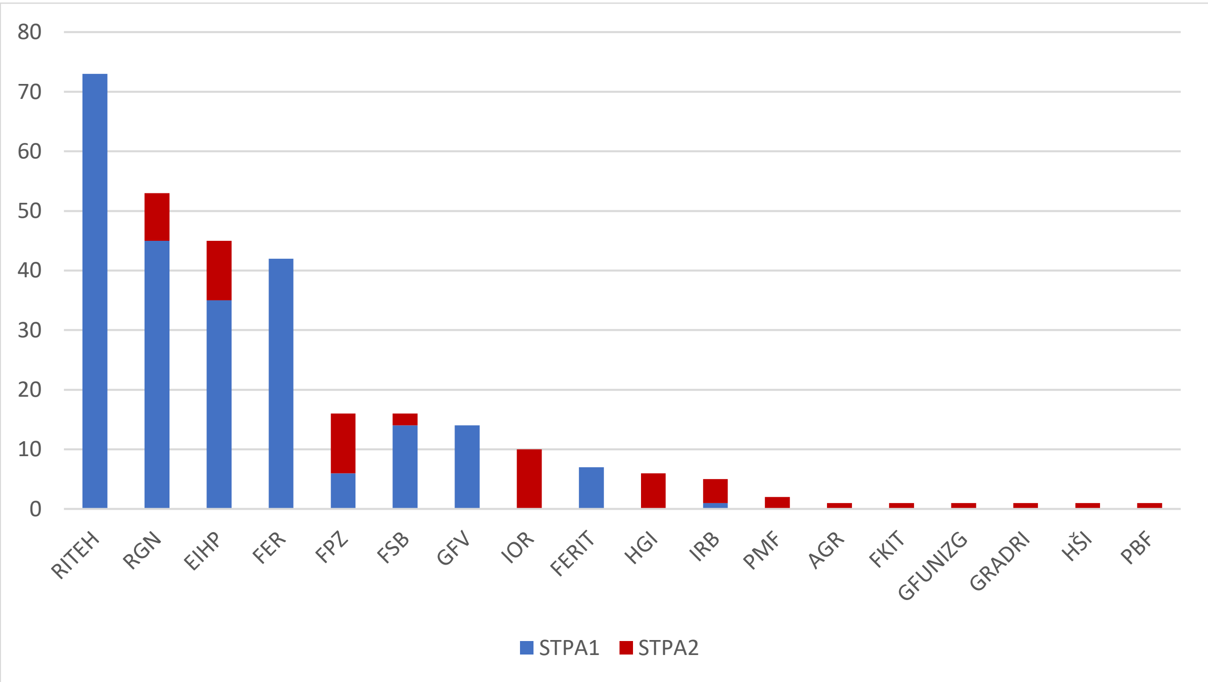
Figure 3.9 shows the **structure of the number of competitive science and research projects**, and Figure 3.10 shows the **structure of the projects with the business sector by institution.** RGN, FSB, IRB, FER, and PBF dominate the research projects, whereas RITEH, RGN, EIHP, and FER dominate the projects with the business sector. **Some institutions have a preference towards the business sector (such as RGN) and at the same time excel at competitive science and research projects as well.**

Figure 3.9 Number of competitive science and research projects by STPA and institution, 2011–2021, n=119



Note: Project leaders and collaborators were included.

Figure 3.10 Number of projects with the business sector by STPA and institution, 2011–2021

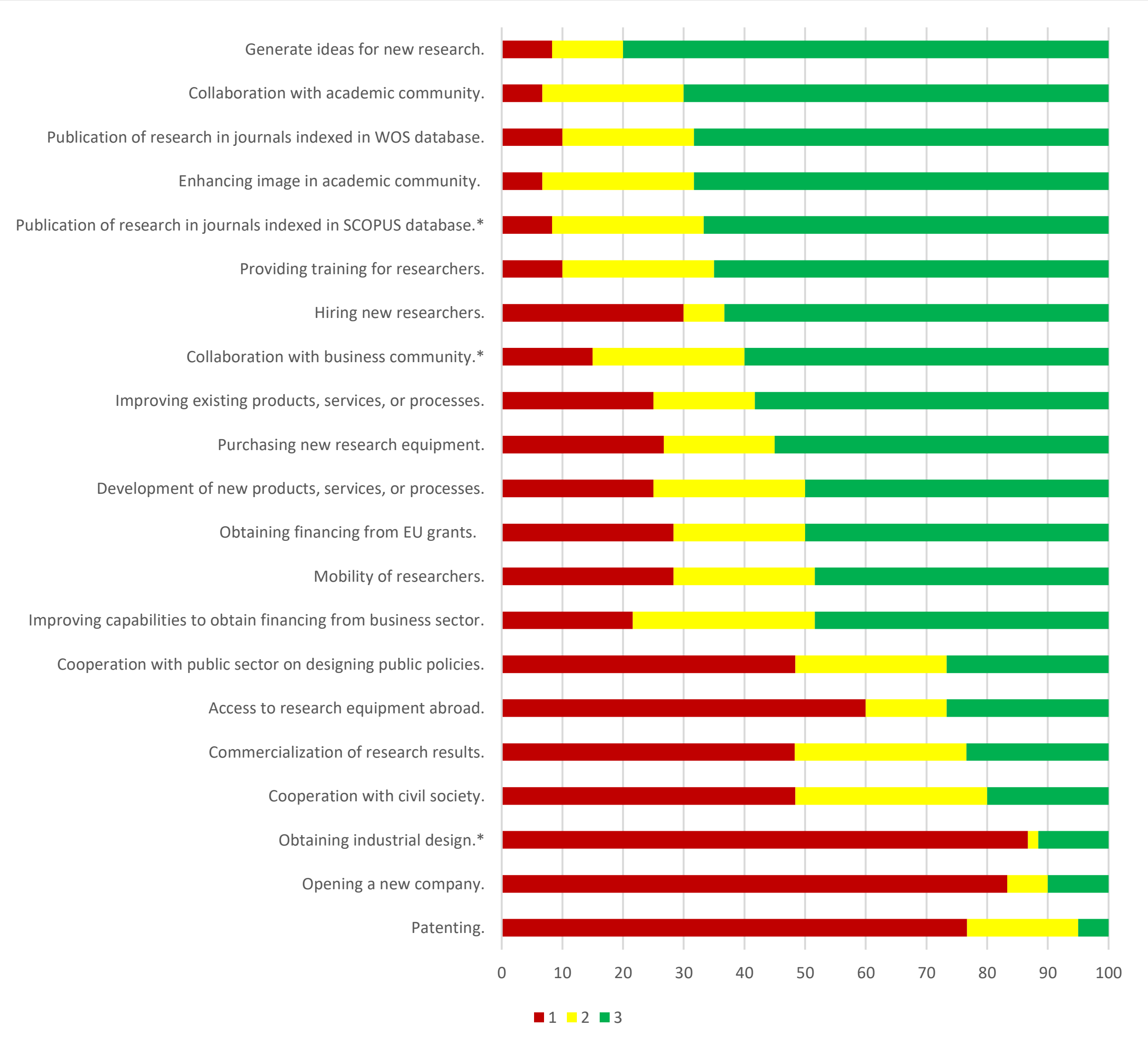


Note: Project leaders and collaborators were included.

In terms of the number of projects where the researchers were project leaders, the City of Zagreb leads with 342 such projects (86.1%; 6.2 projects on average). Split-Dalmatia County (20 projects in total, 2 projects per researcher), and Primorje-Gorski Kotar County (15 projects in total; 3 projects per researcher) follow. There were 501 research projects where the researchers were collaborators in Zagreb (77.8%; 5.9 projects per researcher), followed by Split-Dalmatia County (36 projects in total, 3.6 projects per researcher), and Osijek-Baranja County (28 projects in total; 2.5 projects per researcher). In projects with the business sector, 222 researchers from the City of Zagreb (66.3%) were project leaders (5.6 projects per researcher) and 333 of them were project collaborators (89.5%). Following the City of Zagreb, in projects with the business sector where the researchers were project leaders, the majority of researchers came from Primorje-Gorski Kotar County (71 projects) and Varaždin County (14 projects); in projects where the researchers were project collaborators, Split-Dalmatia County (20 projects) and Osijek-Baranja County (13) follow after the City of Zagreb.

In the questionnaire, we asked the researchers to assess **the impacts of their projects** in the Energy and sustainable environment TPA from 2011 to 2021. (Figure 3.11 and Figure 3.12). Researchers in both STPA1 and STPA2 stated that they believe their projects have a great impact on generating new research ideas, strengthening cooperation with the academic community, publishing research in journals indexed in the WoS and Scopus databases, and training researchers and recruiting new ones. On the other hand, the impacts of the projects were much smaller in terms of research commercialisation, meaning the application of knowledge from the research sector in the business sector for the purpose of manufacturing products and services for the market. Cooperation with the academic community was rated higher than cooperation with the business sector. Perception of the impacts of the projects on cooperation with the business community was significantly greater in STPA1 compared to STPA2. Access to research infrastructure outside of the Republic of Croatia was rated worse in STPA1 than in STPA2.

Figure 3.11 Perceived impacts of projects in STPA1, in %, n=60



Note: 1 indicates a small impact, 2 a moderate impact, and 3 a great impact on the selected indicator. *The differences are statistically relevant at the materiality level of 0.1.

Figure 3.12 Perceived impacts of projects in STPA2, in %, n=108

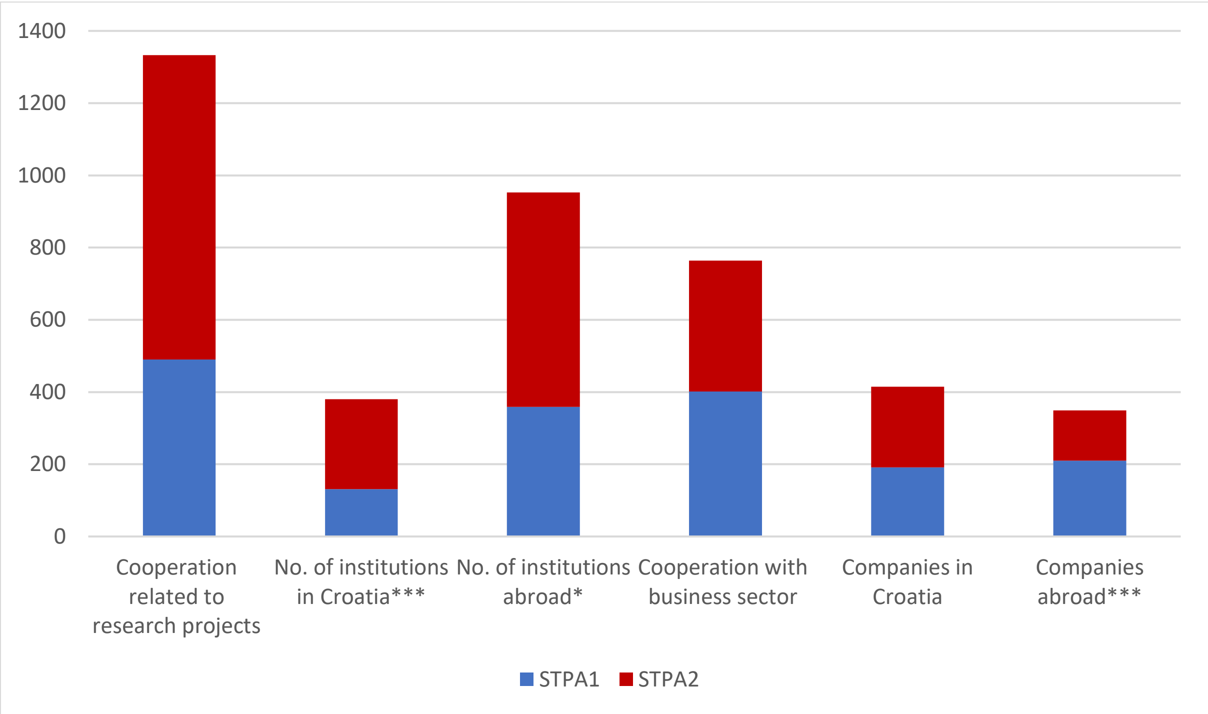
Note: 1 indicates a small impact, 2 a moderate impact, and 3 a great impact on the selected indicator. *The differences are statistically relevant at the materiality level of 0.1.

3.3.3 Collaboration on projects

Contemporary research is increasingly complex, which is why it is necessary to establish collaboration both with other research institutions and with the business sector to acquire the expertise and resources that are lacking. Researchers are under much pressure to publish in quality and prestigious journals, so to reduce the risk of rejection and secure the expertise they lack, they collaborate with other authors when writing their papers, and technology makes this collaboration especially easy (Morrison et al., 2003). Other possible motives for collaboration are the submitting of a joint project application, technological consultations, and obtaining services and technical expertise from collaborators. For this reason, we asked the researchers in the survey about the collaborations they took part in on competitive research projects or projects with the business sector within the analysed TPA.

Out of the total number of researchers, 124 researchers (67.0%) listed some form of collaboration (82 researchers in STPA2 and 42 researchers in STPA1). There was a total of 1,333 collaborations on science and research projects and 764 on projects with the economy. Figure 3.13 shows the total number of collaborations that the researchers were involved with by project type and by geographical orientation of the collaboration (in Croatia or outside of Croatia). On research projects, there were more collaborations with institutions outside of Croatia, whereas on projects with the business community there were more collaborations with companies in Croatia.

Figure 3.13 Number of collaborations on projects over the last 10 years by STPA and collaboration type, n=124



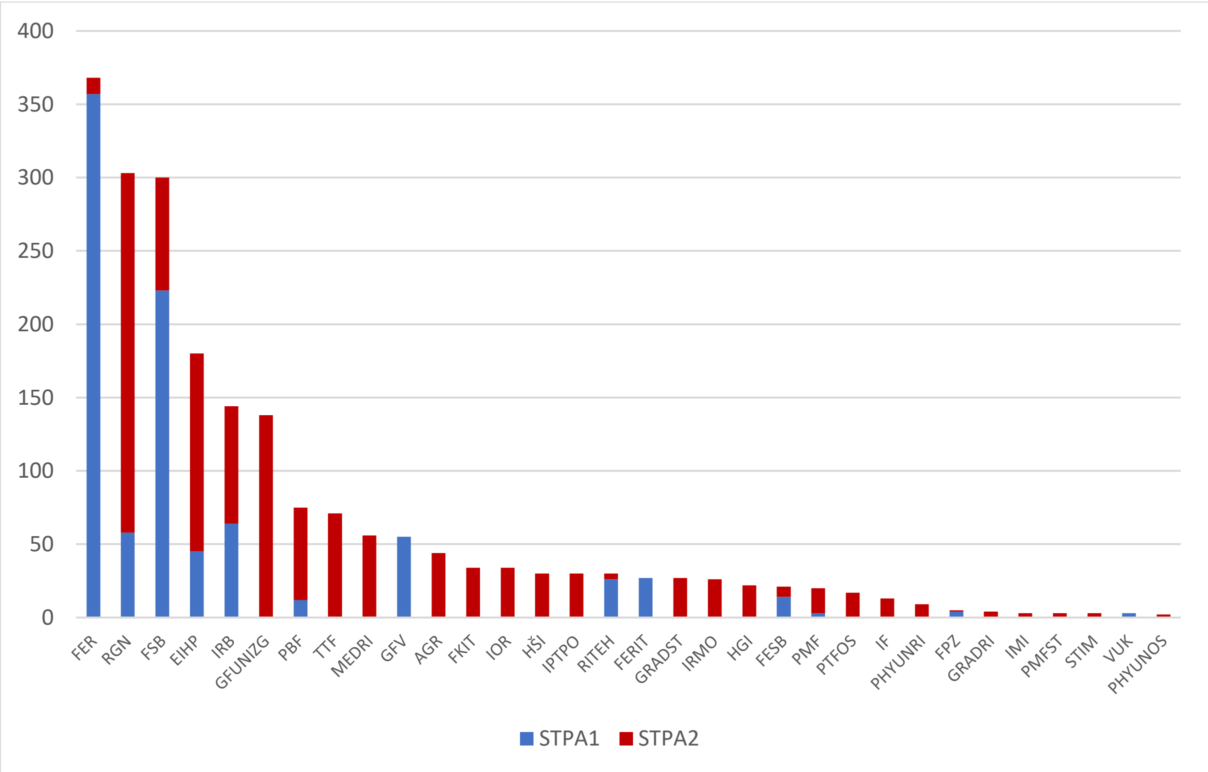
Note: The figure shows collaboration on research projects and projects with the economy, both in Croatia and outside of Croatia. The sum of collaborations by area is given. The differences are statistically relevant at the level of *0.1;***0.01.

STPA2 showed more collaborations on competitive science and research projects (both with Croatian and foreign institutions), while STPA1 showed more collaborations with the business sector. The share of collaborations with institutions outside of Croatia is greater than 70% in the structure of competitive science and research projects (73% for STPA1 and 71% for STPA2). In projects with the business sector, the share of cooperation with foreign companies is 52.4% for STPA1 and 38.3% for STPA2. If we look at the total collaborations per researcher in research projects and projects with the business sector, there are no relevant statistical differences between the areas, although STPA1 had slightly more collaborations per researcher than STPA2—21.2 as opposed to 14.7.

Figure 3.14 shows the **number of collaborations by institution.** In terms of the number of collaborations, FER, RGN and FSB are in the lead—put together, these three institutions account for 46.3% of the total number of collaborations. FER and FSB have more collaborations in STPA1, and RGN has more collaborations in STPA2.

Researchers from Zagreb had most collaborations with research institutions in Croatia (74.5%) and outside of Croatia (87%), as well as with companies in Croatia (79.5%) and outside of Croatia (89.7%). Following the City of Zagreb in terms of the number of collaborations with research institutions in Croatia are the counties of Split-Dalmatia and Primorje-Gorski Kotar (26 and 25 collaborations, respectively). In terms of collaborations with institutions outside of Croatia, Split-Dalmatia County (32) and Varaždin County (30) follow the City of Zagreb. In terms of cooperation with companies, following the City of Zagreb Varaždin County stands out (42) for collaborations with companies in Croatia, and Split-Dalmatia County (11) stands out for collaborations with companies from outside of Croatia.

Figure 3.14 Total number of collaborations on projects with the business community by STPA and institution in the last 10 years, n=124



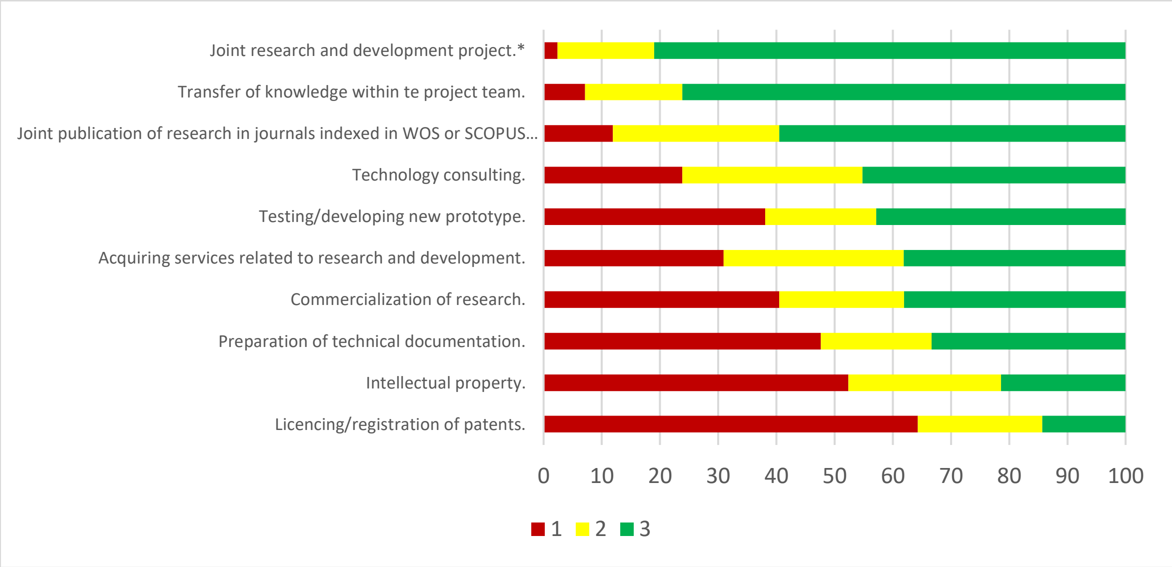
Note: Science and research projects and projects with the economy were included.

We asked the researchers in the questionnaire to name a few **research institutions both in Croatia and outside of Croatia they had collaborated with on projects** in the Energy and sustainable environment TPA. The researchers listed **collaborations with 64 different research organisations in Croatia**. The greatest number of collaborations was with IRB (23), FSB (18), PMF (15), FKIT (14), FER (11), AGR (10), and EIHP (10). Because 42% of all collaborations are concentrated in these seven organisations, we can conclude that these are the most desirable organisations for cooperation in Croatia. All of them have their head offices in Zagreb, which further demonstrates how collaboration between research groups develops with the City of Zagreb as its hotspot, as far as Croatia is concerned.

The researchers collaborated on projects with **247 different institutions outside of Croatia.** When choosing collaborators on science and research projects in the Energy and sustainable environment TPA, the researchers in the sample mostly turn to **EU countries (70.9% of collaborations have been with an institution in an EU country)**. Desirable collaboration partners are found in Austria, Germany, Italy, and Slovenia (32 researchers) and other new EU member states. A lot of researchers turn to partners in the region (**12.6% of researchers**): in Serbia (Belgrade, Novi Sad, Niš; 14 researchers), Bosnia and Herzegovina (Sarajevo, Mostar, Zenica, Tuzla, Prijedor, Banja Luka; 12 researchers), Montenegro (Podgorica, 3 researchers), and North Macedonia (2 researchers). Collaboration has also been established with institutions in **Great Britain (4.9%), Switzerland (1.6%),** and outside of Europe as well, in the USA, China, Japan, and Russia. With regard to collaborations with institutions, the most collaborations were realised with the University of Ljubljana (12) and University of Maribor (8) in Slovenia. This is followed by collaborations with the following institutions: University of Belgrade in Serbia (6), Jožef Stefan Institute in Ljubljana (5), Graz University of Technology in Austria (5) and Fraunhofer Society (5) from Germany. There were four collaborations each with the University of Sheffield (Great Britain), ETH (Zurich), National Technical University of Athens (Greece), University of Niš (Serbia), University of Novi Sad (Serbia), Aalborg University (Denmark), and University of Udine (Italy). Some collaborations were recorded with other research institutions in Europe, but also in the USA (eg New York University, University of Washington, Columbia University, Brookhaven National Laboratory, Goucher College, Saint Louis University, United Technologies Research Center, United States, Benson Ford Research Center, Michigan, University of California), Japan (Kyoto University), China (Chinese Academy of Sciences, Beijing, Institute of Chemistry Chinese Academy of Science, Beijing, Tsinghua University, Beijing, Electric Power University, Beijing), and Russia (Tomsk Polytechnic University, Saint-Petersburg Institute of Mechanical Engineering).

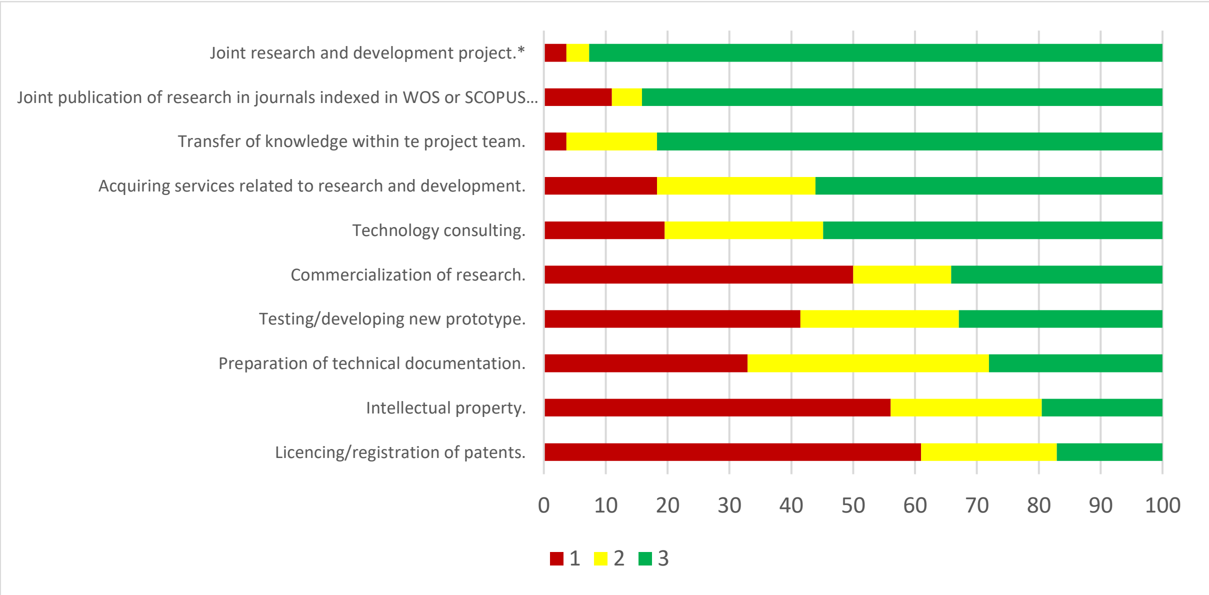
In the questionnaire, the researchers listed the following **most important reasons for collaboration on projects** (Figure 3.15 and Figure 3.16): implementation of a joint research and development project, transfer of knowledge from one project partner to another, and joint publishing of research in journals indexed in the WoS and Scopus databases.

Figure 3.15 Reasons for collaboration on projects in STPA1, % of researchers, n=42



Note: Mark 1 indicates no relevance for collaboration, 2 indicates medium relevance for collaboration, and 3 indicates exceptional relevance for collaboration. *The differences are statistically relevant at the level of 0.1.

Figure 3.16 Reasons for collaboration on projects in STPA2, % of researchers, n=82



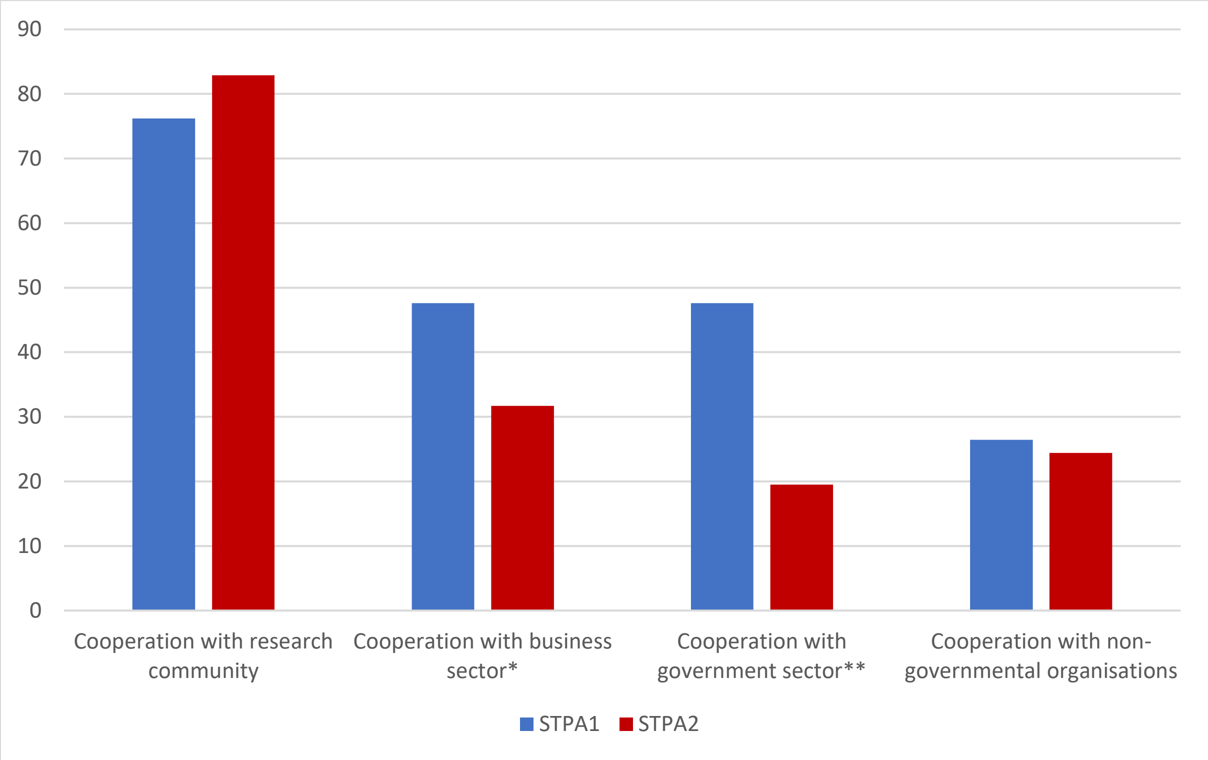
Note: Mark 1 indicates no relevance for collaboration, 2 indicates medium relevance for collaboration, and 3 indicates exceptional relevance for collaboration. *The differences are statistically relevant at the level of 0.1.

In the survey, we also asked the researchers to name a few institutions they **collaborate with as part of their scientific and research activities** (i.e., in writing research articles), excluding the projects in the Energy and sustainable environment TPA. Here the results show that the researchers collaborated on scientific papers with 2.5 times more institutions in Croatia and 1.2 times more institutions outside of Croatia when compared to the number of their collaborations on projects. This can be explained by the challenges of research topics, the flexibility of writing scientific papers, the openness to collaboration with researchers outside the institution who can contribute to the quality of the paper, in contrast to projects which are based on limited topics and research financing, which also translates into smaller teams. The researchers in the sample collaborated on writing scientific papers with 158 institutions in Croatia, out of which 83 were universities and institutes and 38 were companies. In the analysed TPA, the most desirable researchers in Croatia in terms of collaborating on writing scientific papers are at IRB (8 researchers listed collaboration with IRB), FKIT (8 researchers), PMF (8 researchers), and 6 researchers from both AGR and FSB. Out of the companies, the most desirable is HEP (8 researchers listed collaboration with HEP).

Outside of Croatia, the researchers collaborated with 307 different institutions, and 56% of those came from the EU. The most sought-after institutions outside of Croatia are the University of Ljubljana, Slovenia (5 researchers listed collaboration with this university), Technical University of Denmark (4 researchers), University of Trieste, Italy (3 researchers), Aalborg University, Denmark (3 researchers), and University of Banja Luka, Bosnia and Herzegovina (3 researchers). It can be concluded that, in terms of collaboration on research article writing within the analysed *TPA*, when looking at the number of institutions, the researchers collaborated with more institutions outside of Croatia than in Croatia. This points to the international character of research. Today, when research is extremely complex, a quality scientific paper can only be produced and published with the support from quality teams. Because the research space in Croatia is small and there is a lack of expertise in certain areas, researchers are increasingly turning to the international research community in search of quality collaborators, new ideas, and expertise, which in turn not only increases the quality of their papers and articles, but also increases their chances of publishing in quality journals.

Next, the researchers evaluated **the quality of their collaborations on projects** as shown in Figure 3.17.

Figure 3.17 Quality of collaboration on projects is very good and excellent, % of researchers, by STPA and collaboration type, n=124

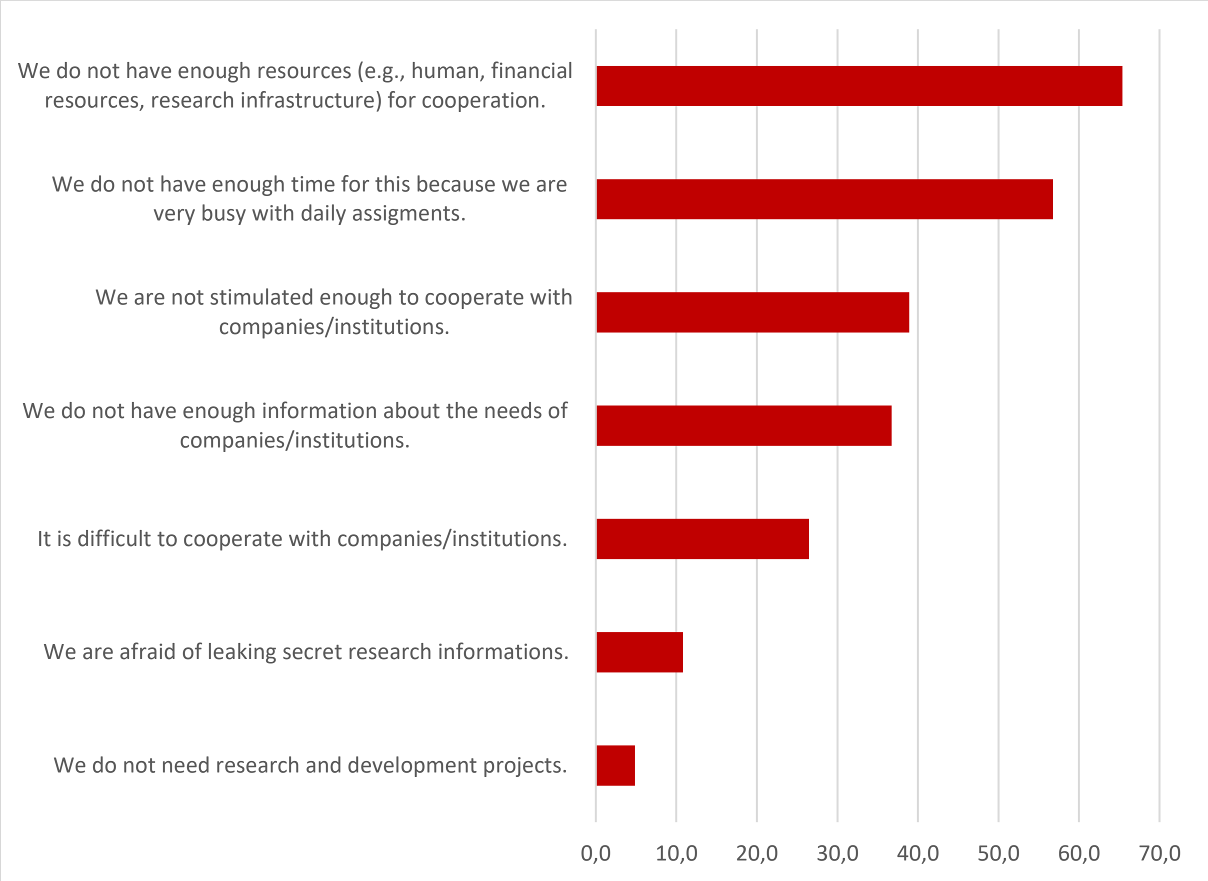


Note: The figure shows the percentage of researchers who have rated their collaborations on projects in the last 10 years as very good or excellent by the type of environment in which the collaboration took place. Values 4 and 5 from the questionnaire are presented. The differences are statistically relevant at the level of *0.1;**0.05.

A high percentage of researchers are satisfied with their collaborations with the research community, and a smaller number of researchers are satisfied with their collaborations with the government sector, the business sector, and the non-governmental sector. Compared to STPA2, the percentage of researchers in STPA1 who are satisfied with their collaborations with the business sector and the government sector is higher. Although there are no statistically relevant differences in the evaluation of the quality of collaboration with the research community between the observed STPAs, a slightly higher percentage of researchers in STPA2 rated the collaboration as very good and extremely good compared to STPA1 (82.9% as opposed to 76.2%).

Figure 3.18 shows the greatest **obstacles to collaboration.** There are no relevant statistical differences between the STPAs in the distribution of the answers to this question. As the greatest obstacles (answers 4 and 5) to better collaboration, the largest percentage of researchers cited a lack of resources and time, as well as a lack of incentives for collaboration. Other listed obstacles included unclear development strategies, lack of support for the project leader, lack of work experience, and lack of companies that would be interested in collaboration.

Figure 3.18 Greatest obstacles to collaboration on projects, % of researchers, n=185



Note: Values of 4 and 5 are shown, which indicate that the researchers consider the factor to be a major obstacle to more intensive collaboration.

3.4 Patents and research commercialisation

As the most important **results of research in the Energy and sustainable environment TPA**, over 50% of respondents cited scientific papers, acquiring new ideas for projects, acquiring new research equipment, establishing long-term collaboration, and applying for further research schemes. Researchers were less active in innovation activities, developing new products, new processes, or new industrial designs (Table 3.5). It should be noted that innovation is a criterion for projects that are oriented towards cooperation with the economy and innovation activities and is often not required in research projects.

In both STPAs, the main research results are similar for most researchers. There are no relevant statistical differences between the STPAs for the analysed indicators, except for the acquisition of new research equipment, which more researchers in STPA2 cited as the result of their research.

Table 3.5 Research results, 2011–2021, n=185

Research results	STPA1		STPA2		Sample	
	n	%	n	%	n	%
Scientific papers	61	92.4	109	91.6	170	91.9
Generation of new research project ideas	56	84.9	108	90.8	164	88.7
Acquisition of new knowledge and expertise	61	92.4	107	89.9	168	90.8
Acquisition of new research equipment**	47	71.2	101	84.9	148	80.0
Establishment of long-term collaboration	50	75.8	92	77.3	142	76.8
Applications for further financing schemes	45	68.2	88	73.9	133	71.9
Creation of a new product	35	53.0	58	50.0	93	51.4
Improvement of existing processes	35	53.0	59	49.6	94	50.8
Improvement of existing products	31	47.0	57	47.9	88	47.6
New processes	27	40.9	48	40.3	75	40.5
Creation of a new product prototype	28	42.4	40	33.6	68	36.8
Establishment of production/service procedures	18	27.3	35	29.4	53	28.7
New industrial design	13	19.7	13	10.9	26	14.1
Creation of spin-off and/or spin-out companies	4	3.4	3	4.5	7	3.8

Note: n indicates the number of respondents who stated that a category represents their research result (answer YES); % indicates the share of researchers who had a specific research result in a STPA.
**The differences are statistically relevant at the materiality level of 0.05. Development of a new product, new processes, and new industrial design is marked if the researchers have stated that they have developed or are in the process of developing these innovations. Process refers to a new or significantly improved method of production, new or significantly improved logistics, delivery, or distribution method, and new or significantly improved supporting activities (e.g., system maintenance, acquisition, accounting, or IT activities). Design is the external look (appearance) of a product.

Over the last 10 years, a total of 152 new products, 99 new processes, and 21 new industrial designs were developed (Table 3.6). STPA2 has more innovations in total, but also more researchers who were involved in innovation activities. On average per researcher, STPA1 has better results in terms of new products and processes developed. If we look at the impact of innovation activities per researcher, compared to STPA2, STPA1 has slightly more new products per researcher (2.2 as opposed to 2.0) and slightly more new processes (2.2 as opposed to 1.4). On average, slightly more new industrial designs were developed in STPA2 (1.4) compared to STPA1 (1.3). In general, if we look at the entire period of the last 10 years, it can be said that innovation in the Energy and sustainable environment TPA is relatively limited.

Innovation **commercialisation rate** is greatest for new products and somewhat smaller for new processes and designs (Figure 3.19). In STPA1, slightly more new processes per researcher (1.5 as opposed to 1.3) and new industrial designs per researcher (1.5 as opposed to 1) were commercialised compared to STPA2, while there were no statistically relevant differences in the commercialisation of new products between the two STPAs.

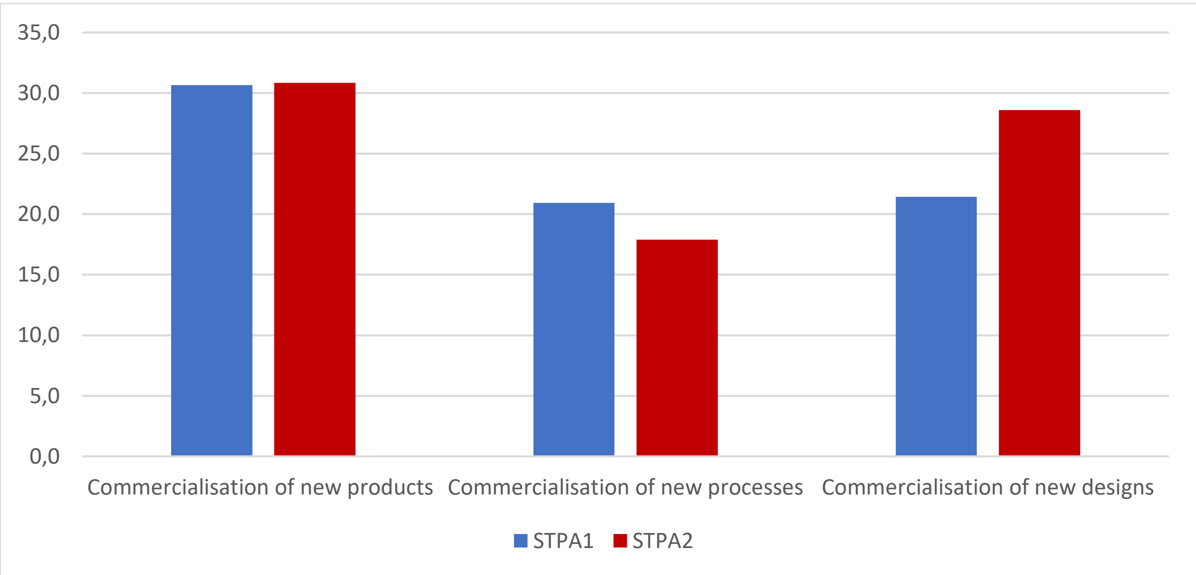
Innovations are concentrated in a smaller number of institutions. In STPA1, the greatest number of new products was developed at FER (27) and FSB (14), new processes at FER (11) and FSB (13), and new industrial designs also at FER (3) and FSB (3). In STPA2, the development of new products was concentrated in the following institutions: RGB (16), GFUNIZG (13), and AGR (8).

Table 3.6 New products, processes and designs developed and commercialised, 2011–2021

Innovation activities and commercialisation	STPA1		STPA2		Sample
	Total	By researcher	Total	By researcher	
Number of new products developed**	62 (n=28)	2.2	90 (n=45)	2.0	152 (n=73)
Number of new products commercialised	19 (n=13)	1.5	27 (n=16)	1.7	46 (n=29)
Number of new products in development***	58 (n=22)	2.6	72 (n=47)	1.5	130 (n=69)
Number of new processes developed***	43 (n=20)	2.2	56 (n=39)	1.4	99 (n=59)
Number of new processes commercialised***	9 (n=6)	1.5	10 (n=8)	1.3	19 (n=14)
Number of new processes in development***	39 (n=19)	2.1	40 (n=31)	1.3	79 (n=50)
Number of industrial designs developed***	14 (n=11)	1.3	7 (n=5)	1.4	21 (n=16)
Number of industrial designs commercialised***	3 (n=2)	1.5	2 (n=2)	1.0	5 (n=4)
Number of industrial designs in development***	4 (n=4)	1.0	12 (n=10)	1.2	16 (n=14)

Note: The number outside the parentheses indicates the total number of innovations that were developed in a category. 'n' indicates the number of researchers who had an innovation/commercialisation in a particular category. An asterisk next to the indicator indicates that there are statistically relevant differences at the *0.1 level, **0.05 level and ***0.01 level.

Figure 3.19 Commercialisation rate of new products, processes and industrial designs developed, by STPA, in %

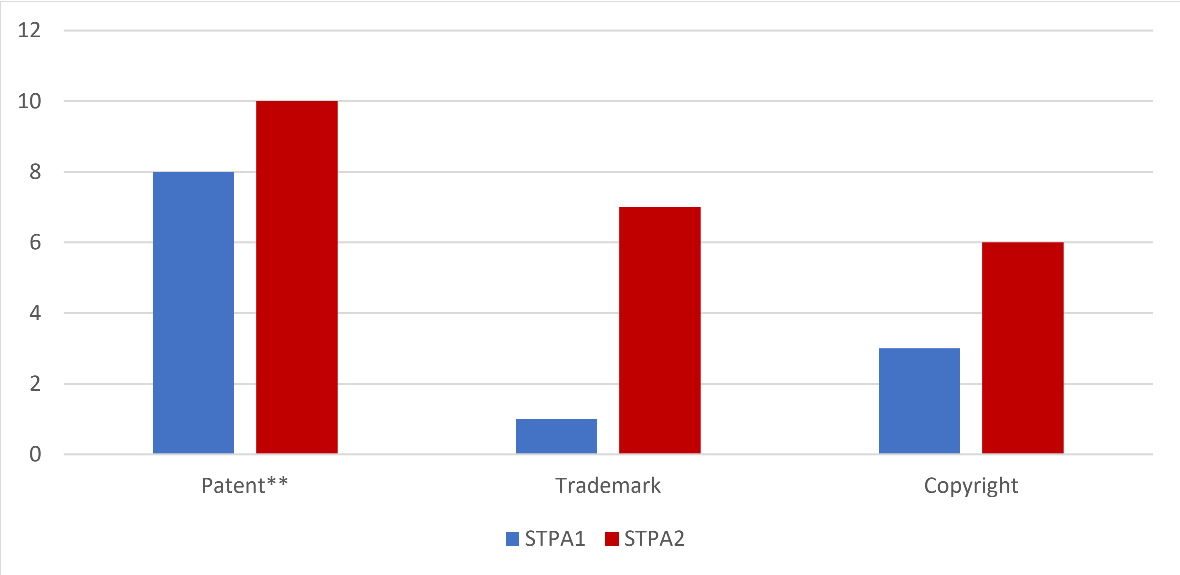


Note: The commercialisation rate is calculated as the percentage of commercialised new products, processes, and industrial designs in relation to the total number of new products, processes, and industrial designs.

Over the last 10 years, **86 new technologies were developed** in the Energy and sustainable environment TPA. Out of those, 28 belong STPA2 *(category 2),* 38 to STPA1 *(category 1),* 6 to *cross-cutting themes (category 4),* and 14 to *other topics (category 3)*. The majority of the new technologies (52.3%) was developed at six research institutions: IRB (12), FSB (9), FER (8), RGN (7), RITEH (5), and FERIT (4). The list of new technologies developed over the last ten years can be found in *Annex 6*.

For their research, 24 researchers (12.9%) used at least one **form of intellectual property** (patent, trademark, or copyright); 8 in STPA1 and 16 in STPA2. At the overall sample level, STPA2 had slightly more researchers who used some form of intellectual property protection compared to STPA1, although the statistical differences between the STPAs are relevant only for patents (Figure 3.20).

Figure 3.20 Number of researchers and forms of intellectual property protection used, 2011–2021

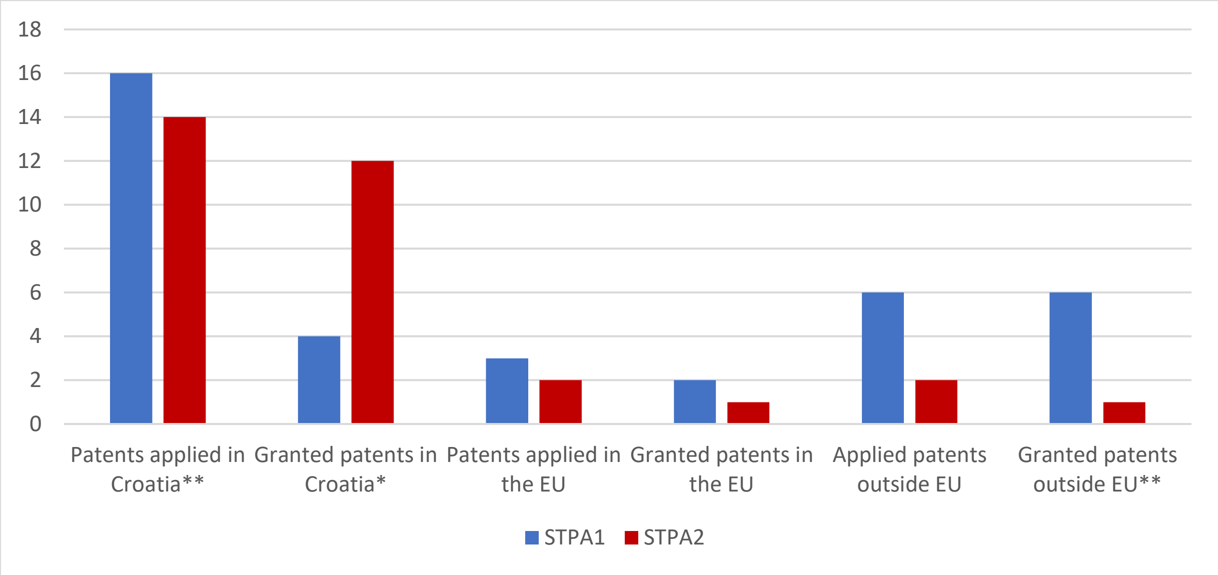


Note: No researcher reported using intellectual property protection for industrial design.

Patent applications were submitted by 8 researchers in STPA1 and 10 researchers in STPA2. Most patent applications were submitted in Croatia, to the State Intellectual Property Office: 16 in STPA1 and 14 in STPA2 (Figure 3.21). The total number of granted patents in Croatia is greater in STPA2 than in STPA1. STPA1 has more patent applications and granted patents both in the EU and outside the EU compared to STPA2.

Researchers who did not use any **forms of intellectual property protection** stated that the main reasons for this were that it is too expensive to apply (53 researchers), that the protection does not provide much protection in the industry (50 researchers), and that it is too expensive to renew (38 researchers). There are no relevant statistical differences between STPA1 and STPA2.

Figure 3.21 Patent applications and granted patents from 2011 to 2021 by place of application/granting, number of researchers



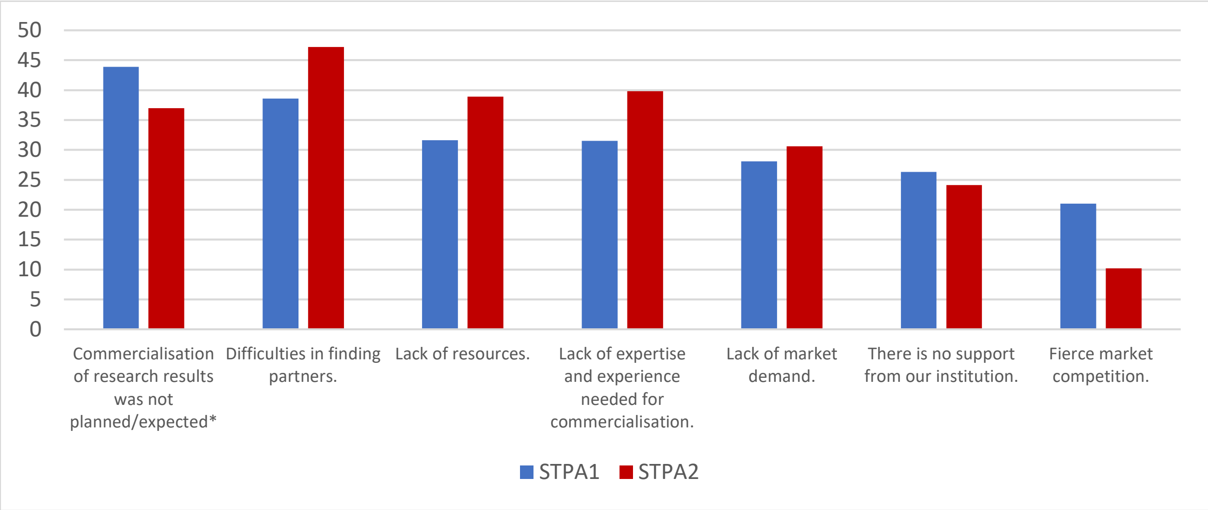
Note: The sum of the total number of patents is given. An asterisk indicates that there are statistically relevant differences at the *0.1 level and**0.05 level.

From 2011 to 2021, only one researcher in STPA1 licensed patents, and 3 researchers in STPA1 used patents to establish a new company. Seven researchers (4 in STPA1 and 3 in STPA2) established **spin-off and/or spin-out companies**. In total, 8 such companies were established, 4 in each STPA. Seven are active. One company has 15 employees, one has 0, and the other two have 1 and 2 employees each. The average annual income of the companies was HRK 162,500.

One **commercialisation agreement with the business sector** was signed, in STPA1. STPA1 had more signed collaboration agreements: 2 with research institutions, 24 with the business sector, and 15 with the government and public sector. In general, if we look at the entire period of the last 10 years, it can be said that the commercialisation of innovations and the establishing of spin-off and spin-out companies were rare.

The respondents in the questionnaire listed the following **largest obstacles to research result commercialisation**: commercialisation of research is not planned, commercialisation partners are difficult to find, and funds and expertise are lacking (Figure 3.22). To this list, some researchers added low market demand and lack of support from their institution. Other listed obstacle included lack of products for commercialisation, lack of time for researchers, complicated paperwork and administration, and lack of skills. It should also be noted that the commercialisation of research results at faculties and institutes is not a part of the basic activities of researchers.

Figure 3.22 Greatest obstacles to commercialisation of research results, % of researchers, n=165



Note: Researchers who have not had their research results commercialised were included. *There are statistically relevant differences at the materiality level of 0.1.

3.5 Research infrastructure

In their research, researchers mostly use databases of scientific journals and books, scientific equipment, measuring equipment and instruments, computer and electronic equipment (Table 3.7).

Table 3.7 Use of research infrastructure and how it contributes to innovation

Research infrastructure	STPA1 (number of researchers)			STPA2 (number of researchers)			Infrastructure contribution, in %	
	STPA1	In Croatia	Outside Croatia	STPA2	In Croatia	Outside Croatia	STPA1	STPA2
Scientific equipment	54	51	13	106	104	50	83.3	95.4
Measuring equipment	51	49	13	93	92	34	76.4	90.45
Instruments	48	47	10	96	94	40	72.9	92.8
Observatories (field laboratories)	10	10	1	31	28	6	50	74.2
Computer and electronic equipment	64	64	15	106	106	29	87.5	84.1
Large-scale research facilities	16	15	3	16	11	9	75	75
Collections, records, scientific data	42	42	19	86	86	36	78.6	87.3
Access to scientific journals/books databases	62	58	26	113	107	60	85.4	94.8
E-infrastructure (data systems, computer systems, communication networks)	43	43	11	66	65	20	76.8	82.1
Communication networks	38	38	10	61	61	16	78.9	83.9
Software solutions	50	50	13	63	60	25	74	88.9
Habitats	2	2	0	9	9	2	50	66.7
Research vessels	0	0	0	8	8	1	87.5	87.5
Satellites	2	2	1	6	5	3	50	83.4
Telescopes	0	0	0	1	1	1	100	100.0
Synchrotrons	1	0	0	11	3	9	72.8	73.2
Accelerators	2	2	1	4	3	2	100	75.0

Note: The researchers indicated which of the listed research infrastructure items they mainly use in their work and to what extent these help in generating new knowledge and technologies in the Energy and sustainable environment area. The table shows the number of researchers (n) by STPA who use the listed research infrastructure items both in Croatia and outside of Croatia. Infrastructure contribution refers to the percentage of researchers who stated that the infrastructure they used contributes (rating 4) or contributes exceptionally (rating 5) to the generation of new knowledge, innovation and new technology in the Energy and sustainable environment area.

The researchers pointed out that the infrastructure is extremely important for their research and that it greatly contributes to the generation of new knowledge, innovation, and new technology in both sub-areas. As far as these responses are concerned, there are no differences between the STPAs. Due to the nature of the projects and the characteristics of individual research, habitats, research vessels, satellites, telescopes, synchrotrons, and accelerators are seldom used. Other used research infrastructure items the researchers listed included a research nuclear reactor, licensed computer software, and specialised laboratory infrastructure.

The purchase of research equipment can be financed from the projects, which the researchers recognised as an important impact of the projects. A considerable number of researchers pointed out that the lack of research infrastructure is a significant obstacle to performance in terms of scientific productivity and more successful collaboration on projects. There is a lack of modern specialised equipment in Croatia, and the equipment outside of Croatia is very expensive. As an impact of the projects, access to research infrastructure outside of Croatia was also rated more poorly as an impact of the projects.

The researchers indicated that there are certain obstacles that hinder the effective use of research infrastructure. Two major obstacles are the lack of financing for the acquisition of equipment and limited research spaces. Another obstacle is the lack of expert associates, such as laboratory technicians and experts in the use of specific instruments. What is lacking the most is large scientific capital equipment that could facilitate obtaining results that would lead to new knowledge. Old laboratory equipment is a big problem. At the same time, there is a lack of funds for maintaining capital equipment and acquiring new capital equipment. Sometimes the problem is the absence of a specific instrument and/or measuring device, or a special device for the production of new materials and/or structures. There are also problems with the bureaucracy in the equipment acquisition process. The acquisition of technology is possible only through projects that allow the acquisition of equipment and software. Information on the product commercialisation process and patent rights is also lacking.

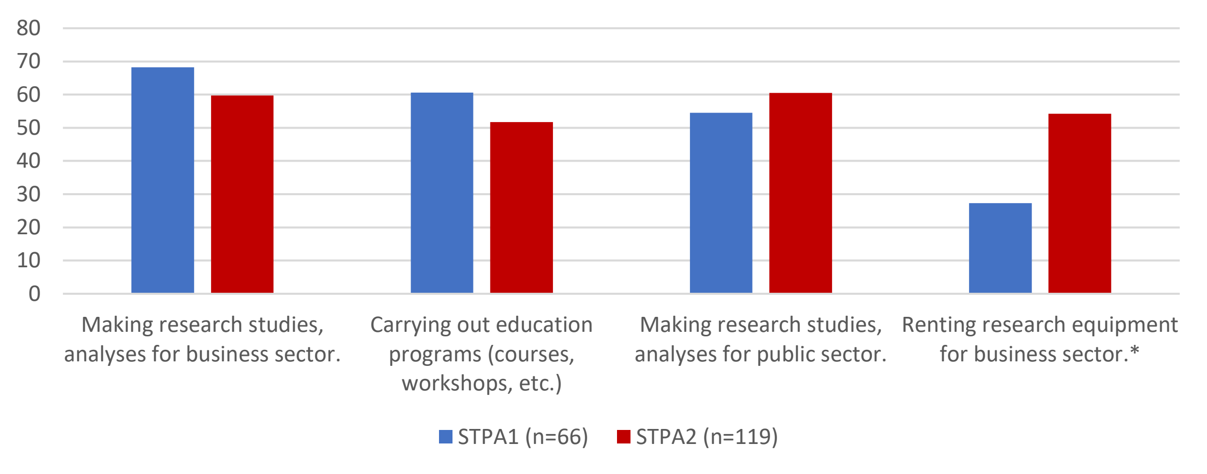
The researchers stated that, in order to generate new knowledge in the analysed TPA, in addition to research and the use of research infrastructure, it is necessary to ensure more financing for the purchase of additional pieces of higher quality equipment, as well as to provide long-term financial support (equipment depreciation and servicing). The researchers pointed out that it is necessary to ensure more advanced research equipment and instruments, access to high- ranking research article databases and specialised software solutions, and to provide adequate space for the equipment. More financing for science and research projects in the Energy and sustainable environment TPA is required. This would enable the acquisition of scientific equipment and instruments, the recruitment of young researchers, and the financing of trips to conferences outside of Croatia and training at research institutions outside of Croatia. Support for the researchers who want to and are able to implement these goals should also be provided. This means rewarding the accomplished researchers and evaluating the submitted and awarded projects and those who lead them. Research requires more experts in the same field.

In terms of knowledge dissemination, 80 researchers stated that they have developed or implemented educational programmes (e.g., new courses or trainings for a wider range of users or online educational courses) in the Energy and sustainable environment area. Out of these, 31 researchers belong to STPA1, and 49 researchers to STPA2.

There are 118 researchers (63.8%) who hold courses at undergraduate and postgraduate level related to the Energy and sustainable environment area. There are 55 researchers (22 from STPA1 and 33 from STPA2) who have participated in an educational programme in the last 10 years organised by universities and institutions in Croatia and outside of Croatia in the Energy and sustainable environment area.

Figure 3.23 gives an overview of the researchers' expectations regarding interest in conducting educational programmes, renting equipment, creating studies, and other forms of expert services in the next five years.

Figure 3.23 Interest in expert services in the next five years, % of researchers, n=185



Note: The figure shows the percentage of researchers who expect the interest in expert services to increase or increase significantly over the next five years. The figure shows the sum of ratings four and five, which indicate an increase or a significant increase of interest in the service.

In the future, researchers believe, the greatest demand will be for studies, analyses, and expert papers. These are followed by a demand for educational programmes and the creation of studies for the needs of the public sector. Other forms of services include consulting for the preparation of projects, establishment of new business models, and various expert services in the sector. There are no statistically relevant differences between the STPAs. Furthermore, 153 researchers (53 in STPA1 and 100 STPA2) stated they were interested in participating in educational programmes in the Energy and sustainable environment area in the future.

3.6 TPA and research groups performance and the main directions of research

3.6.1 TPA performance

The public scientific organisations analysed within this TPA play an important role in the production and dissemination of research results, new knowledge, and newly developed technologies. Published scientific papers, ideas for new projects, new research equipment acquired, long-term collaborations established, and increased opportunities for applications for new research are the most important **research results from the researchers** coming from the sampled institutions active in this field. These greatly benefit the entire research community.

The impact of scientific activities of the researchers on the business sector is weaker. One very important research result is the long-term collaboration that is established between the research community, the economy, and the public sector. Having said that, researchers **were less involved in innovation activities,** and poorer results were achieved in **research commercialisation** in the sense of applying knowledge from the research sector in the business sector to produce products and services for the market, which resulted from the requirements of the projects they were involved with.

If we compare the **two analysed sub-thematic priority areas,** we can see that the average scientific productivity per researcher is higher in STPA2, while the researchers in STPA1 are more project-oriented. While the researchers in STPA2 raised more funds from the structural funds, the researchers in STPA1 raised more EU grants.

There is a high **concentration of research** in several institutions in the analysed area. To illustrate, 75 researchers—40.5% of all surveyed researchers—come from five institutions.

- If we look at the published WoS papers, FSB, FER, and IRB stand out in STPA1, accounting for 67.8% of the total number of WoS papers in STPA1. In STPA2, IRB, STIM (n=1 researcher), AGR, and PBF stand out, accounting for 45.3% of the papers in the analysed thematic area.
- In terms of research projects, RGN, FSB, IRB, FER, and PBF are in top positions. RITEH, RGN, EIHP, and FER dominate projects with the business sector.
- In terms of the number of collaborations, FER, RGN. and FSB are in the lead—put together, these three institutions account for 46.3% of the total number of collaborations. FER and FSB have more collaborations in STPA1, and RGN has more collaborations in STPA2.
- Innovations are concentrated in a smaller number of institutions. In STPA1, the greatest number of new products were developed at FER (27) and FSB (14), new processes at FER (11) and FSB (13), and new industrial designs also at FER and FSB (3). In STPA2, the development of new products was concentrated in RGB (16), GFUNIZG (13), and AGR (8).
- The majority of the new technologies (52.3%) was developed at six research institutions: IRB (12), FSB (9), FER (8), RGN (7), RITEH (5), and FERIT (4).

3.6.2 Research groups and research directions

Due to the many differences between the researchers, we set out to organise the researchers into groups according to the indicators of their activities. Factor analysis was used to determine the factors of scientific activity, and *K-means* cluster analysis was used to group the researches according to activity indicators.

Scientific papers in the WoS and Scopus databases (representing scientific productivity), WoS citations (representing the recognition of the researchers), the number of competitive science and research projects (both implemented and ongoing) as an important source of financing and the number of collaborations on projects were all used as researcher activity indicators. The analysis included the indicators that are important for showing the scientific activity of the researchers.

The exploratory factor analysis produced two factors: Factor 1—scientific activity, and Factor 2—projects and collaboration. Factor 1 includes the number of published WoS papers, number of published Scopus papers, and the number WoS paper citations; Factor 2 includes the total number of projects the researcher was a collaborator on and the total number of collaborations on projects. Table 3.8 shows the factor analysis results.

Table 3.8 Factor analysis results, factor loadings

Scientific activity indicator/factor loadings	Factor 1: Scientific activity	Factor 2: Projects and collaboration
WoS papers	**0.963**	0.091
Scopus papers	**0.939**	0.116
WoS paper citations	**0.833**	0.119
Number of research projects (collaborator on projects)	0.052	**0.886**
Number of collaborations on research projects	0.181	**0.857**

Note: The analysis covered 101 researchers; 84 researchers were excluded because they do not have any of the analysed scientific activity indicators. The analysis included the researchers who had all the analysed scientific activity indicators and who were active in these areas.

The listed factors were used in the K-means cluster analysis in to determine the groups of researchers according to their activity indicators. Three groups of researchers were identified; the differences between the indicators are statistically relevant (Table 3.9).

- **Excellent researchers** (Group 2) have the most research articles, the most citations, and the best reputation. There are three researchers in this group.
- **Project-oriented researchers** (Group 3) are in second place with respect to both indicators, but they are active on projects and in collaborations. There are 15 researchers in this group.
- **Researchers with a smaller scientific contribution** (Group 1) score poorest with respect to both indicators. There are 83 researchers in this group.

Table 3.9 Results of K-means cluster analysis, groups of researchers, mean values

	Group 1 (n=83): Researchers with a smaller scientific contribution	Group 2 (n=3): Excellent researchers	Group 3 (n=15): Project-oriented researchers	Total (n=101)
Scientific activity***	64.8	1,611	466.1	170.3
Projects and collaboration**	10.3	18.7	18.5	11.7

Note: Scientific activity includes the average of papers in the WoS database, the Scopus database, and citations in the WoS database. Projects and collaborations refer to the average number of collaborations and projects that the researchers had. Statistically relevant at the levels of ***0.01,**0.05.

Table 3.10 compares the most important features of the groups with regard to scientific productivity, projects, collaboration, and innovation activities. Table 3.11 compares the groups with regard to demographic characteristics.

Table 3.10 Scientific activity of the groups of researchers

Indicators	Group 1 (n=83): Researchers with a smaller scientific contribution	Group 2 (n=3): Excellent researchers	Group 3 (n=15): Project-oriented researchers
TPA			
Number of researchers in *STPA1*	30	1	7
Number of researchers in *STPA2*	53	2	8
Scientific papers			
Papers in the WoS database, average per researcher***	14.7	78.0	48.5
Papers in the Scopus database, average per researcher***	14.6	64.0	53.4
Citations in the WoS database, average per researcher***	165.0	4,691.0	1,296.3
Projects			
Research project leaders (% of researchers)**	50.6	100.0	73.3
Research project leaders (implemented and ongoing projects), average	4.4	7.3	6.7
Collaborators on research projects (implemented and ongoing), average per researcher**	5.0	7.0	8.7
Leaders of projects with the economy (% of researchers)	31.3	33.3	46.7
Leaders of total projects with the economy, average	9.0	1	4.3
Collaborators on projects with the economy (% of researchers)	46.9	0.0	40.0
Collaborators on projects with the economy, average per researcher	7.5	0.0	5.7
Collaborations within projects, average per researcher			
Number of collaborations with research institutions in Croatia***	2.6	9.0	5.0
Number of collaborations with research institutions outside of Croatia***	7.0	12.3	14.3
Number of collaborations with companies in Croatia	3.2	4.0	4.7
Number of collaborations with companies outside of Croatia	2.7	5.0	4.3
Total number of collaborations*	15.6	30.3	28.7
Innovation activities, average per researcher			
New products developed	1.6	1.5	3.0
New products commercialised	0.6	1.0	0.4
New processes developed*	1.1	0	2.5
New processes commercialised	0.1	0	0.3
Industrial designs developed	0.7	0	0
Industrial designs commercialised	0.1	0	0
Forms of industrial property used, average per researcher			
Patent	0.7	0	1.0
Trademark	0.4	0	0
Patent licensing			
Patent used to establish a new company, number of researchers	3	0	0

Research result commercialisation, % of researchers	76.9	0	23.1
Knowledge dissemination, in %			
Educational programmes developed	45.8	66.7	80.0
Teaching undergraduate and postgraduate courses	66.3	100.0	80.0
Participation in educational programmes to develop competencies in the analysed area	37.3	66.7	33.3
Interested in participating in educational programmes in the future	87.9	66.7	86.7

Note: The differences are relevant at the levels of ***1%, **5% and *10%.

Table 3.11 Demographic characteristics

Features	Group 1 (n=83): Researchers with a smaller scientific contribution	Group 2 (n=3): Excellent researchers	Group 3 (n=15): Project-oriented researchers
Gender, in %			
Female	47.0	33.3	20.0
Male	53.0	66.7	80.0
Employment contract, in %			
Indefinite duration	80.7	100.0	93.3
Fixed-term	19.3	0.0	6.7
Job title, number of researchers			
Teaching assistants	11	0	0
Assistant professor	19	0	1
Associate professor	15	0	5
Full professor	11	0	1
Full professor in permanent position	9	2	1
Research associate	7	0	0
Senior research associate	2	0	2
Senior research fellow	1	0	2
Senior research fellow in permanent position	1	1	1
Years of research experience in the area, average per researcher**	13.8	21.3	19.7
Percentage of time for research in the area, average per researcher	44.6	56.7	59.3

Note: The differences are relevant at the level of **5%.

Excellent researchers (n=3) are full professors and senior research fellows in permanent positions, employed for indefinite duration. The researchers in this group come from IRB, FSB, and PHYUNRI. Out of the total number of the researchers, 66.7% of them are from the City of Zagreb. Two researchers belong to *STPA2*, and one to *STPA1*. If we consider the FOS1 areas, the researchers belong to the *natural sciences* (2 researchers) and the *engineering and technology* (1 researcher) areas, whereas according to the FOS2 areas, the researchers belong to the 1.6 *Biological sciences*, 2.7 *Environmental engineering,* and *1.3 Physical sciences and astronomy* areas. These researchers have many years of experience in research in the analysed area (21.3 years of experience) and allocate more than half of their time (56.7%) to research in the area.

Excellent researchers have, on average, the most scientific papers in the WoS and Scopus databases and the most citations compared to the other two groups, which points to their considerable cumulative scientific output and international recognition. These researchers have, on average, led the largest number of international science and research projects. The number of research projects they were collaborators on is also significant. It should be noted that this group of researchers was less involved in projects and collaborations with the economy, in innovation activities, and in research commercialisation (not a single researcher in the group reported developing new technologies), which is understandable given their commitment to scientific output. The most important impacts of their projects are related to the publication of scientific papers, cooperation with the academic community, researcher mobility and training, and the generation of new research ideas.

The sub-specialities of this group of researchers are related to the following topics: plant response to stress caused by climate change; plant tolerance mechanism; energy planning; advanced material growth, modification, functionalisation and characterisation.

The researchers collaborate with many research institutions outside of Croatia such as *Technische Univesität, Dresden; Academy of Science, Czech Republic; University of Belgrade; University of Siena; University of the Algarve; ANU-Canberra; NanoGune - San Sebastian; J. Stefan - Ljubljana; University of Oslo*), but also with Croatian research institutions such as PMF, IRB, AGR, EIHP, PIO, KRS, IF, FKIT, KTFST. The main reasons for collaborating are the acquisition and transfer of knowledge, joint publishing, and consulting to improve the quality of research.

Excellent researchers are also active in the dissemination of knowledge in the energy and sustainable environment area. A large percentage of the researchers have developed new educational programmes and all of them teach at undergraduate and postgraduate levels. Furthermore, they continue to develop their knowledge and boost their competencies by participating in educational programmes organised by their own university or other universities in the Energy and sustainable environment area. Two out of three researchers in this group are interested in participating in educational programmes in the future.

The future potential of these researchers lies in their recognition (citations and scientific papers), financing sources, and established collaborations. When interesting research topics that have the potential of being published in scientific journals in the next five to ten years in the Energy and sustainable environment TPA are concerned, these researchers have listed the following: the impact of climate change on the agricultural production of different crops, simulation and optimisation models for future configurations of integrated energy systems, photocatalysis on metal oxide sheets using sunlight, and green hydrogen production.

When asked what they lacked and what hinders quality research, the researchers answered that they lack both quality researchers (because it is very difficult to hire quality experts) and quality infrastructure—modern laboratory equipment and microscopes (transmission electron microscopy—TEM). As computer software becomes ever more complex and the tasks ever more demanding, they also cited needing additional advanced expertise in this domain.

Project-oriented researchers (n=15) have less published scientific papers compared to excellent researchers, but they have on average a significant number of research projects, both as leaders and collaborators, which classifies them as project-oriented researchers. These researchers are slightly more involved in innovation activities and with projects where innovation activities are needed. This group has the greatest number of assistant professors and associate professors, and almost all of them are employed for an indefinite duration (93%). They have slightly less experience compared to excellent researchers (19.7 years), but they devote more than 50% of their time to research in this field. The majority of researchers from this group come from FSB (4), IRB (3), FER (2), and one researcher each from FKIT, IF, IOR, PBF, PHYUNOS, and PMF. Out of the total number of the researchers, 86.7% of them are from the City of Zagreb.

According to area, 8 researchers have papers in STPA2 and 7 in STPA1. If we look at the FOS1 areas, 11 researchers belong to the *engineering and technology* area and 4 researchers belong to the *natural sciences area*. Following the FOS2 classification, 4 researchers belong to area 2.07, 3 belong to area 2.05, 2 belong to area 1.05, and the other researchers cover the areas 1.03, 1.04, 2.02, 2.03, 2.08, and 2.11.

As the most important impacts, these researchers cited the following: publication of scientific papers; generation of new research ideas; recruitment, mobility and training of researchers, strengthening cooperation with the research community; securing financing from EU funds; and greater opportunities for purchasing new research equipment.

The researchers in this group collaborate with many research institutions outside of Croatia such as *Columbia University, Brookhaven National Laboratory, Kyoto University, Chinese Academy of Sciences, Italian National Institute for Environmental Protection and Research (ISPRA), National Institute of Oceanography and Applied Geophysics, Italy, University of Ljubljana, CIRCE, Imperial College of London, University of Manchester, NTNU, NTUA, Fraunhoffer, INESC TEC, LIST, Tsinghua University, NCEPU, Fraunhofer Gesellschaft (Germany), United Technology Research Center (USA), Ford Research Center* (USA) etc. Regarding institutions in Croatia, they collaborate with IRB, IF, FER, EIHP, FSB, FERIT, FESB, and EFZG. The researchers listed joint research and development projects, transfer of knowledge from one project partner to another, and joint publishing as the most important reasons for collaboration.

Eight researchers in this group indicated that they had developed new technologies. These are: the synthesis of new atomically thin materials through innovative processes; the preparation of perovskite photovoltaic cells; the preparation of immobilised photocatalysts for the purification of waste water and gases; energy planning software; the cultivation of microalgae for use in the food, pharmaceutical, and cosmetic industries; the Digital Twins technology*;* computer tools for combustion improvement for industrial furnaces; an innovative device for the production of plasma discharge in liquid foods and the associated flow reactors; and a system for purifying water under solar radiation with the operation (palette) of advanced materials.

This group of researchers is also active in the dissemination of knowledge in the Energy and sustainable environment area. A large percentage of the researchers have developed new educational programmes and teach at undergraduate and postgraduate levels. A smaller percentage participate in educational programmes, but they are interested in boosting their competencies in the Energy and sustainable environment area in the future.

With regard to research infrastructure, the researchers indicate the following as lacking: capital research equipment, specialised research equipment, suitable research space (laboratories with ancillary rooms), funds for maintaining existing and acquiring new capital equipment, laboratory equipment, and computer equipment. They also report a lack of expertise in the field of applied research, expertise regarding the possibilities for research result commercialisation, and expertise in using the latest ICT equipment (e.g., machine learning, big data, data analytics). Expertise related to industrial technology development and modelling is also lacking. Many respondents pointed out that what they really lack are contacts with the economy.

Most **researchers with a smaller scientific contribution** (n=83) are employed for an indefinite period, and a smaller number are employed for a fixed-term period. This group has the greatest number of teaching assistants and assistant professors who have just started their careers. By institution, the most researchers in this group come from RGN (9), FER (7), RITEH (6), GFUNIZG (6). Out of the total number of the researchers, 66.3% of them are from the City of Zagreb.

The data shows that they have the fewest published scientific papers, the fewest citations in the WoS database, and the fewest research projects where they were leaders. These researchers participate in research projects mostly as collaborators and are more focused on projects with the economy. Forever, most of them also teach. These researchers achieved some results in innovation activities: 34 researchers stated that they had developed new technologies.

Scientific literature recognises that researchers who have none or only have a few WoS papers tend to spend more of their time on other activities, teaching, or consulting, or they have other types of papers that are not indexed in the WoS or Scopus databases (Gonzales-Brambila and Veloso, 2007).

In this group, 53 researchers belong to STPA2 and 30 belong to STPA1. Following the FOS1 classification, most of the researchers belong to the *Engineering and technology* (59.04%) area, and 32% of them belong to the *Natural sciences* area. According to the FOS2 classification, 20.5% of the researchers belong to area 1.5, 15.7% belong to area 2.7, and 12.1% belong to area 2.2.

Not many researchers with a smaller scientific contribution participated in trainings for boosting their competencies in the field. However, a large percentage of them are interested in participating in such programmes in the future.

They lack a wide range of knowledge in research work because some of them are just starting their careers. The respondents pointed out that they mostly lack advanced expertise related to modelling, analysis, entrepreneurship, product commercialisation, and patenting, as well as the skills necessary for preparing better applications for competitive projects in the S3 field. With regard to research infrastructure, the respondents indicated they lack research space, modern laboratory and specialised equipment, access to databases, modern software tools, and measuring equipment and instruments.

4. SWOT analysis

Based on the collected primary and secondary data, a SWOT analysis was made, which examines the strengths weaknesses, opportunities, and threats. The SWOT analysis includes internal (strengths and weaknesses) and external (opportunities and threats) factors in connection with the analysed Energy and sustainable environment TPA. While internal factors can be influenced, external factors should be understood as a starting point, an initial situation that facilitates action. A summary of the SWOT analysis is given in Table 4.1.

Table 4.1 SWOT analysis of the Energy and sustainable environment TPA

<table>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>
• Recognition of several institutions with regard to providing different expertise
• The expertise of excellent researchers, the recognition of their scientific papers and expertise in securing science and research projects
• Expertise of project-oriented researchers in securing projects
• Possibilities for further career development for young, currently less productive researchers
• Developed long-term collaborations between research institutions in Croatia, as well as collaborations with institutions outside of Croatia
</td><td>
• Excessive teaching load (for faculty staff)
• Insufficient international experience of a large number of researchers, primarily with project implementation
• In the TPA, there is a considerable concentration of institutions and researchers in the City of Zagreb
• Poorer engagement with the development of new products, processes and designs
• Little commercialisation of innovations
• Lack of experience in knowledge transfer between academia and industry
• Poor use of any form of intellectual property (patents, trademark, or copyright)
• Old laboratory equipment (insufficient funds for the acquisition of equipment)
• Limited space for research equipment
• Lack of expert staff
</td></tr>
<tr><th>Opportunities</th><th>Threats</th></tr>
<tr><td>
• Continuity of energy and environmental protection themes in the Smart Specialisation Strategy 2016–2027.
• Significant growth in total allocations for research and development in Croatia from 2018 to 2020
• Increased participation of Croatian researchers in different European programmes
• Strengthened informal cooperation between researchers and different government administration authorities responsible for project implementation
• Promoting collaboration between researchers in different institutions in the fields of energy and environmental protection in Croatia
• Strengthened cooperation with research institutions outside of Croatia with the aim of writing quality scientific papers in prestigious journals and securing international research projects
• Greater international mobility of researchers
• Development of new research topics
</td><td>
• Absence of a sufficiently articulated development strategy in which technologies would have a visible position
• Insufficient incentives aimed at strengthening research teams
• The programmes related to the current S3 strategy (2016–2020) will be implemented in 2023 as well, regardless of the fact that the period of the new S3 strategy had already begun
• Regulatory and financial constraints on recruitments and promotions, which is connected to job titles
• Reduced national funding for different forms of scientific activity
• Complicated procedures regarding project implementation
• A small number of strong industries that have and/or need development activities in Croatia
</td></tr>
</table>

Note: The table lists the most important strengths, weaknesses, opportunities, and threats for the entire TPA. They are not ranked by importance.

The main strength of the Energy and sustainable environment TPA is the presence of several strong research organisations that can greatly contribute to the development of this area as well as the presence of excellent researchers who have recognisable scientific papers and know how to secure international projects and research financing. Within the system there are also researchers who are more specialised in securing projects. Establishing long-term collaborations with domestic and especially with foreign institutions is a great potential for this area. As already pointed out, the intensity of collaboration with research institutions outside of Croatia is almost four times greater than it is with research institutions in Croatia. Young researchers and the further development of their careers are extremely important for the future of this field.

The main weakness of the analysed thematic area is a focus on scientific papers and projects, and, consequently, poorer engagement with the economy, less innovation activities, and less commercialisation of new products. Research is limited by the lack of expert staff, lack of advanced knowledge and skills, limited research space, outdated equipment, and the lack of advanced equipment and measuring instruments. At the TPA level, the insufficient capacity of institutions hinders innovation and commercialisation of activities. There is insufficient knowledge, skills, and incentive for the commercialisation of research results, and the system is set up to prefer research and scientific papers.

Opportunities in the environment refer to a more intensive use of the established collaborations with the research community and a closer coordination with the international network of researchers. These collaborations make it easier to submit applications for international research projects which could facilitate the acquisition of new expertise and equipment, the training of staff, and the recruitment of new staff. Another big area where collaboration needs to be improved is the promotion of informal cooperation[27] between the institutions/organisations implementing individual projects as part of the different S3 programmes and the implementing authorities supervising the implementation of these projects. Researchers often encounter the practice where the projects are reviewed by people with insufficient knowledge about research and development projects. On the other hand, researchers often have insufficient information regarding the formal rules of project implementation.[28] If the right conditions are met and a stimulating environment is provided, innovation and research commercialisation can also present an opportunity. It is important to point out that the topics related to energy and environmental protection are also recognised in the new Smart Specialisation Strategy, so the continuity of this topic is ensured in the next few years. It is also important to note that the financing for research and development in Croatia in 2020 accounted for 1.25% of GDP, which automatically increases the relevance of the entire TPA and the recognition of the researchers associated with it, considering that these are very important R&D areas in Croatia. Given that EU programmes and projects require large teams (e.g., the Teaming programme), in the following period

[27] Unlike formal collaboration, informal cooperation is based on the exchange of information between collaborators from different institutions. Formal collaboration relates usually to a specific activity, such as, for example, product development. The realisation of project goals must be the aim of informal cooperation.

[28] Therefore, it is necessary to organise the exchange of information and even joint seminars to ensure a better understanding of what is necessary for a research and development project and how such a project can be implemented faster.

it is necessary to strengthen the collaboration between teams at different institutions in Croatia in the areas of energy and environmental protection.

The lack of strong collaboration incentives and unclear development strategies can be singled out as the **main threats** to the development of this research sector. There is a lack of advanced specialised equipment in Croatia, while the equipment outside of Croatia is too expensive, and this represents a major obstacle to producing quality research that could be competitive internationally. This is also often connected to the limitations of project applications which limit the percentage of the budget that is allowed to be invested in equipment, and this can further compromise organising the budget according to actual needs. If a sufficiently articulated development strategy which referenced the role of technology more directly was available, the knowledge and expertise of the researchers connected to the thematic areas would be much better used. In addition to these threats, regulatory and financial constraints should also be added. To illustrate, a researcher's salary cannot be determined outside of the COP (Centralizirani obračun plaća/Centralised Salary Calculation), meaning, based on the autonomous decision of their research institution. Therefore, the researchers often have lower salaries on EU projects compared to their colleagues in the EU. Regardless of the fact that, as a consequence of the Europeanisation of the research space in Croatia, the total financing for research is increasing, the national funding of different forms of scientific activity is still decreasing, which can pose a challenge in the event of disruptions in EU financing in the long term. One alternative is securing financing from domestic sources, primarily in cooperation with the business sector. However, there are also threats to consider in this scenario. On the one hand, companies are sceptical towards collaborating with the research sector, and on the other hand, the research community is focused on producing scientific papers that are a condition for promotion within the system, which in turn reduces the impacts of their collaboration with the economy.

5. Conclusions and recommendations

5.1. Main mapping results

The goal of this project was to identify and analyse the areas with the highest concentration of research and innovation excellence in the *Energy and sustainable environment* TPA as specified in the Smart Specialisation Strategy. To that end, primary and secondary data on the participation of Croatian researchers in individual projects within different programmes was collected and processed. These are delivery and additional S3 programmes, as well as selected EU programmes. The primary data was collected using a questionnaire.

Many Croatian researchers who explore the topics of energy and environmental protection either participate or have participated—at the time of writing this report, some of the programmes were concluded, and the majority is still ongoing—in the projects/programmes within the S3 Policy Delivery Instruments and S3 Policy Additional Instruments. In total, this project identified over a thousand researchers who are either involved or who were involved with the analysed policy instruments and who can be associated with this TPA. The largest number of researchers were involved with the projects within the IRI 2 programme, over three hundred researchers, in contrast to the SIIF programme, where over two hundred researchers were involved. Over one hundred and fifty engaged researchers were identified within the ZCI and STRIP programmes, in contrast to the IRI 1 and INFRA programmes, where over one hundred researchers were identified. The other programmes (O-ZIP, CALT, TWINN) were, at least in the period of drafting this report, smaller in terms of the number of engaged researchers. These numbers of engaged researchers per project should be considered with a dose of caution because one researcher may be identified in several projects within the S3 Policy Delivery Instruments. In addition, researchers associated with STPA1 are associated with the following FOS classification fields: 2.2, 2.3, and 2.7. On the other hand, according to the analysed sample, the researchers associated with STPA2 predominantly deal with the following fields within the FOS classification: 1.4, 1.5, 2.5, 2.11, and 4.1. As for the distribution of projects in the delivery programmes, the highest concentration is in the City of Zagreb (over 50%), with significant differences between the different delivery programmes regarding the participation criteria for research institutions from Zagreb and those outside of Zagreb. In some programmes, such as TWINN, there are no participants coming from outside of Zagreb, whereas in other programmes, such as R&D Climate, research institutions from outside of Zagreb are present in almost half of the projects (12 out of 25).

Many institutions from all parts of Croatia participate in the S3 Policy Delivery Instruments, which is positive because the institutions that take part in different policy instruments also advance their own research excellence, strengthen their commercialisation channels, and address societal challenges more appropriately. A large concentration of researchers was noted in the City of Zagreb compared to the rest of Croatia: almost two out of three researchers come from Zagreb (65.4%).

Participation in the S3 Policy Delivery Instruments is largely determined by programme type. The IRI 1 and IRI 2 instruments are dominated by researchers coming from technical faculties, such as FER and FSB, whereas with topics related to societal challenges (e.g., a programme involving climate change) the dispersion of researchers/institutions is greater. Likewise, larger infrastructure projects cover more potential thematic priority areas of activity and, according to the rules of the S3 programmes, include researchers who work in cross-cutting S3 themes in Croatia, such as ICT (one of the key development technologies; for more see Aralica, 2020), or researchers from other TPAs or even from other sciences who are involved with the projects because of their specific competencies. This means these individuals do not necessarily need to work in topics related to this TPA to be involved with projects which are related to this TPA.

Recently, an increased use of HRZZ and European programme (e.g., H2020) funds by different institutions has been noted, and this is conditional and linked to new environmental topics/social challenges, in parallel with a significant increase in the number of publications in FOS area 2.7 (*Environmental engineering*) in Croatia. It is estimated that the number of articles related to FOS area 2.7 published annually has tripled between 2010 and 2020.

In the context of interesting topics for future research, two groups of topics were identified in the Energy and sustainable environment TPA. To identify them, the questionnaire set the possibility of publishing in scientific journals as the criterion. The first group of topics is made up of research related to advanced technologies and materials and sustainable materials. The second group of topics is made up of research in the field of energy. This includes alternative fuels and energy sources, energy transition, and energy storage research. In the context of S3 in Croatia, the topics of advanced technologies and materials are linked to researchers who consider themselves as belonging to STPA2. On the other hand, the researchers linked to the second group of topics—the field of energy—belong to both STPAs.

The public scientific organisations analysed within this TPA play an important role in the production and dissemination of research results, new knowledge, and newly developed technologies. Published scientific papers, ideas for new projects, new research equipment acquired, long-term collaborations established, and increased opportunities for applications for new research are the most important **research results from the researchers** coming from the sampled institutions active in this field. These greatly benefit the entire research community.

Regarding international collaborations on projects, researchers from this TPA mostly collaborate with research institutions from the European Union, followed by universities and institutes from the Western Balkans. If we analyse the collaborations on projects with researchers outside of Croatia by individual country or institution, then the University of Ljubljana, the University of Maribor, and the Jože Štefan Institute, the Slovenian research institutions, and the University of Belgrade appear as the leading research institutions the researchers surveyed in this report collaborate with. As for domestic collaborations on projects, most researchers from this TPA collaborate with researchers from IRB and FSB.

The impact of scientific activities of the researchers on the business sector is weaker. One very important research result is the long-term collaboration that is established between the research community, the economy, and the public sector. Having said that, researchers **were less involved in innovation activities,** and poorer results were achieved in **research commercialisation** in the sense of applying knowledge from the research sector in the business sector to produce products and services for the market, which resulted from the requirements of the projects they were involved with.

If we compare the **two analysed sub-thematic priority areas,** we can note that the average scientific productivity per researcher is higher in STPA2, while the researchers in STPA1 are more project-oriented. While the researchers in STPA2 raised more funds from the structural funds, the researchers in STPA1 raised more EU grants.

There is a high **concentration of research** in several institutions in the analysed area. To illustrate, 75 researchers—40.5% of all surveyed researchers—come from five institutions.

- If we look at the published WoS papers, in STPA1 the following institutions stand out: FSB, FER, and IRB, accounting together for 67.8% of the total number of WoS papers in STPA1. In STPA2 the following stand out: IRB, STIM (n=1 researcher), AGR, and PBF, accounting together for 45.3% of papers in the analysed thematic area.
- In terms of research projects, RGN, FSB, IRB, FER, and PBF are in top positions. RITEH, RGN, EIHP, and FER dominate projects with the business sector.
- In terms of the number of collaborations, FER, RGN. and FSB are in the lead—put together, these three institutions account for 46.3% of the total number of collaborations. FER and FSB have more collaborations in STPA1, and RGN has more collaborations in STPA2.
- Innovations are concentrated in a smaller number of institutions. In STPA1, the greatest number of new products were developed at FER (27) and FSB (14), new processes at FER (11) and FSB (13), and new industrial designs also at FER (3) and FSB (3). In STPA2, the development of new products was concentrated in the following institutions: RGB (16), GFUNIZG (13), and AGR (8).
- Over the last 10 years, **86 new technologies were developed in the Energy and sustainable environment TPA.** Out of those, 28 belong to STPA2 (category 2), 38 to STPA1 *(category 1),* 6 to *cross-cutting themes (category 4),* and 14 to *other topics (category 3)*. The majority of the new technologies (52.3%) was developed at six research institutions: IRB (12), FSB (9), FER (8), RGN (7), RITEH (5), and FERIT (4).

Great differences are present between the researchers with regard to their scientific activity. Cluster analysis was used to identify three groups of researchers with respect to published scientific papers, projects and collaboration.

Excellent researchers have, on average, the most scientific papers in the WoS and Scopus databases and the most citations compared to the other two groups, which points to their considerable cumulative scientific output and international recognition. These researchers have, on average, led the largest number of international science and research projects. The number of research projects they were collaborators on is also significant. It should be noted that this group of researchers is less involved in projects in collaboration with the economy, in innovation activities, and in research commercialisation Excellent researchers are also active in the dissemination of knowledge in the energy and sustainable environment area. A large percentage of the researchers have developed new educational programmes and all of them teach at undergraduate and postgraduate levels. Compared to the other groups, the researchers in this group put a greater emphasis on the need for specialised staff who would be able to support the work of their groups. They also put a greater emphasis on the need for new knowledge that would enable them to perform more complex tasks.

Project-oriented researchers have less published scientific papers compared to excellent researchers, but they have on average a significant number of research projects, both as leaders and collaborators, which classifies them as project-oriented researchers. These researchers are slightly more involved in innovation activities and with projects where innovation activities are needed. They were active in the creation of new technologies in the past period. They took part in international collaborations to the same extent as the first group of researchers. A large percentage of these researchers have developed new educational programmes and teach at undergraduate and postgraduate levels. With regard to research infrastructure, the researchers indicate the following as lacking: first and foremost, capital research equipment, followed by specialised research equipment, suitable research space (laboratories with ancillary rooms), funds for maintaining existing and acquiring new capital equipment, laboratory equipment, and computer equipment. They put a greater emphasis on the need for advanced knowledge in research, but also knowledge that could support a stronger commercialisation of their activities.

Researchers with a smaller scientific contribution have the fewest published scientific papers, the fewest citations in the WoS database, and the fewest research projects where they were leaders. These researchers participate in research projects mostly as collaborators and are more focused on projects with the economy. Forever, most of them also teach. The researchers in this group achieved some results in innovation activities. This group has the greatest number of teaching assistants and assistant professors who have just started their careers. They lack a wide range of knowledge in research work because some of them are just starting their careers. These respondents pointed out that they mostly lack advanced knowledge related to modelling, analysis, entrepreneurship, product commercialisation, and patenting, as well as the skills necessary for producing better applications of competitive projects in the S3 field. With regard to research infrastructure, the respondents indicated they lack research space, modern laboratory and specialised equipment, access to databases, modern software tools, and measuring equipment and instruments.

5.2 Recommendations

These recommendations are aimed at two groups of stakeholders who play a crucial part in the further advancement of this thematic area in Croatia—the first group are the authorities responsible for adopting public policies and the second group are the researchers and their research organisations within this thematic priority area.

5.2.1 Recommendations for authorities responsible for adopting and implementing public policies

Building and implementing a consistent S3 programming framework in the following period is recommended. The primary aim of this framework is to attempt to avoid delays in programme implementation as much as possible. A consistent S3 programme refers to the fact that programmes should be defined in accordance with the set goals and that monitoring and evaluation mechanisms that could help decision makers improve the functioning of the overall S3 framework need to be in place. Furthermore, due to the delays in the implementation of the S3 delivery programmes, the authorities responsible for the adoption and implementation of public policies need to make additional efforts to evaluate the existing implementation mechanisms of different projects in the delivery programmes.

Another recommendation is **to differentiate between the researchers who belong to the analysed TPA** and the researchers who deal with the topics of energy and sustainable environment, but who are not currently identified within the analysed TPA Indeed, the researchers identified in the TPA are the ones who participated in the projects of a part of the programmes of S3 Policy Delivery Instruments. Such policy programmes are aimed at reaching the goals of the S3 strategy and can differ significantly with regard to the goal these programmes set for themselves (the report states the difference between the IRI and R&D climate programmes), which in turn determines the profile of the programme participants. On the other hand, the researchers who were identified in an EU programme related to the topics of energy and environmental protection and who did not participate in S3 projects within this TPA are the ones who deal with this topic but are not part of the TPAs. Similarly, there are researchers with papers dealing with these same topics who have no projects within the S3 delivery programmes. The last two groups of researchers could potentially include TPA researchers because they may participate in future S3 delivery programmes that will have similar goals as the current EU programmes.

An additional recommendation is to **carry out mapping of the other TPAs as well** to have a complete picture of the Smart Specialisation Strategy in Croatia. What this report shows is that pilot mapping provides relevant information about the TPA being analysed and the researchers dealing with topics of energy and environmental protection. Additionally, this analytical procedure can point toward potential improvements for the S3 policy process in the future, where TPAs play a crucial part.

One important recommendation is to **introduce continuous monitoring of projects** that is identical and comparable, with all the usual elements: project duration, eligible costs, project participants, partner institutions, budgets, and project leaders. In addition, monitoring related to project goals, project duration, and planned and achieved value indicators should be included. This would help to better evaluate a programme in S3. In this context, the monitoring of researchers and their institutions is also important, which should preferably be made using numerical identifiers of the researchers (e.g., OIB/PIN, ORCID) and their institutions (OIB/PIN). Unique identifiers facilitate the faster building of databases on researchers and their activities related to S3 in Croatia, which is the basis of any activity analysis.

The final recommendation is to promote collaboration between different research teams working on the same topics in the areas analysed in this report. Specifically, to participate in larger EU projects, larger teams are crucial. For example, Croatian researchers do not participate in Teaming projects, which are a type of infrastructure project financed by the European Commission, because there are no opportunities to create larger teams in a single individual institution. That is why the programmes that promote collaboration in the topics of energy and environmental protection are necessary to support participation in larger EU projects. In doing so, special attention should be directed towards the promotion of international collaboration.

5.2.2 Recommendations for researchers and the associated research organisations

Although, as this report shows, there are clear differences between the researchers and research groups according to different analysis categories, there are some recommendations for further improvement that apply to all profiles and categories.

The first recommendation relates to **the need for continuous monitoring and evaluation of acquisition priorities for different forms of research infrastructure and modern equipment** which is necessary for the work of the researchers, at the level of faculties and institutions. Even though a step forward was made in this programming period in terms of financing infrastructure and that there are national schemes aimed at financing different research equipment, the survey showed that much equipment still needs to be acquired and that different forms of infrastructure necessary for research need to be used. To be specific, the survey found that the existing laboratory equipment is old, there are insufficient funds for the acquisition of new equipment, the space for research equipment is limited, there are not enough expert staff, and the advanced knowledge and skills are lacking.

The next recommendation concerns a **better understanding of the implementation of projects that are part of the S3 Policy Delivery Instruments**, where in such a process there are faculties and project offices on one side and different specialised institutions such as SAFU on the other. Most S3 programmes are behind schedule at this point and there is no single reason for that.[29]

Another recommendation is to **support the development of the competencies of young researchers and the advancement of the knowledge of existing employees** who contribute to research and project activity. In other words, the development of technology and the production of knowledge in this TPA are also connected with the continuous improvement of the activities of researchers concerning research, article publication, and project activities. An important channel for acquiring new knowledge

[29] The reasons for the delays can be different. To illustrate, most of the programmes where institutions in the research sector are participants began implementing in 2018, even though the S3 strategy started in 2016. The completion of the Strategy is scheduled for 2020, but the programmes within the strategy will probably be implemented still in 2023. Furthermore, additional delays are possible because of the lack of understanding between the participants in the project implementation process. To be specific, the implementation of each project is led by an organisation carrying out the project (e.g., faculty/institute), with the implementing bodies, such as SAFU, assisting the implementation through evaluation and approval of financing for individual parts of the project. It is assumed that the differences in understanding the project subject between the participants in a particular project is not substantial and does not add to misunderstandings about the implementation, but this is not necessarily the case in practice.

are international and domestic collaborations, so this recommendation can be implemented by promoting collaboration using specific policy instruments.

As for research work in the sense of publishing WoS papers for experienced researchers, it is recommended to **increase the number of quality WoS papers in high impact factor journals** which are important for the field of research of the individual researchers. Preferably in this situation the individual author and/or their group collaborate with co-authors or researchers from international institutions. Furthermore, it would be most preferred if collaboration on projects would run in parallel with collaboration on publishing articles relevant to the field of research. A recommendation for younger researchers would be to increase the number of WoS papers in general. As stated earlier in this report, the model used for the analysis of research groups (see 3.6.2) identified three groups of researchers. The third group were researchers who have shown no remarkable results neither in terms of research nor in terms of projects. The recommendation for these researchers is to increase their number of WoS papers, ideally while strengthening their research capacities at the same time, to participate in projects. A researcher can increase their number of WoS papers through the possibilities offered by HRZZ, which present an excellent opportunity for networking both on domestic and international levels. Participating in these programmes provides the opportunity for involvement in different EU programmes because it promotes the collaboration between researchers at different institutions in the fields of energy and environment. Likewise, this approach can facilitate the strengthening of international collaboration with the aim of producing quality scientific papers that get published in prestigious journals, it can increase the international mobility of researchers, and it can encourage the emergence of new research topics.

Finally, faculties and institutes should **articulate their views on innovations, technology commercialisation, use of intellectual property and the perspectives of spin-off companies** at faculties and universities. Poorer results in these areas—compared to the results in the areas of production of scientific papers and participation in different types of projects, whether they are research competitive projects or projects aimed at the market—have no one, clear explanation. They could be arising from the fact that this is not the primary focus of the faculty/institution implementing the project, that the researchers do not have enough time or enough material resources to follow that direction, or that they simply do not have the skills and the expertise necessary to perform such activities. Therefore, it is necessary for the faculty/institution to articulate their mission and vision regarding the areas in which the researchers in the analysed TPA have poorer results more clearly.

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Annex 1: Survey questionnaire

QUESTIONNAIRE FOR RESEARCHERS

Date of completing the questionnaire: ____________________

*This questionnaire is carried out as part of the Science and Technology Foresight project of the Ministry of Science and Education of the Republic of Croatia. The goal is to obtain your opinion as a researcher and to gather information about the concentration of research and innovation excellence in the part of the science and technology system that is related to the **Energy and sustainable environment** thematic area as it is defined in the Smart Specialisation Strategy of the Republic of Croatia (S3) (*https://www.obzor2020.hr/userfiles/obzor2020/pdfs/Strategija_pametne_specijalizacije_RH_2016_2020.pdf*; for more information on the area, see Chapter 5.2.2 Energy and sustainable environment, p. 102–114).*

The gathered information will help create the guidelines for reviewing the measures laid down in the strategic documents within the field of science, technology and innovation.

*Please answer all the questions in your capacity as researcher. The period being analysed is from 01.01.2011 to 30.06.2021; if you have been working in science for less than 10 years, please enter your results for the period since you started working in a research organisation. The data you are about to enter is related to the whole of the **Energy and sustainable environment** thematic area. The data will be processed and published on an aggregate level and will be kept as strictly confidential. Thank you in advance for your answers and your cooperation.*

Please send in your answers over the next three weeks. Should you have any questions, please contact Zoran Aralica (zaralica@eizg.hr) or Ivan-Damir Anić (danic@eizg.hr) from the Institute of Economics, Zagreb.

0.1. Please read the GDPR statement and check if you consent to take part in this survey.

By completing this questionnaire, the data subject gives their consent to the Institute of Economics, Zagreb, to collect and process the personal data specified in the questionnaire exclusively for the purpose of implementing the *Science and Technology Foresight* project. The personal data the data subject enters into the questionnaire will be processed in accordance with the applicable personal data protection regulations and will not be made public. The data subject may at any time and without explanation withdraw the given consent and request the processing of their personal data be terminated. Consent may be withdrawn via e-mail.

I have read the above statement and hereby give my consent to participate in this survey:

YES NO

0.2. Would you like to have a summary of the research sent to you after the survey has ended?

YES NO

1 Basic information about the researcher

1.1. Name and surname of the researcher:

____

1.2. Name of research organisation: ____

1.3. Email address of the researcher:

____

1.4. You are employed for:

1. Indefinite duration
2. Fixed-term

1.5 Specify your job title: (*One possible answer only.*)

1. Teaching assistant and/or postdoctoral student
2. Assistant professor
3. Associate professor
4. Full professor
5. Full professor tenure
6. Research associate
7. Senior research associate
8. Scientific adviser
9. Scientific adviser tenure
10. Lecturer
11. Senior lecturer
12. College professor
13. College professor tenure
14. Other job title, please specify: ________________________________

1.6 In which STPA as they are defined in the Smart Specialisation Strategy of the Republic of Croatia (S3) is your research dominant? (For more information about this area see Smart Specialisation Strategy, chapter 5.2.2 Energy and sustainable environment, p. 102–114); https://www.obzor2020.hr/userfiles/obzor2020/pdfs/Strategija_pametne_specijalizacije_RH_2016_2020.pdf). *(One possible answer only.)*

1. Energy technologies, systems and equipment STPA
2. Environmentally friendly technologies, equipment and advanced materials STPA
3. Other sub-area not necessarily within S3, please specify: ____

1.7 Does you have research in BOTH STPAs—both in the Energy technologies, systems and equipment STPA and the Environmentally friendly technologies, equipment and advanced materials STPA?

1. YES 2 NO

1.8 How many years of experience do you have in academia and the research sector with research related to the Energy and sustainable environment thematic area? ______________

1.9 Estimate what percentage of your time you devoted ON A MONTHLY BASIS to research work for research in the Energy and sustainable environment thematic area? (in %) ________

2 Published scientific papers

2.1 Tell us about your scientific productivity in the Energy and sustainable environment area from 2011 to 2021. The thematic areas have been defined in the Smart Specialisation Strategy of the Republic of Croatia (S3), please classify your works accordingly.

(1) Total number of scientific papers published and accepted for publication in journals referenced in the ***Web of Science Core Collection/Current contents connect*** database: _________
(2) Total number of scientific papers published and accepted for publication in journals referenced in the ***Scopus*** database: _________
(3) TOTAL NUMBER of scientific papers published and accepted for publication in journals (**in all databases**, including Scopus, WoS, and any other database that are evaluated when promoting candidates into a research or teaching position): ______

2.2 List up to 5 of your papers that you think are the most significant from the period between 2011 and 2021 which are related to the Energy and sustainable environment thematic area as defined in the Smart Specialisation Strategy. *(Indicate authors, title of paper, name of journal and year of publication.)*

1. ____

2. ____

3. ____

4. ____

5. ____

2.3 With regard to the possibility of publication in scientific journals in the next 5 to 10 years, please list some topics you believe would be interesting for research that are related to the Energy and sustainable environment thematic area. *(Indicate a few.)*

____

3 Research and development projects

3.0 Have you taken part in projects (COMPLETED PROJECTS, ONGOING PROJECTS, SUBMITTED PROJECTS NOT YET IN IMPLEMENTATION STAGE) or are you PLANNING TO SUBMIT APPLICATIONS FOR PROJECTS as PROJECT LEADER AND/OR COLLABORATOR within the Energy and sustainable environment thematic area as defined in the S3 Strategy, either competitive research projects or collaborations with the business community?

1 Yes (go to question 3.1)   2 No (go to question 4.0)

3.1. Were you involved in a competitive project (either completed or ongoing) in the role of PROJECT LEADER from 2011 to 2021 in the Energy and sustainable environment thematic area?

1 Yes (go to question 3.1.1)   2 No (go to question 3.1.2)

3.1.1 COMPLETED AND ONGOING PROJECTS WHERE YOU WERE IN THE ROLE OF PROJECT LEADER

Please provide information about your implemented and ongoing competitive projects from 2011 to 2021 in the Energy and sustainable environment thematic area as it is defined in the S3 Strategy. Indicate the sources, number of projects, and the amounts of financing in HRK. *(If you had no such projects in any of the categories, please put in zero. If you entered a project under the 'project leader' category, the same project should not be entered under the 'project collaborator' category. If you are not certain, please provide an estimate. Round amounts to whole numbers.)*

PROJECT LEADER	**(1) IMPLEMENTED PROJECTS**		**(2) ONGOING PROJECTS**	
	1.1. Total number of projects	1.2. Total amount of financing in HRK	**2.1.** Total number of projects	**2.2.** Total amount of financing in HRK
1. European grants (FP7; Horizon 2020 including sub-programmes, eg COST, EIT)				
2. Structural funds (ERDF), eg, IRI I, IRI II, SIIF				
3. UKF (Unity through knowledge Fund)				
4. PoC (Proof of Concept programme)				
5. IRCRO, RAZUM				
6. HRZZ programmes (Croatian Science Foundation)				
7. Other research projects contracted with the institution where you are employed, please specify:_______________				

3.1.2 Were you involved in a competitive project (either completed or ongoing) in the role of PROJECT COLLABORATOR from 2011 to 2021 in the Energy and sustainable environment thematic area as it is defined in the S3 Strategy?

1 Yes (go to question 3.1.2.1)   2 No (go to question 3.2)

3.1.2.1 COMPLETED AND ONGOING PROJECTS WHERE YOU WERE IN THE ROLE OF PROJECT COLLABORATOR. *If you had no such projects in any of the categories, please put in zero.*

PROJECT COLLABORATOR	**1 IMPLEMENTED PROJECTS**	**2 ONGOING PROJECTS**

	1.1 Total number of projects	1.2 Total amount of financing in HRK	2.1 Total number of projects	Total amount of financing in HRK
1. European grants (FP7; Horizon 2020 including sub-programmes, eg COST, EIT)				
2. Structural funds (ERDF), eg, IRI I, IRI II, SIIF				
3. UKF (Unity through knowledge Fund)				
4. PoC (Proof of Concept programme)				
5. IRCRO, RAZUM				
6. HRZZ programmes (Croatian Science Foundation)				
7. Other research projects contracted with the institution where you are employed, please specify:_______________				

3.2 SUBMITTED AND PLANNED PROJECTS

Do you have any SUBMITTED international competitive science and research projects (submitted and awaiting verification or awaiting evaluation results but not yet in the implementation stage) related to the Energy and sustainable environment thematic area?

1 Yes (go to question 3.2.1)   2 No (go to question 3.2.2)

3.2.1 How many SUBMITTED international competitive science and research projects (submitted and awaiting verification or awaiting evaluation results but not yet in the implementation stage) related to the Energy and sustainable environment thematic area do you have? *If you had no such projects in any of the categories, please put in zero.*

SUBMITTED PROJECTS	(1) Total number	(2) Total amount of financing in HRK
1. European grants (FP7; Horizon 2020 including sub-programmes, eg COST, EIT)		
2. Structural funds (ERDF), eg, IRI I, IRI II, SIIF		
3. UKF (Unity through knowledge Fund)		
4. PoC (Proof of Concept programme)		
5. IRCRO, RAZUM		
6. HRZZ programme (Croatian Science Foundation)		
7. Other research projects, please specify:_________________________________		

3.2.2 Indicate how many international competitive science and research projects related to the Energy and sustainable environment thematic area are you PLANNING to submit an application for

in the period from 2021 to 2027. *(Estimate with regard to the past period). If you had no such projects in any of the categories, please put in zero.*

PLANNED PROJECT APPLICATIONS	(1) Total number
1. European grants (FP7; Horizon 2020 including sub-programmes, eg COST, EIT)	
2. Structural funds (ERDF), eg, IRI I, IRI II, SIIF	
3. UKF (Unity through knowledge Fund)	
4. PoC (Proof of Concept programme)	
5. IRCRO, RAZUM	
6. HRZZ programme (Croatian Science Foundation)	
7. Other research projects, please specify:________________________________	

3.3 If the planned projects you indicated relate to any areas other than the Energy and sustainable environment area, please indicate which. *(If they do not relate to any other areas, leave blank)*

____

3.4.0 Were you involved in a project in cooperation with the BUSINESS SECTOR/THE ECONOMY (either completed or ongoing) in the role of PROJECT LEADER from 2011 to 2021 in the Energy and sustainable environment thematic area as it is defined in the S3 Strategy?

1 Yes (go to question 3.4) 2 No (go to question 3.5.0)

3.4 Please list your projects in cooperation with the BUSINESS SECTOR/THE ECONOMY in which the business sector was the contracting authority and you were the PROJECT LEADER from 2011 to 2021 and which are related to the Energy and sustainable environment thematic area. *(If you had no such projects in any of the categories, please put in zero. If you entered a project under the 'project leader' category, the same project should not be entered under the 'project collaborator' category. If you are not certain, please provide an estimate. Round amounts to whole numbers.)*

PROJECT LEADER	*(1) COMPLETED PROJECTS*		*(2) ONGOING PROJECTS*	
	1.1. Number	*1.2. Total amount in HRK*	*2.1 Number*	*2.2 Total amount in HRK*
1. Contracting authorities in the Republic of Croatia				
2. Contracting authorities outside the Republic of Croatia				

3.5.0 Were you involved in a project in cooperation with the BUSINESS SECTOR/THE ECONOMY (either completed or ongoing) in the role of PROJECT COLLABORATOR from 2011 to 2021 in the Energy and sustainable environment thematic area as it is defined in the S3 Strategy?

1 Yes (go to question 3.5) 2 No (go to question 3.6)

3.5 Please list the total number of projects in cooperation with the BUSINESS SECTOR/THE ECONOMY in which the business sector was the contracting authority and you were the PROJECT COLLABORATOR from 2011 to 2021 and which are related to the Energy and sustainable environment thematic area. *(If you had no such projects in any of the categories, please put in zero. If you entered a project under the 'project leader' category, the same project should not be entered under the 'project collaborator' category. If you are not certain, please provide an estimate. Round amounts to whole numbers.)*

PROJECT COLLABORATOR	*1. COMPLETED PROJECTS*		*2. ONGOING PROJECTS*	
	1.1. Number	*1.2. Total amount in HRK*	*2.1 Number*	*2.2 Total amount in HRK*
1. Contracting authorities in the Republic of Croatia				
2. Contracting authorities outside the Republic of Croatia				

3.6 List up to 5 of your projects that you think are the most significant from the period between 2011 and 2021 which are related to the Energy and sustainable environment thematic area.

1. ____

2. ____

3. ____

4. ____

5. ____

3.7 In the listed projects, which areas are your subspeciality, in which areas do you have the most expertise and experience?

____

3.8 Please evaluate the impacts of all your projects in the Energy and sustainable environment thematic area from 2011 to 2021 according to **each of the items listed in the table, on a scale from 1 (no impact) to 5 (great impact).**

1. Securing research financing from EU funds	1	2	3	4	5

2. Ability to secure new research financing from other sources (eg the economy)	1	2	3	4	5
3. Access to research equipment outside of Croatia	1	2	3	4	5
4. Purchase of new research equipment	1	2	3	4	5
5. Recruitment of new researchers	1	2	3	4	5
6. Mobility of researchers	1	2	3	4	5
7. Training of researchers	1	2	3	4	5
8. Collaboration with the business community	1	2	3	4	5
9. Cooperation with civil society	1	2	3	4	5
10. Cooperation with the public sector on public policy making	1	2	3	4	5
11. Collaboration with the academic community	1	2	3	4	5
12. Advancing the image in the research community	1	2	3	4	5
13. Generating new research ideas	1	2	3	4	5
14. Publication of research in journals indexed in the WoS database	1	2	3	4	5
15. Publication of research in journals indexed in the Scopus database	1	2	3	4	5
16. Development of new products, services, or processes	1	2	3	4	5
17. Improvement of existing products, services, or processes	1	2	3	4	5
18. Commercialisation* of your research results	1	2	3	4	5
19. Establishment of a new company (companies)	1	2	3	4	5
20. Obtaining patents	1	2	3	4	5
21. Obtaining other forms of intellectual property rights (eg trademark, industrial design)	1	2	3	4	5
22. Some other impact, please specify: ______________________________	1	2	3	4	5

*Commercialisation implies the use and application of knowledge from the research sector in the business sector to produce products and services for the market.

4 Collaboration

4.0 Have you collaborated with partners in Croatia and/or outside of Croatia on research in the Energy and sustainable environment thematic area, be it on competitive research projects or collaborations with the business community?

1 Yes (go to question 4.1) 2 No (go to question 4.6)

4.1 Tell us more about your collaborations with partners in Croatia and/or outside of Croatia on research in the Energy and sustainable environment thematic area. How many such collaborations did you have in TOTAL on your projects where you were the leader and/or collaborator from 2011 to 2021? *(If you had no collaborations, please put in 0. If you are not certain, please provide an estimate.).*

PROJECT LEADER / PROJECT COLLABORATOR	Number
1 How many institutions from the research community have you collaborated with?	
1.1. From Croatia?	
1.2. From outside of Croatia?	
2. How many companies from the business community have you collaborated with?	
2.1. From Croatia?	
2.2. From outside of Croatia?	

4.2 Name several research institutions you have collaborated with on your projects in the Energy and sustainable environment area: *(If you don't have a category, leave blank.)*

4.2.1. from Croatia: ____

4.2.2. from outside of Croatia:____

4.3 Rate the importance of the listed reasons for collaboration with partners on projects related to the Energy and sustainable environment thematic area from 2011 to 2021 on a scale from 1 (not important) to 5 (extremely important).

Joint research and development projects	1	2	3	4	5
Transfer of knowledge from one project partner to another	1	2	3	4	5
Acquisition of research and development (R&D) services	1	2	3	4	5
Technological consultations	1	2	3	4	5
Testing/creating a new prototype	1	2	3	4	5
Preparation of technical documentation	1	2	3	4	5
Research commercialisation	1	2	3	4	5
Patent licensing/registration	1	2	3	4	5
Intellectual property	1	2	3	4	5
Joint publishing of research in journals in the WoS or Scopus database.	1	2	3	4	5
Other reason, please specify: ______________________	1	2	3	4	5

4.4 Name several institutions you collaborate with for your research work in the Energy and sustainable environment thematic area (e.g., in writing research articles) that is not related to projects: *(If you don't have a category, leave blank.)*

4.4.1. from Croatia: ____

4.4.2. from outside of Croatia: ____

4.5 How would you rate the quality of your collaborations in the Energy and sustainable environment thematic area on a scale from 1 (extremely bad) to 5 (extremely good)?

1. Collaboration with the research community	1	2	3	4	5
2. Collaboration with the business community	1	2	3	4	5
3. Cooperation with the government/public sector	1	2	3	4	5
4. Cooperation with the non-governmental sector	1	2	3	4	5

4.6 What factors are limiting your possibilities for (more) collaborations? Rate your answers on a scale from 1 (not limiting) to 5 (extremely limiting).

1. There is insufficient information about the needs of companies/institutions.	1	2	3	4	5
2. There are not enough incentives to collaborate with companies/institutions.	1	2	3	4	5
3. Collaborating with companies/institutions is difficult.	1	2	3	4	5
4. The disclosure of business secrets in research is a concern.	1	2	3	4	5

5. There is not enough time, daily tasks take too much time.	1	2	3	4	5
6. There are insufficient resources (eg human potential, financial resources, and research infrastructure) necessary for collaboration.	1	2	3	4	5
7. There is no need for projects in the field of innovation and technology.	1	2	3	4	5
8. Other reason, please specify: ______________________________	1	2	3	4	5

5 Patents and research commercialisation

Commercialisation implies the use and application of knowledge from the research sector in the business sector to produce products and services for the market.

5.1 What were the results of your research in the Energy and Sustainable Environment thematic area?

1. Creation of a new product prototype 1) YES 2) NO
2. Creation of a new product 1) YES 2) NO
3. Improvement of existing products 1) YES 2) NO
4. New processes* 1) YES 2) NO
5. Improvement of existing processes* 1) YES 2) NO
6. Industrial design** 1) YES 2) NO
7. Scientific papers 1) YES 2) NO
8. Generation of new research project ideas 1) YES 2) NO
9. Applications for further financing schemes 1) YES 2) NO
10. Acquisition of new knowledge and expertise 1) YES 2) NO
11. Establishment of production/service procedures 1) YES 2) NO
12. Establishment of long-term collaboration 1) YES 2) NO
13. Acquisition of new research equipment 1) YES 2) NO
14. Creation of spin-off and/or spin-out companies 1) YES 2) NO
15. Something else, please specify_________________________ 1) YES 2) NO

**Process refers to a new or significantly improved method of production, new or significantly improved logistics, delivery, or distribution method, and new or significantly improved supporting activities (eg system maintenance, acquisition, accounting, or IT activities). **Design is the external look (appearance) of a product.*

5.2 If you have developed products, processes, or industrial designs from 2011 to 2021 in the Energy and sustainable environment thematic area, please indicate their number. *(If you don't have a category, please put in 0).*

1. How many new products/services have been developed? ______

    1.1 How many of these have been commercialised________

2. How many new processes have been developed________

    2.1 How many of these have been commercialised? ______

3. How many new industrial designs have been developed? ______

    3.1 How many of these have been commercialised________

5.3 How many of the following are you developing at the moment: *(If you don't have a category, please put in 0).*

1. New products/services? ______
2. New processes? ________________
3. New industrial designs? _________________

5.4 Indicate which NEW TECHNOLOGIES you have developed in your organisation as part of your research in the Energy and sustainable environment thematic area over the last ten years? *(If you don't have this category, leave blank).*

____

5.5.0 Have you used any form of intellectual property protection (patent, trademark, industrial design, copyright, etc.) for the results of your research from 2011 to 2021?

1 Yes (go to question 5.5)   2 No (go to question 5.9)

5.5 Which forms of intellectual property protection did you use for the results of your research from 2011 to 2021?

1.	Patent	1) YES 2) NO
2.	Trademark	1) YES 2) NO
3.	Industrial design	1) YES 2) NO
4.	Copyright	1) YES 2) NO
5.	Other form of protection (please indicate: _________________)	1) YES 2) NO

(If the answer to the **(sub)question on patents is YES,** go to question 5.6; if the answer to the **(sub)question about patents is NO,** go to question 5.10.0.)

5.6 If you have applied for a patent, indicate how many patent applications you submitted from 2011 to 2021 in the Energy and sustainable environment thematic area. *(If you have not submitted any patent applications, please put in zero.)*

	(1) Total number of patent applications	(2) Total number of granted patents
(1) In Croatia (State Intellectual Property Office)		
(2) European Patent Office		
(3) Other patent offices outside the EU		

5.7 Have you licensed your patents from 2011 to 2021?   1) YES 2) NO

5.8 Have your patents been used to establish a new company from 2011 to 2021? 1) YES 2) NO

5.9 If you have not used any forms of intellectual property protection from 2011 to 2021, please indicate why. *(Check all that apply.)*

(1) Application is too expensive.
(2) Renewal is too expensive.
(3) Intellectual property protection does not provide protection in our industry.
(4) Other reason, please specify: ____

5.10.0 Have you established spin-off and/or spin-out companies from 2011 to 2021 in the Energy and sustainable environment thematic area?

1 Yes (go to question 5.10) 2 No (go to question 5.11)

5.10 If you have established spin-off and/or spin-out companies from 2011 to 2021 in the Energy and sustainable environment thematic area, please indicate: *(If you have not established any such companies, go to question 5.11)*

1. How many companies were established: ______________
2. Are these companies still active: YES NO
3. Please provide the name(s) of these companies: _____________________________________
4. How many employees do these companies have on average per year (take the most recent available year): ______
5. In HRK, how much annual sales revenue does the company have on average per year (take the most recent available year): _________

5.11 Have you commercialised the results of your projects from 2011 to 2021?

1) YES 2) NO (If NO, go to question 5.15)

5.12 Who did you commercialise the results of your projects with? *(Check all that apply.)*

(1) With the research community
(2) With the government and public sector (e.g., technology centres in regional agencies or cities)
(3) With the business community
(4) On your own.

5.13 Have you or your institution signed any commercialisation and/or collaboration agreements with other institutions from 2011 to 2021?

1 Commercialisation agreements 1) YES 2) NO

2 Collaboration agreements 1) YES 2) NO

5.14 Who have you signed commercialisation and/or collaboration agreements in the Energy and sustainable environment area with from 2011 to 2021? *(Please put in zero if you had none. Round amounts to whole numbers. If you are not certain, please provide an estimate.).*

1. **With the research community**

1.1 Number of commercialisation agreements: _________

1.2 Value of the commercialisation agreements in HRK: _________

1.3 Number of collaboration agreements: _________

1.4 Value of the collaboration agreements in HRK: _________

2. **With the business community**

2.1 Number of commercialisation agreements: _________

2.2 Value of the commercialisation agreements in HRK: _________

2.3 Number of collaboration agreements: _________

2.4 Value of the collaboration agreements in HRK: _________

3. With the government and public sector (e.g., technology centres in regional agencies or cities)

3.1 Number of commercialisation agreements: _________

3.2 Value of the commercialisation agreements in HRK: _________

3.3 Number of collaboration agreements: _________

3.4 Value of the collaboration agreements in HRK: _________

Go to question 6.1.

5.15 If you have not commercialised your research results from 2011 to 2021 in the Energy and sustainable environment area, please indicate the reasons why. *Rate your answers on a scale from 1 (not limiting) to 5 (extremely limiting).*

1. Lack of commercialisation funds	1	2	3	4	5
2. Lack of expertise and experience necessary for commercialisation	1	2	3	4	5
3. Difficulties in finding commercialisation partners	1	2	3	4	5
4. Strong competition on the market	1	2	3	4	5
5. Insufficient market demand	1	2	3	4	5
6. Lack of support from the institution where the researcher is employed	1	2	3	4	5
7. Commercialisation of research results not planned/expected	1	2	3	4	5
8. Other reason(s), please specify: _____.	1	2	3	4	5

6 Research infrastructure

6.1 Indicate which of the listed research infrastructure items you mainly use in your work and to what extent these help you in generating new knowledge and technologies in the Energy and sustainable environment area. *(If you have NOT USED one of the listed infrastructure items, mark NO and move on to the next item on the list. For the infrastructure item you have used, first mark whether you used it in Croatia, outside of Croatia, or both, and then use grades from 1 (did not contribute at all) to 5 (contributed exceptionally) to indicate to what extent this item has helped you in generating new knowledge, innovation, and new technologies in the Energy and sustainable environment area.)*

	Use			**Infrastructure contribution**				
		In Croatia	**Outside of Croatia**					
1. Scientific equipment	NO	YES	YES	1	2	3	4	5
1.1. Measuring equipment	NO	YES	YES	1	2	3	4	5
1.2. Instruments	NO	YES	YES	1	2	3	4	5
1.3. Observatories (field laboratories)	NO	YES	YES	1	2	3	4	5
1.4. Computer and electronic equipment	NO	YES	YES	1	2	3	4	5
1.5. Large-scale research facilities	NO	YES	YES	1	2	3	4	5
2. Collections, records, scientific data	NO	YES	YES	1	2	3	4	5
2.1. Access to scientific journals/books databases	NO	YES	YES	1	2	3	4	5
3. E-infrastructure (data systems, computer systems, communication networks)	NO	YES	YES	1	2	3	4	5
3.1. Communication networks	NO	YES	YES	1	2	3	4	5
3.2. Software solutions	NO	YES	YES	1	2	3	4	5
4. Habitats	NO	YES	YES	1	2	3	4	5
5. Research vessels	NO	YES	YES	1	2	3	4	5
6. Satellites	NO	YES	YES	1	2	3	4	5
7. Telescopes	NO	YES	YES	1	2	3	4	5
8. Synchrotrons	NO	YES	YES	1	2	3	4	5
9. Accelerators	NO	YES	YES	1	2	3	4	5
10. Other infrastructure, please specify: ____________	NO	YES	YES	1	2	3	4	5

6.2 Indicate what you lack in terms of research infrastructure that makes you unable to generate more new knowledge in research, innovate more, and ensure a better transfer of new knowledge and technology in the Energy and sustainable environment area?

____

7 Knowledge dissemination

7.1 Name a few of the most important educational programmes (e.g., new courses or training for a wider range of users or online educational courses) that you have developed and implemented in the Energy and sustainable environment area over the last ten years? *(If you don't have this category, leave blank.)*

____

7.2 Please list the names of undergraduate and postgraduate courses you participate in either as the head or lecturer which are related to the Energy and sustainable environment area. *(If you don't have this category, leave blank.)*

____

7.3 Indicate how intensely you expect to provide your expert services in the next 5 to 10 years compared to the period from 2011 to 2021 based on your research in the Energy and sustainable environment area? *Rate the answers on a scale from 1 (I expect the interest to significantly decrease) to 5 (I expect the interest to significantly increase).*

1. Conducting educational programmes (courses, workshops, etc.)	1	2	3	4	5
2. Renting research equipment for the needs of the business sector*	1	2	3	4	5
3. Producing studies, analyses, and other forms of expert work for the needs of the business sector	1	2	3	4	5
4. Producing studies, analyses, and other forms of expert work for the needs of the public sector	1	2	3	4	5
5. Other forms of expert services (please specify):__________________	1	2	3	4	5

*Except for equipment financed from the European Regional Development Fund.

7.4. Over the last 10 years, have you participated as professor/researcher in any educational programme organised by a university/institution in Croatia and outside of Croatia in the Energy and sustainable environment area as it is defined within S3?

1. Yes (go to question 7.5) 2 No (go to question 7.6)

7.5. If you answered yes for participating in an educational programme, please name a few of the programmes:

____

7.6. Would you be interested to participate in educational programmes in the Energy and sustainable environment area as it is defined within S3 in the future?

1. Yes 2. No

7.7. Finally, please tell us what expertise you lack in the Energy and sustainable environment area?

____

(END OF QUESTIONNAIRE)

Thank you for your participation!

Annex 2: List of experts in the pilot research

1. Neven Duić, University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Environmentally friendly technologies, equipment and advanced materials STPA within S3, private interview on 17.08.2021 at 1:00 pm via MS Teams

2. Sibila Borojević Šoštarić, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Environmentally friendly technologies, equipment and advanced materials STPA within S3, private interview on 23.08.2021 at 10:00 am via MS Teams

3. Anet Režek Jambrak, University of Zagreb, Faculty of Food Technology and Biotechnology, Energy technologies, systems and equipment STPA within S3, private interview on 25.08.2021 at 11:00 am via MS Teams

4. Siniša Sovilj, Juraj Dobrila University of Pula, Faculty of Informatics, Energy technologies, systems and equipment STPA within S3, completed the paper version of the questionnaire, September 2021

5. Boris Lazarević, University of Zagreb, Faculty of Agriculture, Environmentally friendly technologies, equipment and advanced materials STPA within S3, completed the paper version of the questionnaire, September 2021

Annex 3: List of tables and figures

Annex 4: List of abbreviations

AMPEU—Agencija za mobilnost i programe EU (Agency for Mobility and EU Programmes)

COST—European Cooperation in Science and Technology

DZIV—Državni zavod za intelektualno vlasništvo (State Intellectual Property Office)

EIT—European Institute of Innovation & Technology

Erasmus—EU Erasmus programme

ERDF—European Regional Development Fund

EU—European Union

FOS—Field of Science and Technology

FP7—Seventh Framework Programme for Research, Technological Development and Demonstration Activities

HAMAG-BICRO—Hrvatska agencija za malo gospodarstvo, inovacije i investicije (Croatian Agency for SMEs, Innovation and Investments)

Horizon 2020 (H2020)—EU framework programme for research and innovation

HRK—Croatian kuna

HRZZ— Hrvatska zaklada za znanost (Croatian Science Foundation)

HR-ZOO—Hrvatski znanstveni i obrazovni oblak (Croatian Scientific and Educational Cloud)

ICT—Information and communication technologies

INFRA— Investing in organisational reform and infrastructure in the research, development and innovation sectors

IPA—Instrument for Pre-accession Assistance

IPC—International Patent Classification

IRCRO—Program za istraživanje i razvoj (Research and Development Programme)

IRI—Research and development projects

IVI—Inovacijsko vijeće za industriju Republike Hrvatske (Innovaton Council for Industry of the Republic of Croatia)

KET—Key enabling technologies

MINGOR—Ministarstvo gospodarstva i održivog razvoja (Ministry of Economy and Sustainable Development)

MROSP—Ministarstvo rada, mirovinskog sustava, obitelji i socijalne politike (Ministry of Labour, Pension System, Family and Social Policy)

MZO—Ministarstvo znanosti i obrazovanja (Ministy of Science and Education)

NACE—Statistical classification of economic activities

OECD—Organisation for Economic Co-operation and Development

PCT—Patent Cooperation Treaty

PoC—Proof of Concept

RAZUM—Razvoj na znanju utemeljenih poduzeća (Development of Knowledge-Based Companies)

S3—Smart Specialisation Strategy of the Republic of Croatia

Scopus—Scopus scientific papers database

SIIF—Science and Innovation Investment Fund

STPA—Sub-thematic priority area

STPA1—Sub-thematic priority area Energy technologies, systems and equipment

STPA2—Sub-thematic priority area Environmentally friendly technologies, equipment and advanced materials

STRIP—Jačanje kapaciteta za istraživanje, razvoj i inovacije (Strengthening the economy by applying research and innovation)

TIV—Thematic Innovation Council

TPA—Thematic priority area

UKF—Unity through Knowledge Fund

UNESCO—The United Nations Educational, Scientific and Cultural Organization

ZCI—Centres of research excellence

WoS—Web of Science Core Collection/Current Contents database

Annex 5: List of acronyms of institutions used in the report

Research institution	Acronym
Brodarski institut (The Shipbuilding Institute)	BI
Ekonomski institut, Zagreb (The Institute of Economics, Zagreb)	EIZ
Energetski institut Hrvoje Požar (Hrvoje Požar Energy Institute)	EIHP
Fakultet za menadžment u turizmu i ugostiteljstvu, Opatija (Faculty of Tourism and Hospitality Management, Opatija)	FMTU
Hrvatska akademija znanosti i umjetnosti (Croatian Academy of Sciences and Arts)	HAZU
Hrvatska akademska i istraživačka mreža CARNET (Croatian Academic and Research Network—CARNET)	CARNET
Hrvatski geološki institut (Croatian Geological Survey)	HGI
Hrvatski šumarski institut, Jastrebarsko (Croatian Forest Research Institute, Jastrebarsko)	HŠI
Hrvatsko katoličko sveučilište, Zagreb (The Catholic University of Croatia, Zagreb)	UNICATH
Institut društvenih znanosti Ivo Pilar (The Institute of Social Sciences 'Ivo Pilar')	IDZIP
Institut Ruđer Bošković (Ruđer Bošković Institute)	IRB
Institut za fiziku, Zagreb (Institute of Physics, Zagreb)	IF
Institut za jadranske kulture i melioraciju krša, Split (The Institute for Adriatic Crops and Karst Reclamation, Split)	KRS
Institut za medicinska istraživanja i medicinu rada (Institute for Medical Research and Occupational Health)	IMI
Institut za more i priobalje, Dubrovnik (Institute for Marine and Coastal Research, Dubrovnik)	IMP
Institut za nuklearnu tehnologiju (Institute for Nuclear Technology)	INT
Institut za oceanografiju i ribarstvo, Split (Institute of Oceanography and Fisheries, Split)	IOR
Institut za poljoprivredu i turizam, Poreč (Institute for Agriculture and Tourism, Poreč)	IPTPO
Institut za razvoj i međunarodne odnose (Institute for Development and International Relations)	IRMO
Istarsko veleučilište (Istrian University of Applied Sciences)	IV
Mediteranski institut za istraživanje života (Mediterranean Institute for Life Sciences)	MedILS
Međimursko veleučilište u Čakovcu (The Polytechnic of Međimurje in Čakovec)	MEV
Poljoprivredni institut, Osijek (Agricultural Institute, Osijek)	PIO
Sveučilište J. J. Strossmayer u Osijeku (Josip Juraj Strossmayer University of Osijek)	UNOS
Sveučilište J. J. Strossmayer u Osijeku , Ekonomski fakultet (Josip Juraj Strossmayer University of Osijek, Faculty of Economics)	EFOS
Sveučilište J. J. Strossmayer u Osijeku , Elektrotehnički fakultet (Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering)	FEROS
Sveučilište J. J. Strossmayer u Osijeku, Fakultet agrobiotehničkih znanosti (Josip Juraj Strossmayer University of Osijek, Faculty of Agriculture)	FAZOS
Sveučilište J. J. Strossmayer u Osijeku, Fakultet elektrotehnike, računarstva i informacijskih tehnologija (Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering)	FERIT
Sveučilište J. J. Strossmayer u Osijeku , Građevinski i arhitektonski fakultet (Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering)	GFOS
Sveučilište J. J. Strossmayer u Osijeku, Odjel za biologiju (Josip Juraj Strossmayer University of Osijek, Department of Biology)	BIOUNOS

Sveučilište J. J. Strossmayer u Osijeku, Odjel za fiziku (Josip Juraj Strossmayer University of Osijek, Department of Physics)	PHYUNOS
Sveučilište J. J. Strossmayer u Osijeku, Odjel za kemiju (Josip Juraj Strossmayer University of Osijek, Department of Chemistry)	KEMUNOS
Sveučilište J. J. Strossmayer u Osijeku, Odjel za matematiku (Josip Juraj Strossmayer University of Osijek, Department of Mathematics)	MATUNOS
Sveučilište J. J. Strossmayer u Osijeku , Poljoprivredno-tehnološki fakultet (Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology)	PTF
Sveučilište J. J. Strossmayer u Osijeku , Prehrambeno-tehnološki fakultet (Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology)	PTFOS
Sveučilište J. J. Strossmayer u Osijeku, Strojarski fakultet u Slavonskom Brodu (Josip Juraj Strossmayer University of Osijek, Faculty of Mechanical Engineering in Slavonski Brod)	SFSB
Sveučilište Jurja Dobrile u Puli (Juraj Dobrila University of Pula)	UNIPU
Sveučilište Jurja Dobrile u Puli, Fakultet informatike (Juraj Dobrila University of Pula, Faculty of Informatics)	FIPU
Sveučilište Sjever (University North)	UNIS
Sveučilište u Dubrovniku (University of Dubrovnik)	UNIDU
Sveučilište u Dubrovniku, Pomorski fakultet (University of Dubrovnik, Faculty of Maritime Studies)	UNIDUPF
Sveučilište u Rijeci (University of Rijeka)	UNIRI
Sveučilište u Rijeci, Centar za napredno računanje i modeliranje (University of Rijeka, Center for Advanced Computing and Modelling)	CNRM
Sveučilište u Rijeci, Centar za urbanu tranziciju, arhitekturu i urbanizam - DeltaLab (University of Rijeka, Center for Urban Transition, Architecture and Urbanism - DeltaLab)	DeltaLab
Sveučilište u Rijeci, Centar za visokopropusne tehnologije (University of Rijeka, Centre for High-throughput Technologies)	UNICVPT
Sveučilište u Rijeci, Građevinski fakultet (University of Rijeka, Faculty of Civil Engineering)	GRADRI
Sveučilište u Rijeci, Medicinski fakultet (University of Rijeka, Faculty of Medicine)	MEDRI
Sveučilište u Rijeci, Odjel za biotehnologiju (University of Rijeka, Department of Biotechnology)	BIOTECHUNRI
Sveučilište u Rijeci, Odjel za fiziku (University of Rijeka, Department of Physics)	PHYUNRI
Sveučilište u Rijeci, Pomorski fakultet (University of Rijeka, Faculty of Maritime Studies)	PFRI
Sveučilište u Rijeci, Tehnički fakultet (University of Rijeka, Faculty of Engineering)	RITEH
Sveučilište u Slavonskom Brodu (University of Slavonski Brod)	UNISB
Sveučilište u Splitu (University of Split)	SU
Sveučilište u Splitu – Centar izvrsnosti za znanost i tehnologiju (University of Split – Center of Excellence for Science and Technology)	STIM
Sveučilište u Splitu, Fakultet elektrotehnike, strojarstva i brodogradnje (University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture)	FESB
Sveučilište u Splitu, Fakultet građevinarstva, arhitekture i geodezije (University of Split, Faculty of Civil Engineering, Architecture and Geodesy)	GRADST
Sveučilište u Splitu, Kemijsko-tehnološki fakultet (University of Split, Faculty of Chemistry and Technology)	KTFST
Sveučilište u Splitu, Prirodoslovno-matematički fakultet (University of Split, Faculty of Science)	PMFST

Sveučilište u Splitu, Znanstveni centar izvrsnosti (University of Split, Center of Research Excellence)	ZCIUNST
Sveučilište u Zadru (University of Zadar)	UNIZD
Sveučilište u Zagrebu (University of Zagreb)	UNIZG
Sveučilište u Zagrebu, Agronomski fakultet (University of Zagreb, Faculty of Agriculture)	AGR
Sveučilište u Zagrebu, Arhitektonski fakultet (University of Zagreb, Faculty of Architecture)	AFUNIZG
Sveučilište u Zagrebu, Ekonomski fakultet (University of Zagreb, Faculty of Economics&Business)	EF
Sveučilište u Zagrebu, Fakultet elektrotehnike i računarstva (University of Zagreb, Faculty of Electrical Engineering and Computing)	FER
Sveučilište u Zagrebu, Fakultet kemijskog inženjerstva i tehnologije (University of Zagreb, Faculty of Chemical Engineering and Technology)	FKIT
Sveučilište u Zagrebu, Fakultet organizacije i informatike (University of Zagreb, Faculty of Organization and Informatics)	FOI
Sveučilište u Zagrebu, Fakultet prometnih znanosti (University of Zagreb, Faculty of Transport and Traffic Sciences)	FPZ
Sveučilište u Zagrebu, Fakultet strojarstva i brodogradnje (University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture)	FSB
Sveučilište u Zagrebu, Fakultet šumarstva i drvne tehnologije (University of Zagreb, Faculty of Forestry and Wood Technology)	FŠDT
Sveučilište u Zagrebu, Farmaceutsko-biokemijski fakultet (University of Zagreb, Faculty of Pharmacy and Biochemistry)	FBF
Sveučilište u Zagrebu, Filozofski fakultet (University of Zagreb, Faculty of Humanities and Social Sciences)	FFZG
Sveučilište u Zagrebu, Geodetski fakultet (University of Zagreb, Faculty of Geodesy)	GEOF
Sveučilište u Zagrebu, Geotehnički fakultet (University of Zagreb, Faculty of Geotechnical Engineering)	GFV
Sveučilište u Zagrebu, Građevinski fakultet (University of Zagreb, Faculty of Civil Engineering)	GFUNIZG
Sveučilište u Zagrebu, Medicinski fakultet (University of Zagreb, School of Medicine)	MEF
Sveučilište u Zagrebu, Metalurški fakultet (University of Zagreb, Faculty of Metallurgy)	MF
Sveučilište u Zagrebu, Prehrambeno-biotehnološki fakultet (University of Zagreb, Faculty of Food Technology and Biotechnology)	PBF
Sveučilište u Zagrebu, Prirodoslovno-matematički fakultet (University of Zagreb, Faculty of Science)	PMF
Sveučilište u Zagrebu, Rudarsko-geološko-naftni fakultet (University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering)	RGN
Sveučilište u Zagrebu, Sveučilišni računski centar (Srce) (University of Zagreb, University Computing Center (Srce)	SRCE
Sveučilište u Zagrebu, Tekstilno-tehnološki fakultet (University of Zagreb, Faculty of Textile Technology)	TTF
Sveučilište u Zagrebu, Veterinarski fakultet (University of Zagreb, Faculty of Veterinary Medicine)	VF
Tehničko veleučilište, Zagreb (Zagreb University of Applied Sciences)	TVZ
Veleučilište Velika Gorica (University of Applied Sciences Velika Gorica)	VVG
Veleučilište u Karlovcu (Karlovac University of Applied Sciences)	VUK
Veleučilište u Virovitici (Virovitica University of Applied Sciences)	VV

Annex 6: New technologies developed in the Energy and sustainable environment area over the last 10 years

Institution	New technologies developed	Area
AGR	Improvement of sprayable polymer degradable mulch technology—replacing plastic films	2
IPTPO	Slow pyrolysis of pruning residues in an open device	2
PBF	Non-thermal extraction techniques	2
AGR	Using wastewater treatment plant sludge in the production of energy crops	2
AGR	Development of biocomposites and value-added products from agricultural biomass	2
GFUNIZG	The ECO-SANDWICH product	2
AGR	Encapsulation of bioactive components for nutrition/protection of plant crops	2
FKIT	Advanced nanocomposites for noise and vibration absorption	2
FKIT	Improved additives for lubricating oils	2
FER	Fan coil heat exchanger air clogging detection system	1
FER	Modular hierarchical model predictive control for coordinated and holistic energy management of buildings	1
FESB	Device for ecological treatment of bees	2
FER	Algorithm for optimal bidding on energy markets	1
FER	Lithium-ion battery model	1
PBF	Application of vacuum cooling in the production of food of longer shelf life and freshness	3
PBF	Innovative techniques in the minimal processing of potatoes (*Solanum tuberosum*) and their health suitability after preparation	3
IF	Synthesis of new atomically thin materials through innovative processes	4
RGN	Measuring diffusion through sealing materials	3

FPZ	SPARK SENSE parking space management system that minimises costs and the deficiencies that lead to traffic congestion	3
FKIT	Nanomaterial inkjet printing	4
FER	Lightning Location System	2
IRB	Contribution to the development of Supported Ionic Liquid Phase catalyst systems in the context of hydrogen technologies	1
FERIT	Active methods of island operation for the integration of RES in electricity systems	1
RITEH	Technology for the automatic recording and monitoring of waste disposal in smart cities	2
RITEH	Autonomous sprinkler mission planning and executing system (here, existing technologies from the mobile robotics field were adapted for use in a specific application and product)	2
FSB	Numerical algorithms for designing energy conversion devices	1
TTF	New natural-based sizing agents	3
MEDRI	Port Environmental Index (PEI)	2
PTFOS	Biological pretreatment of lignocellulosic materials in biogas production	1
GRADST	Estuary pollution risk assessment application	2
GRADST	Multisensor probe for measuring physical parameters in surface waters	2
FKIT	New technologies for the treatment of wastewater polluted with pharmaceuticals and pesticides	2
RGN	Device for undisturbed soil sampling	2
AGR	Edible coatings	3
FSB	Improving the waste plastic pyrolysis process	1
FSB	Improving combustion process efficiency in steam generator combustion chambers and reducing pollutant emissions	1
FSB	Increasing the efficiency of thermal power plants	1
IRB	Technology for irradiating nuclear materials with two high-energy accelerated ion beams simultaneously (dual-	1

	beam ion irradiation of materials), to simulate damage to nuclear materials during neutron irradiation	
IRB	Preparation procedures for obtaining materials for energy storage and conversion	1
FERIT	Automated induction machine testing system	1
FERIT	Rapid electric motor regulation techniques prototyping system	1
FERIT	Induction engine smart management system with possible failures	1
TTF	Textile dust generation measuring system	2
FSB	New metal material processing methods	1
FESB	Segmented fuel cell with the ability to regulate the temperature field by measuring the water content along the active surface and the current density	1
FESB	Relative humidity and temperature sensor with heat loss compensation	1
FESB	Micro fuel cell bundle as a replacement for batteries (currently under development, successfully demonstrated operation of a single fuel cell)	1
FKIT	Development of nanocomposite coatings	4
PMF	System for assessing the biological quality of Croatian waters	2
EIHP	Process and system for treating, recycling treated digestate and for obtaining fertilizer mixture from digestate obtained by anaerobic digestion of biomass in cogeneration biogas plants	1
RGN	Straight line rock cutting tool	1
RGN	Method for determining the optimal geometry of cutting tools on a chain saw	1
RGN	Method of determining the specific rock cutting energy by measuring the specific drilling energy	1
AGR	Pest management using aggregation pheromones (New techniques for detecting pest resistance)	3
GFUNIZG	Purification of waste water by electrochemical process	2
GFUNIZG	Manufacturing innovative construction elements from concrete and brick with recycled waste	2

IRB	Preparation of perovskite photovoltaic cells; Preparation of immobilised photocatalysts for the purification of waste water and gases;	2
EIHP	Energy management system with the use of battery storage	1
EIHP	Solar thermal cogeneration plant for the production of electricity and thermal energy using direct solar radiation (with the use of concentrated solar panels with an automated sun tracking system) based on the organic Rankine cycle	1
PTFOS	Supercritical CO2 extraction—a new technology	1
FSB	Energy planning software	1
IRB	Cultivation of microalgae for use in the food, pharmaceutical and cosmetic industries	3
FER	Control algorithms for the areas of: microgrid renewable energy sources, electric machines, advanced building battery systems, advanced logistics, electrified rail systems, advanced retail, digital agriculture	1
GRADST	Implementation/validation of new methods and equipment related to intact rock strength and deformability testing (development of a new device for sample control) and the properties of soil/rock in an unsaturated state (a laboratory for unsaturated soil and other geomaterials within the Geotechnical laboratory was established)	3
RITEH	Shell-and-tube latent thermal energy storage was designed and manufactured	1
RITEH	Heating systems with a heat pump and a latent thermal energy storage were designed	1
VUK	Vane motor for small hand-held tools	1
FER	Digital Twins Technology	3
PBF	Technique of accelerated solvent extraction at elevated pressure	3
PBF	Advanced techniques (SCO2, MAE, ASE) for isolating bioactive molecules from organic waste in wine production	3
IRB	Manufacture of high-capacity nanostructured silicon anode in Li-ion batteries	1

IRB	New LED production procedures using the MOCVD method on ZnO films on silicon substrates	1
IRB	Chemical vapor deposition (CVD) methods for depositing thin semiconductor films	4
IRB	Manufacturing processes for optical (SERS and optical microresonators) and electrical sensors (metal oxides and silicon based)	4
FSB	Computer tools for combustion improvement for industrial furnaces	1
FSB	Wind power plant with the help of balloons. Heat exchanger	2
FSB	Biocomposites for vessels	2
RGN	Test analysis method for pressure buildup in unconventional oil and gas reservoirs	2
IRMO	New technology (integrated system) developed for the simultaneous production of energy and drinking water using three natural forces (renewable energy sources, seawater, and gravity) called Seawater Steam Engine	2
IOR	Sound protection at shellfish farms	2
IRB	Immobilized photocatalysts	4
IRB	Transparent nanostructured thin films	4
FER	New base station for efficient IoT system management	3
FER	Modular hierarchical model predictive control for coordinated and holistic energy management of buildings including auxiliary estimation and forecasting algorithms; parameterisation of low-carbon energy systems using mathematical optimisation algorithms; determining microgrid or building work and reserve schedules for entering the flexibility market; set-based management for the maintenance of safe *envelope* energy process operation; fault-tolerant electric machine control; time series prediction systems	1
PBF	Innovative device for the production of plasma discharge in liquid foods and the associated flow reactors	3
FKIT	Extractive deacidification with DES	2
RGN	Productivity monitoring system for mineral raw material extracting processes	2
FESB	Battery systems for energy storage	1

GFV	Crowdfunding and social entrepreneurship platform Rural area electrification system based on solar energy and batteries	1
TVZ	Technologies related to biogas production from biodegradable waste substrates	1
FKIT	system for purifying water under solar radiation with the operation (palette) of advanced materials	2
HŠI	Applying different remote sensing technologies (photogrammetry, laser scanning) to improve the process of forest mensuration and collect new data on forests	3
RITEH	Developed numerical procedure for the modelling of heat transfer when the state of matter changes within the commercial CFD software	1

Annex 7: NACE Rev. Concordance 2

IPCV8-NACE Rev.2 Update (version 2.0) Eurostat 09/10/2015

1	Manufacture of Food Products	A23J A01H A21D A23B A23C A23D A23F A23G A23J A23K A23L 1/* A23L 3/* A23P C12J C13B C13F C13J C13K
2	Manufacture of Dairy Products	A01J
3	Manufacture of Beverages	A23L 2/* C12C C12F C12G C12H
4	Manufacture of Tobacco Products	A24B A24D A24F
5	Manufacture of Textiles	D04D D04G D04H D06C D06J D06M D06N D06P D06Q
6	Manufacture of Wearing Apparel	A41B A41C A41D A41F
7	Manufacture of Leather and Related Products	A43B A43C B68B B68C
8	Manufacture of Wood and of Products of Wood and Cork. Except Furniture; Manufacture of Articles of Straw and Plaiting Materials	B27D B27H B27M B27N
9	Manufacture of Paper and Paper Products	B42F D21C D21H D21J
10	Printing and Service Activities Related to Printing	B41M B42D B44F
11	Manufacture of Coke and Refined Petroleum Products	C10G C10L

12	Manufacture of Basic Chemicals. Fertilisers and Nitrogen Compounds. Plastics and Synthetic Rubber in Primary Forms	B01J B09B B09C C01B C01C C01D C01F C01G C02F C05B C05C C05D C05F C05G C07B not A61K except A61K 8/* C07C not A61K except A61K 8/* C07F not A61K except A61K 8/* C07G not A61K except A61K 8/* C08B C08F C08G C08J C08K C08L C09B C09C C09K C10B C10C C10H C10J C10K C12S not A61K except A61K 8/* C25B F17C F17D F25J G21F
13	Manufacture of Pesticides and Other Agrochemical Products	A01N A01P
14	Manufacture of Paints. Varnishes and Similar Coatings. Printing Ink and Mastics	B27K C09D
15	Manufacture of Soap and Detergents. Cleaning and Polishing Preparations. Perfumes and Toilet Preparations	A61K 8/* A61Q C09F C11D D06L
16	Manufacture of Other Chemical Products	A62D C06B C06C C06D C08H C09G C09H C09J C10M C10N C11B C11C C14C C23F C23G C40B not A61K except A61K 8/* D01C F42B F42D
17	Manufacture of Man-Made Fibres	D01F
18	Manufacture of Basic Pharmaceutical Products and Pharmaceutical Preparations	A61K except A61K 8/* A61P C07D C07H C07J C07K C12N C12P C12Q
19	Manufacture of Rubber and Plastic Products	B29C B29D B60C B67D
20	Manufacture of Rubber Products	C08C
21	Manufacture of Other Non-Metallic Mineral Products	B32B
22	Manufacture of Glass and Glass Products	C03C C03B
23	Manufacture of Clay Building Materials	B28B B28C
24	Manufacture of Other Porcelain and Ceramic Products	E03D

25	Manufacture of Cement, Lime and Plaster	C04B
26	Manufacture of Basic Metals	B21C B22D C21B C21C C21D C22B C22C C22F C25C C25F
27	Manufacture of Basic Precious and Other Non-Ferrous Metals	G21H
28	Manufacture of Structural Metal Products	A44B A47H B21G F27D
29	Manufacture of Tanks. Reservoirs and Containers of Metal	F16T F22B F22G F24J
30	Manufacture of Steam Generators. Except Central Heating Hot Water Boilers	G21B G21C G21D
31	Manufacture of Weapons and Ammunition	B63G F41A F41B F41C F41F F41G F41H F41J F42C G21J
32	Forging. Pressing. Stamping and Roll-Forming of Metal; Powder Metallurgy	B22F
33	Treatment and Coating of Metals; Machining	C23D C25D
34	Manufacture of Cutlery, Tools and General Hardware	E05B E05D E05F E06B
35	Manufacture of Other Fabricated Metal Products	A01L E05C F16B
36	Manufacture of Electronic Components and Boards	B81B B81C B82B B82Y C30B G11C H01C H01F H01G H01J H01L H05K
37	Manufacture of computers and peripheral equipment	G02F G06C G06D G06E G06F G06G G06J G06N G06T G09C
38	Manufacture of Communication Equipment	G03H G08B H01Q H01S H03B H03C H03D H03G H03H H03J H03M H04B H04H H04J H04K H04L H04M H04N H04Q H04R H04S H04W
39	Manufacture of Consumer Electronics	H03F H03K H03L
40	Manufacture of Instruments and Appliances for Measuring. Testing and Navigation; Watches and Clocks	F15C G01B G01C G01D G01F G01H G01J G01K G01L G01M G01N G01Q G01R G01S G01V G01W G04B G04C G04D G04F G04G G04R G05B G05F G08C G12B

41	Manufacture of irradiation. Electro-medical and electrotherapeutic equipment	A61N G21K H05G H05H
42	Manufacture of Optical Instruments and Photographic Equipment	G02B G02C G03B
43	Manufacture of Magnetic and Optical Media	G03C
44	Manufacture of Electric Motors. Generators. Transformers and Electricity Distribution and Control Apparatus	H02B H02J H02K H02N H02P H02S
45	Manufacture of Batteries and Accumulators	H01M
46	Manufacture of Wiring and Wiring Devices	H01B H01H H01R H02G
47	Manufacture of Electric Lighting Equipment	F21P F21H F21K F21L F21M F21Q F21S F21V F21W F21Y H01K
48	Manufacture of Domestic Appliances	A21B A45D A47G A47J A47L B01B D06F E06C F24B F24C F24D F25C F25D H05B
49	Manufacture of other electrical equipment	B60M B61L G08G G10K H01P H01T H02H H02M H05C
50	Manufacture of General Purpose Machinery	A47K B23F F01B F01C F01D F01K F01M F01N F01P F02C F02G F02K F03B F03C F03D F03G F04B F04C F04D F15B F16C F16D F16F F16H F16K F16M F23R G05D G05G
51	Manufacture of Other General Purpose Machinery	A62C B01D B04C B05B B41J B41K B43M B60S B61B B65G B66B B66C B66D B66F C10F C12L E02C F16G F22D F23B F23C F23D F23G F23H F23J F23K F23L F23M F23N F24F F24H F25B F27B F28B F28C F28D F28F F28G G01G G03G G06K G06M G07B G07C G07D G07F G07G G09D G09G G10L G11B H05F
52	Manufacture of Agricultural and Forestry Machinery	A01B A01C A01D A01F A01G A01K A01M B27L

53	Manufacture of Metal Forming Machinery and Machine Tools	B21D B21F B21H B21J B21K B21L B23B B23C B23D B23G B23H B23K B23P B23Q B24B B24C B24D B25B B25C B25D B25F B25G B25H B25J B26B B26F B27B B27C B27F B27G B27J B28D B30B
54	Manufacture of Other Special Purpose Machinery	A21C A22B A22C A23N A24C A41H A42C A43D B01F B02B B02C B03B B03C B03D B05C B05D B06B B07B B07C B08B B21B B22C B26D B31B B31C B31D B31F B33Y B41B B41C B41D B41F B41G B41L B41N B42B B42C B44B B44C B65B B65C B65F B65F 1/* B65F 5/* B65F 7/* B65F 9/* B65H B67B B67C B68F C13C C13D C13G C13H C14B C23C D01B D01D D01G D01H D02G D02H D02J D03C D03D D03J D04B D04C D05B D05C D06B D06G D06H D21B D21D D21F D21G E01C E01D E01F E01H E02D E02F E05G E21B E21C E21D E21F F04F F15D F16N F16P F26B
55	Manufacture of Motor Vehicles	B60B B60D B60G B60H B60J B60K B60L B60N B60P B60Q B60R B60T B62D F01L F02B F02D F02F F02M F02N F02P F16J G01P
56	Manufacture of Parts and Accessories for Motor Vehicles	B60W
57	Manufacture of Other Transport Equipment	B60F B60V B61C B61D B61F B61G B61H B61J B61K B62C B62H B62J B62K B62L B62M B63B B63C B63H B63J B64B B64C B64D B64F B64G B65F 3/* E01B F03H
58	Manufacture of Furniture	A47B A47C A47D A47F
59	Other Manufacturing	A41G A42B A44C A45B A45C A45F A46B A46D A63B A63C A63D A63F A63G A63H A63J A63K B43K B43L B44D B62B B68G C06F D07B F16L F23Q G10B G10C G10D G10F G10G G10H
60	Manufacture of Medical and Dental Instruments and Supplies	A61B A61C A61D A61F A61G A61H A61J A61L A61M A62B B04B C12M not A61K except A61K 8/* B01L G01T G21G
61	Manufacturing N.E.C.	B65D G03D G03F G09B G09F

62	Construction of Utility Projects	E03B E03C
63	Construction of Other Civil Engineering Projects	E02B
64	Specialised Construction Activities	E03F E04B E04C E04D E04F E04G E04H
65	Computer Programming. Consultancy and Related Activities	G06Q
66	NACE of NACE-allocation by following the Co-	F16S B29K B29L C12R -99Z