GO WITH THE FLOW:
HIGH PERFORMANCE COMPUTING AND INNOVATIONS IN THE DANUBE REGION

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Borut Roncevic, Raluca Coscodaru, Urska Fric, *Editors*

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High-Performance Computing as a Tool of Transnational Innovation Policy

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1. Introduction

There exists overwhelming evidence in the European Union (EU) that the pathway to economic growth and competitiveness is largely connected to research, innovation and to the existence of a local ecosystem which is embedded into the globalized and interconnected economy (Cepoi and Golob, 2017; Modic and Roncevic, 2018, Novotny et al, 2019). To tap into Europe's yet unexploited potential in research and innovation, the individual strengths of every Member State and region need to be further exploited. Since research and innovation performance is correlated with the efficiency of the national research, the high added value technologies, the transfer mechanisms available in the region and the presence of innovation eco-systems, a comprehensive support is needed for the low performing Member States and regions to improve their research and innovation systems and policies.

Technological advances in specific areas can add an interesting dimension (Rončević and Tomšič, 2017; Fernandez et al, 2019). They play an especially important role whilst we observe the rise of so-called big data. Big data was more traditionally characterised by high volume, high variety and high velocity of changes (Kitchin and McArdle, 2016; Chen and Zhang, 2014) and, more recently, also by veracity and volatility (Hammer et al, 2017) – hence moving from 3V's to 5V's. Several attempts have been made to understand what big data means and how new approaches, techniques and technologies can help companies to understand, analyse and utilize this new wealth of information, e.g. for patent and other innovation connected data in Modic et al (2019). It is nonetheless clear that traditional data-processing applications and infrastructures have become insufficient to capture, store and analyse big data and instead a network of human skills, advanced technologies and data (access) infrastructure is needed (Hammer et al, 2017), if we are to harness big data to 'unleash new organisational capabilities and value' (Davenport et al, 2012: 43). In sum, the emergence of novel digital technologies, powerful digital platforms and infrastructures has transformed innovation and entrepreneurship in significant ways with broad organizational and policy implications (Nambisan et al, 2019; Nambisan, 2017; Yoo et al, 2012; Yoo et al., 2010).

Inside this context high performance computing (HPC) is an emerging general-purpose technology. It can improve framework conditions for innovations by drastically increasing effectiveness of innovations and reducing product development time. HPC can process massive data with unprecedented efficiency, thus drastically increasing innovative capacity of companies (including SMEs) by shortening product development cycle and simulating complex industrial value chains (Zelkowitz, 2002). In general, HPC is understood as the practice of aggregating computing power in a way that delivers much higher performance to solve large problems in science, engineering, or business (Sravanthi et al., 2014).

EU's problem however inter alia lies in the fact that the EU organisations are lagging in having the strongest supercomputers in the world, as also recognized by the European Commission (2018)[1]. Indeed, in 2018 only one among the strongest ten supercomputers was housed in Europe: SuperMUC-NG (Strohmaier et al, 2018), a supercomputer by the Bavarian Academy of Sciences and Humanities servicing the universities in Munich – hence, a supercomputer embedded in the academia environment. However, one of the advantages of the HPC is that the supercomputers can be accessed remotely, thereby reducing the need for prohibitively expensive investments.[2] This introduces potential also for cross-sectorial cooperation, where universities, which have relevant HPC infrastructures and skills, aim to enhance their societal impact, generating social, cultural, environmental, and economic returns from publicly funded research

1 European Commission (2018). The European High-Performance Computing Joint Undertaking – EuroHPC, retrieved from: https://ec.europa.eu/digital-single-market/en/eurohpc-joint-undertaking, last accessed on February 17, 2019.

2 The Communication from the Commission of 10 May 2017 on the Mid-Term Review on the implementation of the Digital Single Market Strategy – A Connected Digital Single Market for AI, retrieved from https://eur-lex.europa.eu/resource.html?uri=cellar:a4215207-362b-11e7-a08e-01aa75ed71a1.0001.02/DOC_1&format=PDF, last accessed on June 7, 2019.

(Bornmann, 2013; Fini et al., 2018). Research in general is considered to bring societal benefits if it informs policy, is useful for industry, and/or leads to a solution to a real-world problem (Roberts, 2009).

All above is also particularly relevant in the Danube region, a rather curious European macro-region, which includes some of the most developed (e.g. Baden Württemberg, Bavaria, Austria) and least developed (e.g. Moldova, Ukraine) parts of Europe. However, while most advanced HPC infrastructure and knowledge are located in well-off western parts of the Danube region, enterprises – especially SMEs – from its eastern parts have limited access and competencies. Transnational cooperation in the region is limited, which is further hindering innovation and technology transfer.[3]

As a result, any viable and sustainable effort to disseminate application of HPC technology in the Danube region and to use it as a tool of sustainable transnational innovation policy would benefit from creating a transnational HPC laboratory for co-designing knowledge-intensive innovative products with high value-added in transnational value-chains. Such a lab would pool regional HPC infrastructure and competencies, provide web platform enabling HPC access, integrated services and capacity building tools, and sustainability toolkit, to support durability of such transnational laboratory.

This was the rationale behind the InnoHPC project.[4] This volume presents transnational analysis with national case studies on HPC, its dissemination and role in industrial innovation in the Danube region, conducted as a part of InnoHPC project. To develop a transnational laboratory, InnoHPC first, conducted a focused regional HPC benchmark. This was the basis to, second, design and create a transnational InnoHPC Lab. The Lab is accessed through, third, HPC web platform providing HPC access and capacity-building tools. Finally, this organizational and online platform was pilot-tested with two pilots with SMEs in electronic and automotive sectors.

InnoHPC Lab primarily targets industrial SMEs and clusters, providing the opportunity to increase efficiency of innovations and join transnational value-chains in the Danube region. But SMEs are not the only beneficiaries. Higher education and research institutions with HPC get access to exciting real-life cases and opportunities to exploit their entrepreneurial potential. Last but not

3 Danube Transnational Programme 2014–2020, retrieved from http://www.interreg-danube.eu/, last accessed on June 7, 2019.

4 InnoHPC project (2017-2019), fully titled as High-performance Computing for Effective Innovation in the Danube Region, was supported by the Interreg Danube Region. More info on the project: http://www.interreg-danube.eu/approved-projects/innohpc.

least, policy-makers and business support organizations receive a valuable institutional support for their policies and initiatives.

InnoHPC project was designed as a pioneering effort in the Danube region to improve framework conditions for innovation by providing unique institutional and technological infrastructure, to pool and exploit HPC infrastructure on a transnational level.

2. Strategic relevance of HPC support in the Danube region

HPC development addresses some of the most visible challenges of the Danube region, namely its relative backwardness and substantial disparities between its well-off westernmost parts and the rest of the region. This situation is fuelled by the relatively substantial disparities in innovative capabilities, inefficient utilization of available resources, poor entrepreneurial spirit, and poor technology transfer between academia and the business sector, as well as across the borders[5].

The re-industrialization goals of the EU have in recent years been upgraded to emphasize the need for digital transformation of European companies. According to the Report of the Strategic Policy Forum on Digital Entrepreneurship[6], digitalization of European manufacturing can contribute to 15% to 20% growth by 2030. But the problems related to establishing a dialogue between European businesses and technology platform providers, increasing the supply of new, highly specialized skills and establishment of new centres of digital transformation excellence, persist.

Furthermore, there is a clear need to provide for a European world-class HPC capability, both on the supply and user side. Despite some valuable initiatives, European HPC is lagging far behind that in the global leaders United States and China and is still fragmented in terms of funding and critical mass applications. Also, not all countries in Europe have the capacity to build and maintain such infrastructure. Pooling and rationalizing efforts at the European Union level as well as macro-regional levels, such as the Danube region, is therefore a necessity, according to EC HPC Communication (2012)[7].

5 The Communication from the Commission of 08.12.2010 on the European Union Strategy for Danube Region, retrieved from https://www.danube-region.eu/images/Communication_from_the_Commission_2010.pdf, last accessed on June 7, 2019.

6 European Commission, Report of the Strategic Policy Forum on Digital Entrepreneurship (2016), retrieved from http://ec.europa.eu/DocsRoom/documents/15856/, last accessed on June 7, 2019.

7 The Communication from the Commission of 15.02.2012 on the High-Performance Computing: Europe's place in a Global Race, retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0045:FIN:EN:PDF, last accessed on June 7, 2019.

Bottom-up needs assessment analysis for the Danube region (including interviews with business experts, focus groups and analysis of HPC infrastructure)8 has shown some critical issues that need to be tackled not only in InnoHPC, but also in various spin-off initiatives. First, there is a critical mass of SMEs in the region with the need to use HPC, although they are not yet aware of available opportunities and benefits. Second, the available applications – both closed and open source – already include highly relevant products for business process simulation and optimization, testing products in virtual environments etc. Third, HPC provides the opportunity for transnational product co-creation and consequently formation of transnational industrial value chains. Fourth, HPC providers from academia are to an important extent focused on using the HPC infrastructure to deal with basic science, or do not have the necessary skills to deal with applied issues relevant for the businesses, creating a lack of HPC supply for SMEs. Finally, electronic and automotive industries are the best candidates for rapid take-up of HPC technologies and provide excellent opportunities for relevant pilot projects.

InnoHPC benefitted from in-depth review of HPC capabilities on supply and user side and explored opportunities of its applications to increase efficiency of innovations, co-creation and development of transnational value chains. InnoHPC Lab offers transnational institutional infrastructure with all relevant training and collaborative tools, linking interested partners and providing structured access to HPC capabilities. This was pilot-tested in real-life cases with SMEs from electronic and automotive sectors across the Danube region[9].

3. Transnational strategic dimensions and approach

InnoHPC is in line with Europe 2020[10] and is contributing and will continue to contribute to its implementation, especially its focus on delivering smart, sustainable and inclusive growth. Furthermore, InnoHPC focus is on better utilization of expensive HPC infrastructure and development of integrated services for enterprises, especially SMEs, and capacity building materials, thereby increasing effectiveness of past and future investments in education, research and innovation. European cooperation in education and training strategy is

8 Conducted during InnoHPC project.

9 InnoHPC Pilot Projects for automotive and electronics. More information on http://www.interreg-danube.eu/news-and-events/project-news/2936, last accessed June 7, 2019.

10 The Communication from the Commission of 03.03.2010 on the EUROPE 2020, A strategy for smart, sustainable and inclusive growth, retrieved from http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf, last accessed on June 7, 2019.

particularly enhanced with this project, as lifelong learning of both providers and users of HPC technology and services are the core essence of InnoHPC.

HPC also specifically contributes to achieving the goals of the EC High-Performance Computing Strategy[11], especially its second pillar: providing access to the best supercomputing facilities and services for industry and especially SMEs in order to achieve European leadership in the use of HPC systems and services by 2020. It also contributes to the EC goal of achieving excellence in HPC applications by further developing HPC applications and disseminating the knowledge and developed solutions to relevant stakeholders (especially SMEs)[12]. Furthermore, regional smart specialization strategies[13] (in the EU parts of the Danube region) or corresponding relevant strategies in its non-EU regions have been particularly taken into account; the preliminary analysis showing perceived need and strategic prioritisation of advanced ICT support. Regional benchmarking and audit further identified specific areas and specific modes of HPC contribution to more effective implementation of these specific strategies, taking additional national and regional nuances into account.

The goal of the European Union Strategy for Danube Region (EUSDR)[14] is to develop coordinated policies and actions in the Danube region in line with Europe 2020 strategy. InnoHPC is specifically designed to tackle some of the key challenges as identified in the EUSDR. Utilization of HPC is not a goal in itself, but a vehicle to overcome relative backwardness of the most of the Danube region and reduce gaping disparities within the region by developing transnational links between its western and eastern parts, as well as the links between academia and enterprises. The key focus of InnoHPC is not at the national or local levels. Instead, its scope was to develop transnational operational platform for the entire Danube region. This has positive effects by encouraging the increase in the level and quality of transnational networking between academic HPC providers, enterprises (with particular emphasis on SMEs), infrastructural institutions, business support institutions and policy-makers on different levels

11 The Communication from the Commission of 15.02.2012 on the High-Performance Computing: Europe's place in a Global Race, retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0045:FIN:EN:PDF.

12 The Communication from the Commission of 10 May 2017 on the Mid-Term Review on the implementation of the Digital Single Market Strategy — A Connected Digital Single Market for AI, retrieved from https://eur-lex.europa.eu/resource.html?uri=cellar:a4215207-362b-11e7-a08e-01aa75ed71a1.0001.02/DOC_1&format=PDF, last accessed on June 7, 2019.

13 European Commission, Smart Specialization Platform, http://s3platform.jrc.ec.europa.eu/, last accessed on June 7, 2019.

14 The Communication from the Commission of 08.12.2010 on the European Union Strategy for Danube Region, retrieved from https://www.danube-region.eu/images/Communication_from_the_Commission_2010.pdf, last accessed on June 7, 2019.

from different countries, strengthening and upgrading the existing regional cooperation and, above all, enhancing development of transnational knowledge-intensive and higher value-added value chains od SMEs in prospective electronic and automotive sectors.

Transnational approach is one of the key aspects of InnoHPC and the project would not be viable without it, at least not in the specific circumstances of the Danube region. HPC is a relatively recent, prohibitively expensive and rapidly developing technology. Costs of investments in HPC hardware and its maintenance are very high, where even smallest systems cost several hundred thousand EUR, but more significant investments cost many millions EUR. As a consequence, most of the HPC infrastructure is located in the westernmost parts of the Danube region. Even these systems have recognized the need for transnational cooperation in the framework of PRACE (Partnership for Advanced Computing in Europe), uniting most advanced European HPC systems and providing HPC access to researchers from academia and industry.

However, while HPC hard infrastructure is not transferable in itself, it can be remotely accessed and operated, which invites transnational dissemination of its capacities.[15] The key to this are competencies and tools, which can be, if properly designed, highly transferable on a transnational level. Therefore, when we create projects to enhance technology transfer and increase effectiveness of innovations with the application of HPC, transnational dimension ensures the best utilization of available infrastructure. Additionally, due to the possibility of remote access[16], HPC is one of the few currently relevant technologies where capacity-building does not substantially increase the adverse results of out-migration of the most competent population.

InnoHPC is therefore enabled by the transnational:

1. Partners jointly participated in development of InnoHPC and in preliminary needs assessment, with a view to produce transferable project results that benefit the Danube region as a whole and all territories covered by the EUSDR.
2. Transnational transferability is possible if regional nuances are taken into account. Hence, the regional HPC audit covered all relevant parts of the Danube region, from its westernmost to its easternmost parts.

15 The COUNCIL REGULATION (EU) 2018/1488 of 28 September 2018 establishing the European High Performance Computing Joint Undertaking, retrieved from file:///C:/Users/Raluca/Desktop/Regulation.pdf, last accessed on June 7, 2019.

16 Zelkowitz, M. (Ed.). (2002). Advances in computers (Vol. 56). Elsevier, pp. 111–113.

3. InnoHPC is not a collection of local or national actions. Its activities are transnational in design and implementation. The foci that were identified during the needs analysis are not territorial, but sectoral in nature; SMEs that can participate in value chains of electronic and automotive industries are existing in all Danube region countries.
4. InnoHPC Lab is designed to have members from all Danube region countries and has invited and will continue to invite all interested SMEs, HPC providers, business support institution, policy-makers etc., especially within planned spin-off projects.
5. Pilot projects were being based on real-life cases, linking SMEs in transnational value chains on the basis of their capacities and specific competencies and not on the basis of their locations. The pilots therefore contributed to establishment of transnational clusters in these two sectors.
6. Dissemination activities covered the entire Danube region. There were no location-specific priorities.

4. Innovative and transnational aspects of HPC as a tool of regional innovation

Policies and projects targeting Danube region, especially its least developed parts, traditionally tend to draw on poorly-defined advantages and are trying to focus on supposedly unique cultural and natural heritage of the region. As a consequence, they often support low value added and labour-intensive activities and, ironically, equip participants with skills that make them even more likely candidates for out-migration. Such projects contribute to a vicious circle of underdevelopment. Instead, projects promoting HPC development can provide tailor-made and transferable technology and skills necessary for knowledge-intensive and high value-added entrepreneurial activities.

This approach is innovative in several dimensions. First, it takes into account qualitative and quantitative development of not only the available hard HPC infrastructure and competencies, but also intangible aspects that can either hinder or lubricate (transnational) cooperation. Second, it not only focuses on development of competencies in the business sector, but also builds competencies of HPC providers (HEIs and RIs) to properly evaluate the needs of SMEs. Finally, InnoHPC has a specific additional innovative dimension, as the functionality of the web platform and capacity-building materials were developed for and pilot-tested on real-life cases of SMEs that are mainly Tier II suppliers (and some Tier I) in value chains in electronic and automotive sectors, aiming to foster creation of transnational SME value chains with joint innovation.

Any such infrastructural activities need to be based on these pillars and should be connected and combined in logical sequences. As a result, regional HPC benchmark was used to assess and catalogue both regional HPC needs, with a specific focus on SMEs in the electronic and automotive sector and to assess and catalogue the relevance of regional HPC providers' infrastructure and competencies from this perspective, and to develop a database of HPC providers and users. This was used as an important input for design of transnational infrastructure, i.e. InnoHPC Lab, providing a one-stop-shop with comprehensive list of available capabilities, services, protocols and procedures for cooperation. On the basis of detailed regional HPC benchmark one can also develop and test transferable capacity-building tools and programs, which also operate in the framework of InnoHPC Lab. The web platform is a tool to provide structured distance access to InnoHPC Lab and to allow optimum transferability, one should use results of analysis to determine technology requirements and conduct a specific user experience design exercises in different parts of the Danube region.

By focusing on the role of HPC in innovation policies in the Danube region, InnoHPC project addressed not only the relationship between innovation policies and regional development, but also the extent to which HPC can reinforce existing poles of science and technology, and stimulate the development of low-performance economies. Policies towards high-performance computing as enabling feature in regional development, the role of HPC going beyond science and encompassing both an entrepreneurial and innovation role17.

Based on the results of the benchmarking process conducted in the InnoHPC project, within the Danube region a multilevel polity driven by HPC could be developed to support socio-economic development: first of all, at European level, the EC HPC Strategy set the framework for successful implementation of HPC policies not only at EU level, but also at national level; at the level of the Danube region, HPC could be considered a tool facilitating cooperation and the emergence of regional science collaboration and policies; last but not least, at national level, there are HPC capacities and capacities which need to be developed – the spill over around them will foster the design of new projects and strategies from the bottom about and these will turn into benefits for the whole Danube region and EU.

Digitalization fosters regions to make a transition from traditional to dynamic economy, with high added value. Alongside with the hard infrastructure

17 The Communication from the Commission of 10 May 2017 on the Mid-Term Review on the implementation of the Digital Single Market Strategy – A Connected Digital Single Market for Al, retrieved from https://eur-lex.europa.eu/resource.html?uri=cellar:a4215207-362b-11e7-a08e-01aa75ed71a1.0001.02/DOC_1&format=PDF, last accessed on June 7, 2019.

development, communities of innovation actors and new skills and capacities were added on the agenda. Recognition of the strength of HPC in economic development came with the good performance of countries, which are HPC developed, as for examples Austria and Germany18.

5. Transferability and Durability of HPC

All infrastructural projects, including those focusing on HPC, need to include activities to design durability and transferability tools. This should result in transferable document outlining elements and detailed methodology for durability and transferability strategy, dedicated business plan for any transnational infrastructural entity, and also a transnational action plan providing sustained political support. This can provide institutional, financial and political durability of the InnoHPC results. To exemplify, we provide is the outline of these specific measures as developed in InnoHPC project.

5.1. Institutional durability

- InnoHPC Lab was developed as the institutional framework for the continuation of activities after conclusion of the project. All relevant documents, regulations and protocols were elaborated. As a result of strong dissemination activities and successful pilot projects InnoHPC Lab membership will expand beyond original partnership also after the end of financing. Lead Partner is providing provide hosting and administrative support.
- Durability strategy includes provisions for continued upgrade, development and adoption by organizations across the Danube region and beyond.
- Lead Partner will continue to host InnoHPC web platform developed on its servers after the end of funding, including capacity-building materials and simulation tools. These remain freely available.

5.2. Financial durability

- InnoHPC developed a business plan with the purpose to ensure the continuation, expansion and economic sustainability of InnoHPC after the end of the project. This plan acknowledges limitations with respect to revenues generated from the project. Identified financial sources include consulting services, custom-made HPC training fees, spin-off project ideas and Lab membership fees.

18 InnoHPC (2018), Output3.2. Database of HPC providers and industrial beneficiaries, retrieved from http://www.interreg-danube.eu/uploads/media/approved_project_output/0001/13/0cc1d1d8dcd14f85b2462f328229470885773c38.pdf, last accessed on June 7, 2019.

- InnoHPC web platform was designed for low-cost maintenance. This was taken into account from the onset in developing technology requirements and user experience design.

5.3. Political durability

- The key tool ensuring continued political durability and support will be the Transnational Action Plan, designed through a series of workshops with participation of transnational, national and regional stakeholders.

Transferability will be enhanced by accounting for regional and national nuances as outlined in the analysis presented in this volume that have to be taken into account in designing the web platform. Furthermore, dissemination activities were detailed with a specific purpose to exploit the current wave of increasing application of HPC technology as a global trend by contributing to appreciation of HPC in the Danube region, especially among SMEs. Finally, InnoHPC followed the open access paradigm to the greatest possible extent (yet ensuring confidentiality and secrecy of all intellectual property) when granting access to the platform and services, thus allowing intensified cooperation in the years to follow.

6. Meeting specific objectives in HPC projects

HPC technology, if properly applied and disseminated, can significantly improve framework conditions for innovations in the Danube region by connecting HPC providers, business and innovation support organizations, higher education and research institutions and policy-makers on a transnational level. InnoHPC developed organizational, technological and educational protocols and materials to pool existing HPC infrastructure in the Danube region to achieve its better utilization without the need for further expensive investments. This enables structured access to integrated HPC services for enterprises (especially SMEs) developing innovative products to enhance their innovative performance across the Danube region and also beyond. For that purpose, InnoHPC developed online one-stop-shop, a web platform and capacity building tools for providers and users of HPC, initially with a focus on SMEs from automotive and electronic industries with potential to operate as Tier I and Tier II suppliers to multinational companies. For them, establishing a networked HPC Lab enables HPC-enhanced co-design in knowledge-intensive transnational high value-added products or industrial value chains.

As a result, InnoHPC, first, diffuses HPC as a general-purpose technology capable to enhance innovative capacities of enterprises, especially SMEs, by increasing access to existing HPC infrastructure and providing integrated services, focusing on automotive and electronic sector. In this process, InnoHPC continues to narrow the gap between research institutes and enterprises, by improving awareness about the potentials of HPC to solve business problems and by enhancing the business relevance of scientific expertise.

Second, InnoHPC has developed capacity building tools to enhance knowledge and skills required to efficiently use HPC in innovative processes. The tools focus both on HPC providers and beneficiaries. They enhance entrepreneurial skills of HPC providers (HEIs and RIs), their real-life problem-solving capacities, as well as develop capacity of enterprises, especially SMEs, to understand and detect opportunities provided by HPC, with a focus on electronic and automotive sector.

Finally, InnoHPC increases transnational cooperation in the Danube region, connecting SMEs, HPC providers, regional development agencies and public business support institutions in InnoHPC Lab and enabling formation of industrial value chains in the electronic and automotive industries. Transnational access to existing HPC capacities, across the entire Danube region, increases utilization of existing infrastructure without the need for additional expensive investments in hardware.

7. Conclusion: Why InnoHPC?

HPC is not a minor obscure technology. The ability to efficiently process huge amounts of data dramatically increases innovative capabilities. It can be applied to develop, redesign and test products in virtual environments, optimize production and delivery processes, store and process large amount of data etc. Since physical proximity plays lesser role in utilization of HPC - HPC can be accessed and operated remotely – it provides excellent opportunity for transnational co-creation and technology transfer without the need for extensive investments in expensive hardware infrastructure in all parts of the Danube region. Hence, the main objective of InnoHPC was to improve the efficiency of innovation in the Danube region by connecting HPC providers, business support organizations, higher education institutions (HEIs), research institutions (RIs) and policy-makers in a transnational HPC laboratory. It aimed and continues to aim to improve framework conditions for transnational co-design in developing knowledge-intensive innovative high value-added products.

InnoHPC Lab diffuses HPC as a general-purpose technology capable to enhance innovative capabilities of enterprises by increasing access to existing HPC infrastructure and providing integrated services. Inside the European Single Digital Market, HPC is seen as a strategic resource for Europe's future, so the excellence in HPC applications by developing (new) HPC applications and dissemination of this knowledge is crucial. The project contributes to this.

However, successful utilization of HPC also depends on the (predominantly) academic HPC providers’ understanding the needs of the businesses, especially SMEs, on the businesses’ ability to understand and identify the opportunities provided by HPC, and on the willingness of both actors to cooperate. InnoHPC hence developed capacity building tools to enhance knowledge and skills required to efficiently use HPC in innovative processes, recognizing the co-operative dimension of these processes. These tools support building entrepreneurial skills of HPC providers and increase enterprises' ability to understand and detect opportunities provided by HPC. This directly correlates to the need detected inside the digital transformation of companies to establish a dialogue between companies (and especially SMEs) and the HPC providers.

Transnational HPC Laboratory increases transnational cooperation in the Danube region, connecting enterprises, HPC providers (HEIs and RIs), national and regional policy-makers and business support. Enterprises will be able to utilize distant infrastructure for effective innovation. Remote access and tailor-made services promote technology transfer and transnational clustering, improving inclusion of less developed regions in high-tech and knowledge intensive development thus allowing the pooling and rationalizing efforts inside the Danube region. In the next chapters, we try to provide a comprehensive overview of work done, our conclusions and hopefully, valuable lessons for future projects in this field.

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Part I

HPC in the Danube Region: The Big Picture

Innovation, Digitalisation, and the HPC in the Danube Region

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Abstract: In this paper, we introduce the technological and economic position of the countries jointly referred as Danube region. We discuss the potentials of digital transformation and the role of HPC within the EU initiatives of re-industrialisation. In this context the importance of industry for the Danube countries is assessed by outlining the gross value added and income by industry along with percentages of employed in industry. Furthermore, we continue the comparisons of Digital Technology Integration Indexes and Digital Technology Enabling Indexes to assess the openness and readiness of counties for Digital Transformation. The comparison is supported by Guidelines for Digital Transformation as they were elaborated within Interreg InnoHPC project. By this point we already notice consistent division between east and west counties of the Danube region. This division is somehow reflected also in participation of countries in EURO HPC initiative – the initiative to boost HPC capabilities of the EU by promoting national participation. In the end of the article we discuss about innovation and technology transfer through the prism of European Innovation Scoreboard, Patent Application at European Patenting Office. Additionally, we discuss about degree of openness to technology from the perspective of R&D personnel by sector and Employment in High technology manufacturing and knowledge-intensive sectors. The article concludes with tentative proposition that digital transformation with application of HPC might be a possible path towards re-industrialisation of the Danube region. Re-industrialisation would assure a steady and resilient economic growth.

Keywords: Innovation, digital transformation, supercomputing, HPC, knowledge transfer, Danube Region, DTP, Interreg Danube

1. Instead of an introduction

Innovations, especially, technological innovations are oftentimes considered as prerogative to economic growth. It is innovation in its different forms, let be the technological (telecommunications, transport) or in the field of health (medicine) has enabled not only economic growth but also societal progress.

In today's world, characterised by interconnectedness and globalisation, innovation seldom occur in isolation. We rather speak about innovation systems, as 'genotype' (see Modic and Rončević, 2018) with different 'phenotypes': national, regional, local, metropolitan, sectoral, organisational. The authors follow elaboration of Cooke (2004) on regional innovation systems as "*interacting knowledge generation and exploitation subsystems, linked to global, national and other regional systems*". Innovation systems can be seen as more or less broad and dense infrastructure (Modic and Rončević, 2018) of knowledge-based enterprises, universities and research institutions, as well as a network of intermediary institutions (liaison offices and technology transfer offices) or their functional substitutes (think tanks) to role of the intermediary institutions is to foster formal and informal interactions between institutions who operate in the knowledge production.

1.1. Danube region and its geopolitical specifics

Danube region is formally not a region per se-it is rather a community of countries joined together under a DTP financing instrument of the European Territorial Cooperation (ETC), known as Interreg. The DTP follows the goals of the EU cohesion policy and provides the framework to support joint actions and policy exchanges between actors from different Member States (DTP, 2019). The DTP financial instrument seeks to support the broader EU strategy for the Danube Region (EUSDR, 2019). The Danube regional strategy is one of the four macro-regional Strategies EU has elaborated. The strategic vision of the DTP is in 'policy integration' below the EU level and above the national level in specific fields of action. (DTP, 2019a, Cooperation programme). It covers the issues related with the needs to improve institutional frameworks for cooperation, how to improve, the quality of policies and their delivery, and how to deliver solutions through concrete investments and smart pilot actions. (ibid.).

The Danube region, as covered by the Strategy is spread from the Black forest in Germany, to the Black sea (Romania, Moldova, Ukraine) and it inhabits 115 million inhabitants. It covers the EU member states (Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Romania, Slovakia, Slovenia), Pre-accession countries (Bosnia and Herzegovina, Montenegro, Serbia) and Neighbouring Countries (Moldova and Ukraine). The Region is therefore composed of 69 NUTS-II regions.

The Strategy addresses four main topics: connecting the regional, protecting the environment, Strengthening the region and building prosperity. The InnoHPC project contributes to building prosperity by enhancing the competitiveness of companies by providing them access to HPC centres and competence centres.

What is additionally worth outlining, is the fact that all non-EU countries being included in the Danube region are characterised by the developmental lag behind the more developed countries of the EU. Moreover, there are two cases of Bulgaria and Romania, where the developmental lag is still notable despite being part of the EU. At this stage we could even speak about more segments of distinction, with developed countries of the EU, moderately developed countries of the EU, and less developed countries of the EU, along with less developed countries not part of EU. In such situation we would have 4 distinct groups of countries to work with that would most accurately define the characteristics of the Danube region.

Picture 1: Cooperation area 2014–2018 in the Danube Region

Source: Cooperation programme, DTP 2019a

The main source of division is in different framework conditions countries have developed during time. Having said that, this chapter will focus on technological innovation in connection to digitalisation and European HPC initiative as taking place in the Danube region analysed in the context of Danube region specifics.

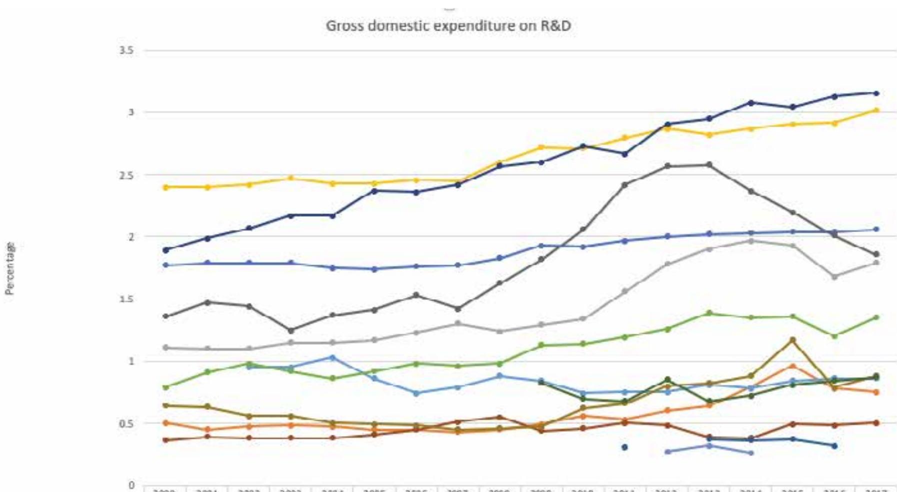
2. The position of industry and re-industrialization in EU

Apart from processes of innovation, the industry as one of the backbones of EU economic prosperity and growth faces a challenge and opportunity of digitalisation. The nine (9) key technologies that encompass the processes of digitalisation are: Social Media, Mobile Services, Cloud technologies, Internet of Thing (IoT), Cybersecurity solutions, Robotics and automated machinery, Big data and data analytics, 3D printing, and Artificial Intelligence. While some key technologies outlined above are not technologically too demanding, the developments in the fields of Artificial Intelligence, Big Data, and IoT increasingly demand more powerful computational sources in form of Supercomputing (or High-Performance Computing – HPC. Supercomputing can support development in form of assisting in overcoming time barriers in finding complex solutions, computer modelling, simulation and data analysis. Doing so the technology speeds the process of innovation and consequently increase competitiveness (EIB, 2018). The HPC has the potential to become widespread across all branches of government, academia and in almost all industries and sectors (ibid.). The EIB study from 2018 shows on how the use of supercomputing for industrial and commercial applications in Europe has rapidly grown (especially in sectors of automotive, renewable energy, and mechanical engineering). About the EU approach in supporting the HPC initiative, we will discuss later on.

- The importance of innovation in the political agenda of the EU is notable since Lisbon treaty in 2000, when the so-called innovation policy (part of which is digitalisation of industry) was pushed to the forefront. At the level of EU, the Europe 2020 was supported with nearly EUR 80 billion budget. EU member states have the goals of reaching 3 % of GDP invested in R&D. Taking in consideration countries members of the Danube region formation we notice, only Austria and Germany are already reaching the desired 3 % of GDP invested in R&D (Austria already in 2014 and Germany in 2017). Other countries are way below the desired end point although we need to consider the goal of 3 % is to be reached by 2020. Considering the data of the Graph 1, a distinct pattern is shown: Austria (3,6 %), Germany (3,02 %), and Slovenia (1,86 %) first below the EU 28 average. Serbia is relatively high. The countries that invest least, apart from Bosnia and Herzegovina, and Montenegro, there are Romania and Bulgaria. Observing the trend for the past 17 years, the countries have systematically raising their share of GDP dedicated to R&D (Bulgaria, Czech Republic, Germany, Austria, Slovakia and Slovenia, especially after 2007), there are countries that are more or less stagnant with relatively low shares (Croatia, Romania, Serbia, Montenegro, Bosnia and Herzegovina).

- However, observing trend in 17-year span, we note, several countries share of expenditure on R&D is decreasing (see Slovenia after 2013, Czech Republic after 2015, Slovakia after 2015 and Bulgaria after 2015). The decrease was in many cases result of austerity measures in times of economic crisis, and some trends already show the increased national R&D expenditure (Czech Republic, Hungary, Slovakia).

Graph 1: Gross domestic expenditure on R&D



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
EU (28 countries)	1.77	1.79	1.79	1.79	1.75	1.74	1.76	1.77	1.83	1.93	1.92	1.97	2	2.02	2.03	2.04	2.04	2.06
Bulgaria	0.5	0.45	0.47	0.48	0.47	0.45	0.45	0.43	0.45	0.49	0.56	0.53	0.6	0.64	0.79	0.96	0.78	0.75
Czechia	1.11	1.1	1.1	1.15	1.15	1.17	1.23	1.3	1.24	1.29	1.34	1.56	1.78	1.9	1.97	1.93	1.68	1.79
Germany	2.4	2.4	2.42	2.47	2.43	2.43	2.46	2.45	2.6	2.72	2.71	2.8	2.87	2.82	2.87	2.91	2.92	3.02
Croatia			0.95	0.95	1.03	0.86	0.74	0.79	0.88	0.84	0.74	0.75	0.75	0.81	0.78	0.84	0.86	0.86
Hungary	0.79	0.91	0.98	0.92	0.86	0.92	0.98	0.96	0.98	1.13	1.14	1.19	1.26	1.39	1.35	1.36	1.2	1.35
Austria	1.89	1.99	2.07	2.17	2.17	2.37	2.36	2.42	2.57	2.6	2.73	2.67	2.91	2.95	3.08	3.05	3.13	3.16
Romania	0.36	0.39	0.38	0.38	0.38	0.41	0.45	0.51	0.55	0.44	0.46	0.5	0.48	0.39	0.38	0.49	0.48	0.5
Slovenia	1.36	1.47	1.44	1.25	1.37	1.41	1.53	1.42	1.63	1.82	2.06	2.42	2.57	2.58	2.37	2.2	2.01	1.86
Slovakia	0.64	0.63	0.56	0.56	0.5	0.49	0.48	0.45	0.46	0.47	0.62	0.66	0.8	0.82	0.88	1.17	0.79	0.88
Montenegro												0.31		0.37	0.36	0.37	0.32	
Serbia										0.82	0.7	0.68	0.85	0.68	0.72	0.81	0.84	0.87
Bosnia and Herzegovina													0.27	0.32	0.26			

Source: Eurostat, 2019

- How expenditure of GDP on R&D connects with the topic of re-industrialisation? Heyman and Vetter (2013) claim the industry is currently enjoying a form of renaissance in terms of its public perception (ibid.). One of the reasons might be the fact Germany as strongly industrial country being more successful than the rest of EU at dealing with the economic crisis. What is more, industry is not any more connected with 'smoking chimneys' but is rather seen as knowledge intensive and technologically supported activity that involves research-intensive activities and demands highly skilled labour force (ibid.). Innovation and R&D activities are therefore key components of successful re-industrialisation of the EU and Danube region.
- Having said that, we are aware of declining manufacturing in the EU over the past decades. The Heyman and Vetter (2013) report of declining shares of industrial sectors in all countries except for Germany, where it remained unchanged. However, there are differences between countries like Czech Republic with industrial sector's share at 24,7 % or Hungary (22,7 %) and Germany (22,4 %) on the one hand and countries with industrial sector's share less than 10 % (Greece, France and the UK).
- Apart from the described situation, the EU commission set a target of increasing the industrial sector's share from 16 % to 20 % by 2020 as Heyman and Vetter (2013) write.
- Considering the data from the Eurostat on importance of manufacturing in EU (% of share of value added and income by industry) we observe the following trends for the Danube countries: All countries except Montenegro are above the EU average (ranging at about 19,5 %). Montenegro obtains the trend of declining values of Gross value added from the industry from 14,6 % to last available 11,2 % for year 2017. This is supported with the data on Gross value added from the industry that remains relatively important for Danube countries. The dynamics shows some countries having stable growth in Gross Value Added in industry, where others express decline.
- Brief view overt the Table 1 below, gives the impression the Gross value added in income by industry is either stable or is slightly increasing. Major decline in Gross value added in income by industry is notable for Romania, (fall from 32,2 % in 2011 to 23,6 % in 2018 % in 2018). The decline is also notable in Serbia, and Croatia.
- With the Austria, Germany, Hungary, and Czech Republic experiencing stable growth in gross value added in income by industry and Slovenia, Slovakia, Bulgaria on the other hand, resulting in increasing the Gross value added in income by industry.

Table 1: Gross value added and income by industry breakdown

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
EU	16,7	17,2	17,4	17,3	17,2	17,1	17,4	17,5	17,5	17,4
Bulgaria	18,1	17,6	20	20	19,3	19,8	20,3	21	21,1	20,1
Czech Republic	27,2	27	27,8	27,9	27,7	29,3	28,9	28,6	28,4	27,5
Germany	21,2	23,3	23,5	23,6	23,1	23,2	23,3	23,7	23,6	23,2
Croatia	16,8	17,2	17,9	18,2	17,8	17,9	17,8	17,7	17,3	16,7
Hungary	21	21,8	21,9	22	21,8	22,2	23,1	22,6	22	21,8
Austria	19,7	19,7	19,8	20	19,8	19,7	19,6	19,6	19,6	19,7
Romania	25,7	29,9	32,2	25,1	25,2	25,4	24,1	24	23,8	23,6
Slovenia	20,6	21,1	21,8	22,4	23	23,4	23,4	23,5	23,7	23,7
Slovakia	22	23,9	24,1	24,1	23	24,1	24,1	24	24	23,5
Montenegro	11,8	12,2	10,2	10,2	11,8	10,9	10,6	10,1	9,1	n/a
Serbia	21,3	21,9	22,9	23,2	23,8	22	22	21,8	22	21,3
BIH	17,6	18,1	18,1	17,6	18,4	18,1	18,6	19,2	n/a	n/a

Source: Eurostat, 2019a, own calculation

- Industry is an important employer in the countries of the EU and in the Danube region. If EU average stands at around 16% of total employees, only Austria result in share similar to EU average, all the rest of the Danube EU countries consistently obtain higher shares of employees in industry than the EU average. This is also due to the fact of importance of industry for the countries of the Danube region.
- In the period of economic crisis after 2007, despite major drops of numbers of employees in industry, the shares remained relatively high, with respect to EU average. None of the observed countries was able to manage to increase the share of employees in industry to pre-crisis levels.
- The shares of employees in industry keeps declining in the following countries: Hungary, Croatia, Austria, where in Slovenia, Slovakia and Romania the shares are growing.

Table 2: Employed in industry; percentage of total employed

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
EU	17	16,9	16,2	15,8	15,8	15,7	15,6	15,5	15,3	15,3	15,3	15,3
Bulgaria	22,4	22,3	20,5	20	20,2	20,4	19,9	19,9	20,2	20,2	20,1	20,2
Czech Republic	29,9	29,5	27,8	27,3	28,2	28,4	28,2	28,5	29	29,2	29,1	29,1
Germany	19,4	19,6	19,2	18,8	18,9	19	19	18,9	18,8	18,6	18,5	18,6
Croatia	21,9	21,6	20	19,8	20,6	20,9	20,4	20,3	19,7	19,8	19,7	n/a
Hungary	23,3	23,5	22,8	22,5	22,4	22,2	20,8	20,4	19,8	19,8	20	20,1
Austria	17,3	17,1	16,6	16,3	16,2	16,2	16,2	16	16	15,8	15,8	16
Romania	24	23,7	21,9	21,1	21,6	20,5	20,7	21,3	20,9	21,8	22	22,1
Slovenia	25,8	25,1	23,3	22,5	22,8	22,8	22,6	22,6	22,5	22,7	22,7	23
Slovakia	26,3	26,3	24,1	23,6	24	23,8	23,6	23,7	23,7	24	24,3	24,4

Source: Eurostat, 2019b, own calculation

- There are various solutions countries can obtain to turn to industry and strive for re-industrialisation. The initiatives hidden under the name of Digital transformations will be discusses further on along with some other initiatives: increased funding of R&D with the aim to support industry, and investments into human capital. We will be able to assess the potentials of the EU with the focus of the Danube region to support the desires for re-industrialisation.

3. Digitalization of Industry in the Danube and Guidelines for future work as the results of the InnoHPC Interreg Danube project

- The Digital transformation of Industry is one strong support and predictor of potential re-industrialisation of the EU and Danube region. Some comparisons further on will give us the insight of the elaboration of the Digital transformation processes in the EU and Danube region countries. We are following the results of the Digital Transformation Scoreboard for the year of 2018, Scoreboard prepared by the EC. The Digital Transformation Scoreboard monitors two indexes, first being Digital Technology Integration Index (DTII) and second Digital Transformation Enablers' Index (DTEI). Unfortunately, the data we were able to obtain concern only the EU countries but nevertheless worth elaborating: the EU average values are the following as visible from the Table 3. The distribution of values confirms a distinct pattern of east-west division of Austria, Germany preforming above the EU average, Czech Republic and Slovenia being either slightly below or slightly above the EU 20 average, and with all the rest of the countries far below the average line.

Table 3: Digital Technology Integration Index and Digital Transformation Enablers' Index

Country	DTII	DTEI
EU (28 countries)	37,3	49,2
Austria	39,4	59,9
Bulgaria	22,5	33,8
Croatia	34,6	30,7
Czech Republic	40,8	50,5
Germany	42,8	59,9
Hungary	23,5	39,9
Romania	8,6	22,2
Slovakia	30,2	34,6
Slovenia	46,0	40,0

Source: Digital Transformation Scoreboard, 2018

The Digital Economy and Society Index Report for the 2018 (DESI, 2019) again confirms the division of the region with Austria (57,94 %) and Germany (55,62 %) ranking above the EU average DESI index score set at 53,91 %. Slovenia (53,01 %) and Czech Republic (52,38 %) are just below the EU average followed by Slovakia (49,54 %), Croatia (46,75 %), and Hungary (46,53 %) with Bulgaria (41 %) and Romania (37,51 %) at the bottom.

But, can we find data showing any of potential challenges to the existing and described division? Going further into details of the DESI index, we can observe the trends of the index of Business digitalisation (DESI, 2019a). For the year 2018 the values are the following: Slovenia (51,37 %) ranking highest, together with Austria (45,89 %) above the EU 28 average (40,99 %). With Slovakia (37,26 %), Germany (35,31 %), Croatia (34,28 %), Bulgaria (30,56 %), Czech Republic (30,3 %) below the EU average and with Hungary (21,65 %) and Romania (19,25 %) at the bottom of the score. The presented data clearly indicate the potentials of the digitalisation that were already incorporated in business sector in some countries.

From the policy level, the EU monitors the individual strategic approach towards Digitalising of Industry. Out of the Danube countries, the following have elaborated and adopted Digital transformation national initiatives[19]: Austria (Industries 4.0 Österreich and Digital Roadmap Austria), Czech Republic (Průmysl 4.0), Germany (Industrie 4.0, Mittelstand 4.0, Autonomik for Industrie 4.0), Hungary (IPAR4.0 Technology Platform), Romania (Manifesto for Digital Romania), Slovenia (Slovenian Digital Coalition – digitalna.si), Slovakia (Koncepcia inteligentného priemyslu pre Slovensko), while Bulgaria and Croatia have national strategies under preparation (European Commission, 2019). This might be the explanation behind the DTII, DTEI and DESI indexes, resulting in higher value where countries are well prepared for the challenges of digitalisation, embracing the future trends in their policy initiatives.

3.1. Digitalization of Industry Guidelines by DTP Interreg InnoHPC project

Within the InnoHPC project (High-performance computing for effective innovation in the Danube Region), an extensive amount of work was done in order to get information about the status of Digital transformation in the Danube region. National initiatives and strategies were assessed and on the basis of this the five general guidelines were elaborated. We present them below (the below text is summaries from InnoHPC, 2018):

1. *Accelerate awareness of the digital transformation and role of high-performance computing in this process*. We are aware the digital transformation and high-performance computing go hand in hand. However, at this point, some parts of the region and even some important target groups poorly understand the immense applicability. Increased awareness is one important step to increase its utilization across the region.
2. *Continue, enhance, and target support for knowledge-exchange and cooperation between universities and industry.* Various existing schemes, encourage knowledge- exchange and cooperation between universities and industry. However, they need to become more targeted on industrial research, training and development of infrastructure to fully support the processes of Digital Transformation.
3. *Promote, educate and train for Industry 4.0 throughout the Danube region*. Being aware the Industry 4.0 refers to processes of Digital transformation in one specific country the guideline targets the background knowledge – namely, the guideline refers to the need to spread the best practices in

19 National initiatives aim to analyse framework conditions at national level and are aiming towards rolling out digital policies (DTM, 2019).

process of digital transformation to parts of the regions that lags behind. Such approach might contribute to bridge the gap between traditionally more and traditionally less developed parts of the region.

4. *Support regional infrastructure for research and development*. The Danube regional gap between more and less developed parts is notable also with the access of the infrastructure – also at the level of HPC but not limited to. The research and innovation infrastructure need further support in the eastern parts of the region to enable the stakeholders to engage in innovation activities more efficiently.
5. *Harmonize relevant legal regulation for digitalization and its enforcement*. The main aim behind the guideline is the need to establish a framework where transnational cooperation will be enables, namely by creation of trans-national value chains. The main example is the need to harmonise the legislation dealing with protection of intellectual property rights.

4. HPC in Europe and in the Danube region

The development and support to European HPC is, on the level of EU incorporated into effort of the strategy for the Digital Single Market. The policy aiming towards support for development of HPC is known as The European High-Performance, Computing Joint Undertaking – Euro HPC. The main aim of the policy is to pool European resources to develop top-of-the-range exascale[20] computers for processing big data, based on competitive European technology (European Commission, 2019). Two main aims of the policy are in firstly, develop a Pan-European supercomputing infrastructure, and secondly, supporting research and innovation activities, especially with the aim in making supercomputing resources available to large number of public and private users including small and medium sized enterprises. The total budget provided for the activities is EUR 1 billion, with EU's financial contribution at EUR 486 million.

The HPC Joint Undertaking officially, set of in November 2018 and will be operational until 2025 addressing the needs and challenges of the citizens (healthcare, public service efficiency, cyber security, safer and greener transport), responding to the needs of researches (e. astrophysics and deep space research) and the needs or the industry (helping manufacturers and SMEs to be more innovative and save money, time, and resources). The financial support will be provided by public procurements and research & innovation grants following open and

20 Exascale refers to the speed of the computing systems capable of at least one exaflop, equivalent to billion calculations per second or 1,000 petaflopc (EIB, 2018).

competitive calls (Digital single market, 2019, Pooling resources to build world class European supercomputers).

The Euro HPC declaration, as predecessor of the EuroHPC joint undertaking was launched on 23rd of March 2017, with Belgium and Slovenia being the first two EU member states to join the initiative in July 2017. From Danube countries, the following EU member states also joined: Bulgaria in October 2017, Croatian in November 2017, Czech Republic in January 2018 and Austria in June 2018. From the EU counties, Slovakia, Hungary and Romania did not join the initiative (yet).

Another initiative worth mentioning is the PRACE initiative – Partnership for Advanced computing in Europe. The PRACE partnership currently has 26 members representing EU Member States and Associated Countries. Following the information on the official PRACE website (PRACE, 2019) the main mission of the Partnership is to enable high-impact scientific discovery and engineering research and development across all disciplines to enhance European competitiveness for the benefit of society. The main activities of the partnership are in the field of established Research Infrastructure (RI), it enables PRACE HPC access and most importantly it offers Trainings end education via seasonal schools, workshops and scientific and industrial seminars throughout Europe. Participation in training events is free of charge for both academia and industry (ibid., 2019).

Nevertheless, the EIB report (2018) notes that EU making substantial progress in the development of its HPC eco-system, there are still large investment gaps that hinder EU position in the global level. Furthermore, the report elaborates that the needs from the industry SMEs and researchers far exceed the current European supply of HPC resources. The report further on emphasises, the European innovators increasingly use HPC resources outside EU (ibid., p. 11).

With this strong EU effort in development of HPC and its usage the concerning part is the lag shown in the Eastern countries of the EU. Considering the fact, that Slovakia, Hungary and Romania have not joined the Euro HPC joint undertaking (as of 2019) we can only imagine the lag than non-EU countries are facing at the filed. The InnoHPC project (DTP Interreg funded) is valuable contribution offering benchmark in all Danube countries, ranging from ERDF[21] to IPA[22] and ENI[23] countries.

21 European Regional Development Fund

22 Instrument of Pre-Accession

23 European Neighbouring Instrument

Additionally, the PRACE initiative mentioned earlier is, without a doubt, a valuable contribution towards connecting relevant actors in the field of HPC, but checking roughly, we can see that not many actors from Danube countries are actively involved in the partnership. Out of 14 Danube region countries only the following ones have a representative in the PRACE network: Austria, Bulgaria, Czech Republic, Germany, Hungary, Slovakia, Slovenia, and Croatia included as Observer. The countries missing their representative are: Serbia, Bosnia and Herzegovina, Montenegro, Romania, Moldova, Ukraine (PRACE, 2019a). It is worth noticing the list of countries not having a representative in the PRACE partnership, somehow collides with the east-west division of the developmental line in the Danube Region. In such situation the contribution of the InnoHPC project implementing an InnoHPC LAB as sort of an eastern supplement to PRACE partnership is important.

5. **Innovation and technology transfer in the Danube region**

Before starting on evaluation of the potentials of the regions, we need to be aware of the main characteristics of each of the Danube countries. In the context of vast division between east and west, we were able to outline three groupings of countries: the countries include Austria and Germany that are considered to be innovation core. The countries of semi-periphery include: Slovenia, Czech Republic, Hungary, Slovakia, and Serbia (where the data is available for Serbia). The countries of the semi-periphery are most diverse, with Slovenia and Czech Republic ranging very high therefore aiming towards developed countries, and with countries as Serbia and Croatia aiming very modestly according to some measures. The innovation periphery includes the countries of Bulgaria and Romania, and where data is available also Ukraine and Moldova.

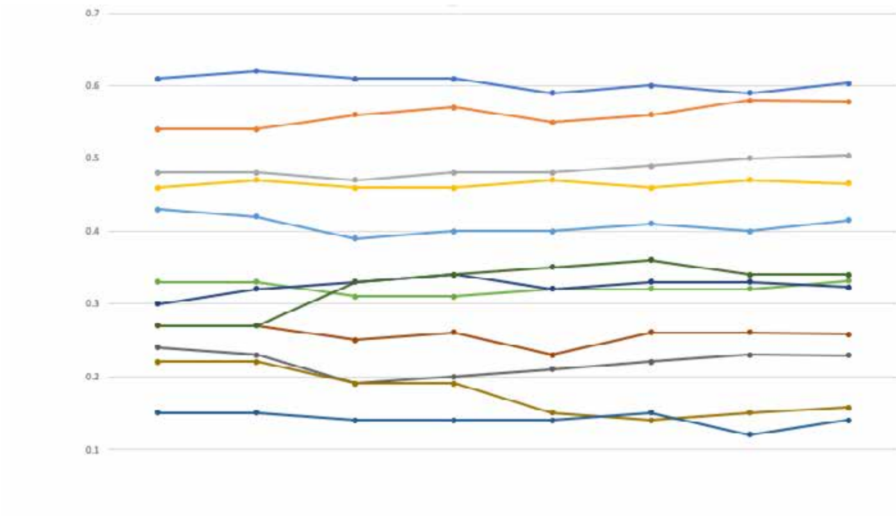
It is innovation potential of the countries that has been an object of scientific debate for years now. Considering the research by Fagerberg and Srholec (2008) the main factors, defined as 'capabilities' (p. 1431) for the economic performance are the following: the development of *innovation system*, the *quality of governance*, the character *of political system*, and the degree of *openness* to technology /knowledge from above. The authors elaborate, about innovation system being prerequisite for the development, but not being sufficient, good governance is also critical for the ability to realize the desired outcomes. In the context of the Danube regions, where the countries are so diverse in their innovation performance it is important to analyse the situations and the seek for explanations on what are the conditions for the present state of the art. Partially following the elaboration of Fagerberg and Srholec we will elaborate the tentative comparison among the Danube countries. The comparison will be elaborated, based on comparison of development of innovation systems and comparison of openness to technology/knowledge from above.

5.1. Development of innovation system

When elaborating the characteristics of innovation system, we primarily look at the differences between countries bases on comparing the data from Innovation Union Scoreboard (comparing Innovation index, comparing Innovation friendly environment, and data on Opportunity driven entrepreneurship). Following this we will present the differences and similarities between countries regarding their patenting activities, as results of innovation activities. To illustrate the diversity of the countries joined together into Danube macro region we will firstly present statistics on the innovation activities of Danube countries and later we will present information on shares of GDP being invested in R&D activities. We finish with information about Employment in high technology manufacturing and knowledge intensive service sectors (we will compare the shares of total employment in EU country).

Following the results of the European Innovation Scoreboard from 2010–2017, we can observe wide differences between the Danube region countries, with Ukraine, Bulgaria and Romania being among modest innovators scoring lowest on the rank. For Moldova no information is provided, but we can assume the country would be in the group of Modest innovators EU average is set on the value of 0.5 place well above the average of Danube countries. Only Germany and Austria, as strong innovators are placed above the EU average. Slovenia is also placed among strong innovators but below the EU average. As for the rest of the countries, they are ranked ad moderate innovators. There are several countries that were not included in the European innovation union Score board. We refer here, to the before mentioned Moldova, but also Bosna and Herzegovina and Montenegro. It is worth noticing, there is no Innovation leader among Danube countries, with innovation leaders being placed on the north west of the EU (Sweden, Denmark, Finland, Netherlands, United Kingdom and Luxembourg). There is also Switzerland, as strongest innovation leader in Europe.

Graph 2: European Innovation Score Board for selected countries



	2010	2011	2012	2013	2014	2015	2016	2017
Germany	0.61	0.62	0.61	0.61	0.59	0.6	0.59	0.60
Austria	0.54	0.54	0.56	0.57	0.55	0.56	0.58	0.58
EU Average	0.48	0.48	0.47	0.48	0.48	0.49	0.5	0.50
Slovenia	0.46	0.47	0.46	0.46	0.47	0.46	0.47	0.47
Czech Republic	0.43	0.42	0.39	0.4	0.4	0.41	0.4	0.42
Hungary	0.33	0.33	0.31	0.31	0.32	0.32	0.32	0.33
Slovakia	0.3	0.32	0.33	0.34	0.32	0.33	0.33	0.32
Croatia	0.27	0.27	0.25	0.26	0.23	0.26	0.26	0.26
Bulgaria	0.24	0.23	0.19	0.2	0.21	0.22	0.23	0.23
Romania	0.22	0.22	0.19	0.19	0.15	0.14	0.15	0.16
Ukraine	0.15	0.15	0.14	0.14	0.14	0.15	0.12	0.14
Serbia	0.27	0.27	0.33	0.34	0.35	0.36	0.34	0.34

Source: European Innovation Scoreboard edition 2018, own calculation

As noticed from the Graph 2, there the distinct geographical groupings of countries continue from the all previously presented data. Currently, the far eastern countries continue being on the lower parts of the scale and with most western countries (Germany, Austria, Slovenia) occupying the top positions. The countries in between the classification range from Czech Republic with higher Innovation index, with Serbia surprisingly high and Croatia, surprisingly lower.

Comparing different aspects of the European Innovation Scoreboard Index as visible in Table 4, for the year of 2017 gives insight of the figures being the Innovation index presented above. Analysing Table 4, we conclude, that Germany hosts most Innovation friendly environment, with Hungary being second already below the EU average. Slovenia and Austria follow. Croatia and Serbia conclude the list as countries with least innovation friendly environments. Additionally, interesting is the information on the values each of the country scores under the index of Opportunity driven entrepreneurship. Germany is still ranking highest, with all other countries below the EU average. Austria is ranking second, with Slovenian being behind Czech Republic and Hungary, with Romania before Croatia, Bulgaria and Serbia.

Table 4: European Innovation Scoreboard Index breakdown, 2018

	EU28	BG	CZ	DE	HR	HU	AT	RO	SI	SK	RS	UA
FRAMEWORK CONDITIONS												
Human resources												
1.1.1 New doctorate graduates	2,0	1,5	1,7	2,8	1,2	1,0	1,9	0,8	3,5	2,2	1,1	1,8
1.1.2 Population completed tertiary education	39,0	33,4	33,8	31,3	32,7	30,2	40,3	25,6	44,5	35,1	n/a	n/a
1.1.3 Lifelong learning	10,9	2,3	9,8	8,4	2,3	6,2	15,8	1,1	12,0	3,4	n/a	n/a
Attractive research systems												
1.2.1 International scientific co-publications	517	227	755	812	492	456	1376	182	1135	439	353	61
1.2.2 Scientific publications among top 10% most cited	10,6	4,2	6,6	11,3	4,6	6,9	11,1	4,8	8,6	6,2	4,1	3,6
1.2.3 Foreign doctorate students	26,1	6,3	14,8	9,1	3,9	11,6	28,3	3,8	9,7	9,1	6,5	7,0
Innovation-friendly environment												
1.3.1 Broadband penetration	16,0	12,0	12,0	14,0	7,0	16,0	13,0	17,0	16,0	12,0	3,0	0,7
1.3.2 Opportunity-driven entrepreneurship	3,3	1,0	2,7	4,0	1,2	2,4	3,0	1,2	2,4	1,3	n/a	n/a
INVESTMENTS												

Finance and support												
2.1.1 R&D expenditure in the public sector	0,70	0,21	0,64	0,94	0,46	0,29	0,87	0,21	0,49	0,39	0,55	0,23
2.1.2 Venture capital investments	0,116	0,037	0,006	0,069	0,021	0,079	0,060	0,037	0,006	0,014	0,003	0,019
Firm investments												
2.2.1 R&D expenditure in the business sector	1,32	0,57	1,03	2,00	0,38	0,89	2,20	0,27	1,51	0,40	0,33	0,38
2.2.2 Non-R&D innovation expenditure	0,76	0,74	0,94	1,26	1,20	0,75	0,47	0,23	0,81	0,58	1,79	0,50
2.2.3 Enterprises providing ICT training	21,0	9,0	23,0	28,0	23,0	17,0	31,0	4,0	27,0	17,0	22,0	n/a
INNOVATION ACTIVITIES												
Innovators												
3.1.1 SMEs with product or process innovations	30,9	14,0	30,8	41,6	25,4	15,1	40,7	4,9	32,6	16,7	28,3	7,4
3.1.2 SMEs with marketing or organisational innovations	34,9	14,8	25,7	49,1	30,8	15,2	46,1	8,8	33,2	22,4	32,9	10,5
3.1.3 SMEs innovating in-house	28,8	11,2	28,0	37,9	21,1	11,7	35,0	4,5	26,1	13,9	23,8	18,7
Linkages												
3.2.1 Innovative SMEs collaborating with others	11,2	3,1	10,0	10,1	6,8	6,2	20,5	1,8	13,2	8,4	4,9	1,5
3.2.2 Public-private co-publications	40,9	3,0	21,0	62,4	17,3	29,6	82,3	3,7	56,1	10,3	4,5	1,0

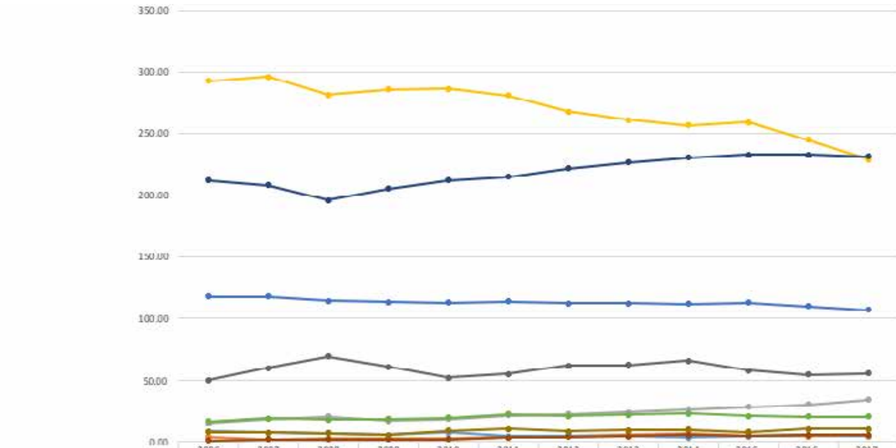
3.2.3 Private co-funding of public R&D expenditures	0,05	0,02	0,03	0,12	0,03	0,03	0,05	0,03	0,05	0,04	0,19	n/a
Intellectual assets												
3.3.1 PCT patent applications	3,53	0,64	0,93	6,11	0,61	1,34	4,70	0,22	1,65	0,51	n/a	0,55
3.3.2 Trademark applications	7,86	9,10	5,09	9,51	4,00	4,15	13,09	2,64	11,09	4,49	3,68	1,85
3.3.3 Design applications	4,44	5,56	4,07	6,72	0,90	1,15	6,98	1,31	2,97	1,46	0,12	0,39
IMPACTS												
Employment impacts												
4.1.1 Employment in knowledge-intensive activities	14,2	10,2	12,9	14,8	11,6	11,6	15,0	7,7	13,7	10,6	14,4	12,9
4.1.2 Employment fast-growing firms innovative sectors	4,8	6,6	6,5	4,6	3,5	8,7	1,9	2,6	3,2	7,7	n/a	n/a
Sales impacts												
4.2.1 Medium & high tech product exports	56,7	33,8	65,7	68,2	39,9	68,5	58,0	55,8	57,0	66,4	44,9	29,4
4.2.2 Knowledge-intensive services exports	69,2	39,0	43,8	74,6	19,1	49,0	43,1	46,2	36,0	33,2	47,6	49,2
4.2.3 Sales of new-to-market and new-to-firm innovations	13,37	4,80	14,57	13,34	4,91	12,47	11,98	6,51	12,44	19,12	7,94	3,30

Source, European Innovation Scoreboard, 2018, own calculation

Another set of data confirming the diversity and division of the Danube region is the data on Patent applications to the European Patent Office (Eurostat, 2019c). For the time span of 2006–2017, the EPO reports the following trends: Germany and Austria are both far above the EU28 average of 106,84 patents applied at EPO per million inhabitants in 2017, with Austria ranking top at 231,35 patents applications per million inhabitants in 2017 and Germany ranking second with 228,31 in 2017. Well below the EU average, there is Slovenia with 55,3 in 2017 and Czech Republic with 33,78 patent applications per million inhabitants in 2017. Hungary and Slovakia follow, with Hungary applying 20,8 patents and

Slovakia applying 10,14 patents per million inhabitants in 2017. The bottom three countries we were able to retrieve the data are Romania (8,07), Croatia (4,8) and Bulgaria (4,13) for 2017. The information that is missing is for the non-EU countries of Bosnia and Herzegovina, Serbia, Montenegro, Moldova, and Ukraine. Nevertheless, we tend to believe the chart would remain showing the same division between east and west of the region as we are able to observe it below. The same set of data comparing the years prior to the global crisis shows the same east-west division.

Graph 3: Patent application to the EPO, per million inhabitants



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
European Union - 28 countries	117.65	117.56	114.03	113.16	112.82	113.87	112.29	112.03	111.97	112.55	109.71	106.84
Bulgaria	3.56	1.61	2.48	2.12	2.29	3.58	4.62	5.47	6.55	4.43	4.34	4.13
Czechia	14.96	18.46	20.27	16.89	18.41	21.25	22.08	23.83	25.68	28.03	30.19	33.78
Germany	292.94	296.38	281.85	285.84	286.59	280.89	267.95	261.24	256.97	259.00	245.06	228.81
Croatia	8.24	7.24	6.700	5.11	7.05	3.96	4.53	4.34	3.43	4.24	5.03	4.80
Hungary	16.37	18.99	18.04	18.38	19.52	22.19	20.92	21.76	22.51	20.82	20.47	20.08
Austria	212.05	207.89	195.74	205.31	212	214.96	221.57	226.400	230.54	233.15	232.76	231.35
Romania	0.95	1.54	1.62	1.52	1.71	2.99	3.56	4.25	5.11	4.71	5.01	5.07
Slovenia	50.13	59.75	69.100	60.64	51.91	54.69	61.65	62.11	65.54	57.73	54.43	55.30
Slovakia	7.51	7.24	6.86	5.36	8.63	10.17	8.24	9.19	9.39	7.73	9.99	10.14

Source: Eurostat, 2019c, own calculation

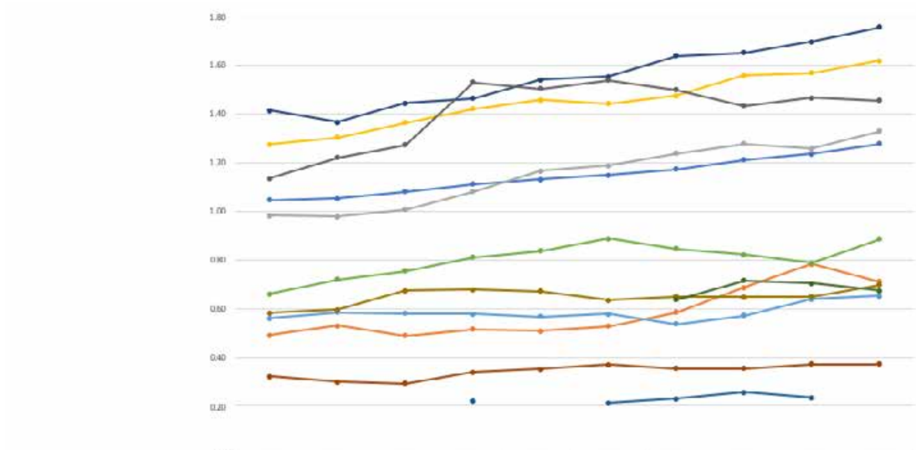
5.2. Degree of openness to technology/knowledge from above

As we were able to observe the distinctions between East and west of the Danube countries through the prism of European Innovation Scoreboard and numbers of patent applications, we will further elaborate data on human capacity as one of the aspects of openness to technology/knowledge. Especially, we focus on employment of highly educated staff. We will compare the data on R&D personnel in comparison to working population. Additionally, we will present data on Employment in High technology manufacturing and knowledge-intensive service sectors.

Considering the already presented data, we believe the distinctions will reveal in the same pattern East-West as all previously presented cases.

The data below offers to confirm the proposed statement of the division between countries. Observing the data on R&D personnel by sector where there are included shares of employees by the following institutional sectors: business enterprise, government, higher education, and private non-profit. On the one hand, we have countries with shares of R&D employees higher than EU average set at 1,28 % of active population. Those are, not surprisingly Austria (1,75 %), Germany (1,61 %), Slovenia (1,45 %), Czech Republic (1,32 %). The trend in Slovenia is interesting to observe, with share of R&D employees in 2011 surpassing all before mentioned countries, reaching the value of 1,53 % of active working population. The change in situation of Slovenia (the leap in 2011) is connected to methodological change of data collection (STAT, 2013). The countries below the EU average are the following: Hungary (0,88 %), Bulgaria (0,71 %), Serbia (0,67 %) with the share relatively high mainly due to the fact of higher number of R&D staff at higher education intuitions, Slovakia (0.69 %), Croatia (0,65 %) with the Bottom two: Romania (0.37 %) and Montenegro (0,23 % with data from 2016).

Graph 5: R&D personnel (as % of active population)



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
European Union - 28 countries	1.05	1.05	1.08	1.11	1.13	1.15	1.17	1.21	1.24	1.28
Bulgaria	0.49	0.53	0.49	0.51	0.51	0.53	0.58	0.69	0.78	0.71
Czechia	0.98	0.98	1.01	1.08	1.17	1.19	1.24	1.28	1.26	1.33
Germany (until 1990 former territory of the FRG)	1.28	1.30	1.37	1.42	1.46	1.44	1.48	1.56	1.57	1.62
Croatia	0.56	0.58	0.58	0.58	0.57	0.58	0.54	0.57	0.64	0.65
Hungary	0.66	0.72	0.75	0.81	0.84	0.89	0.85	0.82	0.79	0.89
Austria	1.42	1.37	1.45	1.46	1.54	1.55	1.64	1.65	1.70	1.76
Romania	0.32	0.30	0.29	0.34	0.35	0.37	0.35	0.35	0.37	0.37
Slovenia	1.14	1.22	1.27	1.53	1.50	1.54	1.50	1.43	1.47	1.46
Slovakia	0.58	0.60	0.67	0.68	0.67	0.64	0.65	0.65	0.65	0.70
Montenegro				0.22		0.21	0.23	0.25	0.23	
Serbia							0.64	0.71	0.70	0.67

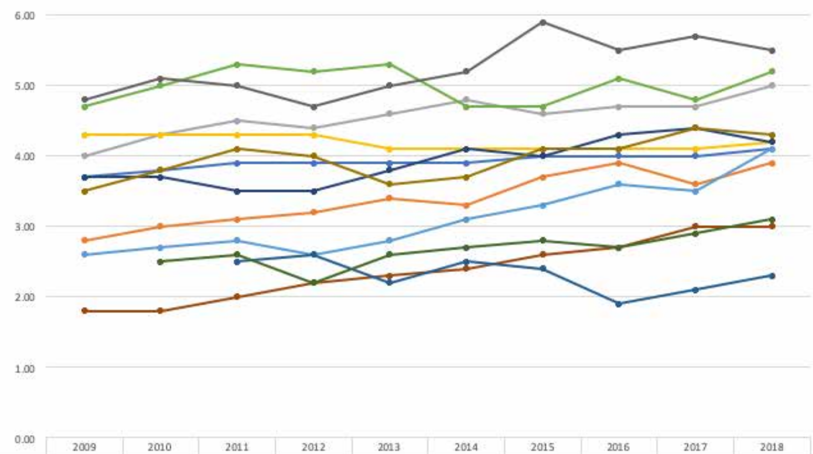
Source: Eurostat, 2019d, own calculation

In the final comparison table, we present the trends of shares of employment in high technology manufacturing and knowledge-intensive service sectors. We retrieved the data from the Eurostat, unfortunately, again lacking the data from several non-EU countries. Observing the trends in the past ten years, the most employment in high- and medium-high technology manufacturing sectors and knowledge intensive service sectors as share of total employment go to Slovenia (ranked highest since 2014, despite a relatively harsh drop in 2015 and with final value of 5,5 % of total employment in 2018). Constant growth of the share shows the importance of sector in Slovenia. The second ranked is Hungary, experiencing severe drop in 2014 but showing major catching up since 2017 to final score of 5,2 % of total employment in 2018. Third, with steady growth, somehow resistant to sudden drops, is Czech Republic with final value of 5,00 % in 2018. The countries are followed by Slovakia, with experience of drop after 2012 and with steady growth from then on reaching the final 4,30 % of total employment in 2018. Steady growth is distinct also for Austria where for Germany we can speak of slight decrease of % of employment in the past 9 years, still reaching end values of 4,20 % in 2018. The above-mentioned countries were all above the EU average that reaches the value of 4,1 % for 2018.

Just below the EU average there are two countries that have experienced major growth in percentage of employees in high technology manufacturing and knowledge intensive service sectors. Those are Bulgaria, experiencing a growth from 2,8 % to 3,9 % of total employees, and Croatia experiencing a growth from 2,6 % to reaching the EU average at 4,1 % in 2018.

The next two countries are Serbia and Romania. Serbia experiencing growth from 2,5 % in 2010 to 3,1 % in 2018 where Romania experiences growth from 1,8 % in 2009 to 3 % in 2018. The lowest share of employed in high technology manufacturing and knowledge intensive service sectors obtains Montenegro, experiencing the total decrease, from 2,5 % in 2011 to 2,3 % in 2018.

Graph 6: Employment in High technology manufacturing and knowledge-intensive service sectors (as % of total employment)



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
EU - 28 countries	3.70	3.80	3.90	3.90	3.90	3.90	4.00	4.00	4.00	4.10
Bulgaria	2.80	3.00	3.10	3.20	3.40	3.30	3.70	3.90	3.60	3.90
Czechia	4.00	4.30	4.50	4.40	4.60	4.80	4.60	4.70	4.70	5.00
Germany	4.30	4.30	4.30	4.30	4.10	4.10	4.10	4.10	4.10	4.20
Croatia	2.60	2.70	2.80	2.60	2.80	3.10	3.30	3.60	3.50	4.10
Hungary	4.70	5.00	5.30	5.20	5.30	4.70	4.70	5.10	4.80	5.20
Austria	3.70	3.70	3.50	3.50	3.80	4.10	4.00	4.30	4.40	4.20
Romania	1.80	1.80	2.00	2.20	2.30	2.40	2.60	2.70	3.00	3.00
Slovenia	4.80	5.10	5.00	4.70	5.00	5.20	5.90	5.50	5.70	5.50
Slovakia	3.50	3.80	4.10	4.00	3.60	3.70	4.10	4.10	4.40	4.30
Montenegro			2.50	2.60	2.20	2.50	2.40	1.90	2.10	2.30
Serbia		2.50	2.60	2.20	2.60	2.70	2.80	2.70	2.90	3.10

Source: Eurostat, 2019e

6. Towards a tentative conclusion

Danube region is one of the most sensitive group of countries since it covers, by DTP definition, both EU and non-EU member states with very different levels of development. It includes, some of the most developed regions of Germany on one hand, and Moldova and two regions of Ukraine, as least developed countries on the other. Additionally, it includes IPA countries with their developmental trajectory. The set of countries is culturally and economically very different therefore their innovation performance varies differently. In the same way as countries differ, so do differ their innovation systems. In todays' world the innovation systems combine the work of universities, research institutions, intermediary institutions and knowledge-based enterprises and in this article, we are focusing on technological innovation. We claim innovations always occur as result of cooperation and in interaction of knowledge generation and exploitation. Innovation nowadays are supported by digital transformation initiatives and joint Euro HPC initiative.

The main topic the presented article desires to highlight is the topic of re-industrialisation and the possible paths towards it. The starting point is that re-industrialisation of Danube region could play a key role in economic development of the countries of the Danube. The path towards re-industrialisation include the digital transformation and its benefits, and the usage and applicability of high performance computing to support innovation. Industry plays strong role in in the countries of the Danube and it seems even the economic crisis did not diminish the importance of it. By improving specific framework conditions (e.g. Raising the share of GDP in R&D activities) might lead towards improving developmental performance of the Danube countries using also EU initiatives on digital transformation and HPC joint undertaking. The industrial base gives a solid starting point and offers possible success.

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Gap Analysis: HPC Supply and Demand

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Abstract: Application of innovative solutions, simulations or testing approaches and decreased time to market empowers SMEs to benefit from reduced cost by using HPC. Since having HPC technology in the house is costly and unsustainable, SMEs can now rely on the help from several competencies centres across the Danube region. The network of competencies centres that InnoHPC project is trying to establish is rich in competencies and modes of operation. The main discrepancy between demand and supply, revealed through the gap analysis, was the low level of expertise and scarcity of experts on the emerging HPC market. Thus, companies who seek expert help in the developmental process may be faced by the lack of supply.

Keywords: HPC technology, gap analysis, SMEs, TIER I and II suppliers, providers or competencies centres.

1. Introduction

According to European Commission, High-Performance Computing (HPC) is a strategic resource for Europe's future. HPC allows researchers to study and understand complex phenomena and at the same time is decision makers in their excellence as well as enabling industry to innovate in products and services. This been said, it has been established that the European Commission funds are directed toward HPC related projects. One such project in InnoHPC. Furthermore, HPC has a fundamental role in driving innovation leading to societal impact through better solutions for societal challenges and increased industrial competitiveness (Porter, 1998). Koller et al. (2015) sees the disruptive power of HPC technology to be able to transcend from solving complex problems in a highly industrial environment to become a tool widely used by business and academia to enhance competitiveness and innovation.

Same as EU, also other countries had announced ambitious plans for HPC technology and solutions, so some may call it a global race toward modern, scientific and innovative data discovery approach. By using HPC power companies can benefit from reduced cost, application of innovative solutions, simulations or testing approaches and decreased time to market. So in a way HPC helps industry increasing their competitiveness (Shephard et al., 2013) and on the other hand helps academia achieving their scientific excellence. Due to costs and usage complexities, engineers working with HPC are forming clusters of application-development teams or scientific communities to gather support. Due to scalability potential of HPC, the push is toward multi-layered strategy consisting of community-oriented, high-level support infrastructures and cross-sectional methodology-oriented units (Attig et al, 2011; Alowayyed et al., 2019).

HPC Strategy was adopted by EU in 2012 in order to optimise national and European investments, addressing the entire HPC ecosystem. The strategy is implemented through Action Plan Objectives of 1) build exascale systems, 2) access to the supercomputing facilities and services by industry and academia – PRACE, 3) excellence in HPC application delivery and disseminate knowledge to stakeholders, 4) EU's position as a global actor. Apart from just specifying the pillars, the European Commission wants also to raise awareness, providing training as well as education and skills development within HPC areas. In the past 20 years the investment strategy has focused partly on high-performance computing systems due to their performance and productivity potential. However, some scholars are noticing that the investments could be more fruitful if more planning, integration (with other technologies) and coordination of the community would be involved. There are the so called "critical holes" individuated in the software environment that pose potential if properly addressed (Dongarra et al., 2009).

Chakode et al. (2010) has publish an article discussing that owning a cluster infrastructure of high performance computing (HPC) is crucial for software vendors who need to provide their software as services via the Internet, but out of reach (acquisition costs, operating costs) for SMEs and/or start-up businesses. That is the reason why they come up with the idea of sharing a common infrastructure, instead of just paying Amazon, Google, IBM, Sun, etc. to use remote infrastructures.

As noticed by Ziegler et al. (2014) SMEs running industrial simulation codes on Cloud resources are rare, mainly because: 1) industrial simulation codes are complex, 2) simulation codes are often designed for parallel execution, 3) industrial simulation codes are protected by software licenses for executing the simulation locally. To fix this gap, Fortissimo project was funded. Its aim is at supporting SMEs when they need to perform simulations using HPC Cloud resources. To this end Independent Software Vendors, Cloud Providers, SMEs and experts work together implementing and testing a "one-stop-shop" for SMEs that delivers computational resources, applications and the corresponding software licenses in an integrated way.

On the other hand, Zarza et al. (2012) discuss the innovative teaching strategy to understand HPC, since as they put it: "university education in HPC often suffers from a significant gap between theoretical concepts and the practical experience of students". They implemented new teaching tools and resources designed to promote active learning. Nevertheless, their article is very informative also because, they specified in detail what are the specific (knowledge, expertise, and attitude) and general skills that need to be acquired by students.

A very in depth report that was also taking into account within InnoHPC team is the document from 2016 prepared by Ezell and Atkinson on the importance of HPC to US Competitiveness. They foresee the need concerted public and private collaboration and investment to maintain its leading position in both HPC production and application to maintain frontier of competition. Apart from that, they explain the potential of HPC as the forefront of scientific discovery and commercial innovation. The report focuses on several areas or industries within the Commercial Applications and Benefits of HPC use, where automotive and electronics sector as well as on global HPC market.

Industry can benefit from HPC in many ways which are closely linked primarily to discovery and innovation. With the help of HPC companies can use advanced modelling, simulation, and data analytics, optimize processes and design, improve quality, predict performance and failure, and accelerate or even eliminate prototyping and testing. Using this cutting edge technology companies can design new products, improve existing products, and to bring products to market more promptly and efficiently. In this way we can see HPC, although being expensive, cost-effective tool for accelerating the research and development (R&D) process.

Ezell and Atkinson (2016) on automotive sector:

"HPC has transformed how vehicles and their components are designed, modelled and simulated, safety tested, and ultimately manufactured, playing a key role in reducing vehicle design costs, introducing innovative new features, and improving the fuel efficiency and safety of vehicles".

2. Regional HPC Mapping: GAP analysis

From collected and analysed data from first HPC survey with information on relevant small and medium enterprises in the electronic and the automotive sectors, and the other survey on HPC providers and competence centres'. In the first survey our efforts were focused on cataloguing needs, competences and expectations of relevant enterprises in the electronic and the automotive sectors. Secondly, the survey done among HPC providers and competence centres' focused on available infrastructure and in-house competencies.

Our survey among enterprises, which aim to establish their needs, expectations and competencies in the field of HPC data yield results that are going to be summaries and compared to infrastructure and competencies that are provided by HPC providers and competence centres (the second survey) in order to establish a gap between the needs of the SMEs operating as TIER I and II suppliers in the electronic and automotive sectors and the infrastructure, competencies and motivation of HPC providers and competence centres.

In our sample there were 94 enterprises responding the questionnaire, form which: 45.2 % from the automotive sector, 21.5 % from electronic sector, while others (33.3 %) are mostly both, ICT sector, consulting services, training services. According to their size are large enterprises (29.8 %), followed by medium-sized enterprises (25.5 %), micro-companies (24.5 %) and small companies (20.2 %), 53.8 % of companies employ less than 10 people, 17.2 % employ between 11 and 30 people, 5.4 % of companies in the sample have between 31–50 or 51–100 employees, 11.8 % between 101–300, 1.1 % between 301–500 and 3.2 % above 500 employees.

When we focus more in general information about company's, the results tell us that 68.1 % of enterprises (n=94) has its own research and development (R&D) department in-house, however 54.3 % (n=74) of the companies does not rely on HPCs to meet their business requirements. On the other hand, 43.6 % (41 companies) are skilled or have developed competencies to use HPC solutions to meet their business requirements, the majority of such companies it's been using HPC solutions to meet their business requirements. Among them, 43.9 % of companies has been using HPC for more than 5 years, 12.2 % has been using HPC for last year, 22.0 % from 1 to 3 years and the same percentage of the companies were using it for 4 to 5 years. Generally, companies decided to use HPC solutions to **solve problems that couldn't be addressed through other means** (26.6 %), **address problems more efficiently, faster, at the lower cost** (24.5 %), develop new products or services (22.3 %), improving business innovation process (10.6 %). Companies are using HPC for **R&D purposes** (42.9

%), **engineering and design** (29.9 %), manufacturing or production (14.3%), large-scale data management (11.7 %). Software application and infrastructure that used is predominantly used is a **bought software and infrastructure** (33.3 %), developed in the house (23.2 %), commercial infrastructure (23.2 %) as well as open source software applications and infrastructure (20.3%). In order to access HPC facilities companies mainly use **Linux OS** (40.0 %), followed by Windows XP (27.3 %) and Windows Vista (12.7 %). The direct benefit that companies are noticing about implementation of HPC solutions is an **increased competitiveness** (25.7 %), **increased productivity** (22.9 %), **and accelerated innovation** (22.9 %), faster time to work (18.1 %). HPC resources are mainly used within the organisation (33.3 %), over a GRID network to access HPC resources from other organisations (21.1 %), over the GRID network to access HPC resources from other departments of the organisation (19.3 %) or over a network connection to access HPC resources from other departments of the organisation (17.5 %). Reasons why companies **do not use** HPC solutions are satisfaction with the actual level of technologies (44.9 %), no financial resources to integrate HPC in the current work (21.7 %), lack of knowledge about HPC (20.3 %). So here we see a potential basin of SMEs that need help in gathering sufficient knowledge about HPC usage and application. Among actual non-users, only 5.9 % of companies envisage integrating HPC to meet business requirements in the next 12 months, while the majority of the companies is either unsure (37.3 %) either against (41.2 %), because their customers do not require HPC usage (90.2 %), companies do not require their suppliers to use HPC (92.2 %).

When we focus more in detail on company's needs, we can see that the degree of HPC development in DANUBE area is the most prominent in the field of availability of commercial HPC infrastructure (M=3.1), degree of science-industry cooperation related to HPC (M=2.9), availability of skilled human resources (M=2.9), the degree of science-public authorities' cooperation related to HPC (M=2.9). On the other hand, there is still some **place for improvement** within HPC prioritization in legislative documents and strategies (M=2.4), availability of free HPC infrastructure (e.g. public funding) (M=2.4), availability of private funding for R&D related to HPC (M=2.3).

According to enterprises, the need of the companies in integrating/using HPC is the highest within: **training for the employees in the field of HPC** (M=3.6), **finding well trained human resources** (M=3.5), **finding partners from business sector to collaborate with** (M=3.5), **awareness and knowledge about possible applications and the potential of HPC technologies** (M=3.5), **access to the infrastructure** (M=3.5). Less important factors in integrating/using HPC according to companies are: regulatory and tax environment to improve conditions for investment in HPC (M=3.3), access to infrastructure (M=3.3), securing funding for HPC (M=3.3). Enterprises see the potential of HPC in the **development of new products or redesign of products** (22.4 %), in the **use of tools to improve their activity** (13.8 %), to **optimise production and delivery process** (10.8 %). Potential reasons to adopt HPC or to expand the use of HPC is in the **increased competitiveness of the company** (M=3.8), **improve in the quality of products/services** (M=3.7), **cost reduction** (M=3.7), but less in large-scale data management (M=3.1) or supply chain optimisation (M=3.0). Enterprises believe that they need HPC **infrastructure** (27.8 %) in order to further develop their business, 8.3 % believe that they need resources in the form of **equipment**, while 33.3 % believe they need **services** or other (30.6 %). Among other resources Software (IBM, HP, CAD), Resources for simulation, for design, HPC services and AI services for our new products (IoT, Industry 4.0), We need hardware capable to perform fast parallel simulation for large models, distributed memory clusters, were listed.

Top 3 business problems related to the use of HPC are: **high costs** of using HPC (16.5 %) connected with the **lack of funds** to support development based on HPC (16.1 %) and finding well prepared **human resources** (14.9 %). If companies would have access to more free HPC infrastructure (e.g. having sort of public funding), 15.8 % would work with larger/more complex data or models, 63.2 % of enterprises would consider HPC training if available in the sector of operation of the company, 26.1 % of enterprises are aware how HPC could help them in solving problems, but they do not intend to use it because it's expensive, 24.3 % will acquire HPC resources to solve computational problems, 19.8 % of companies know how HPC could help them in solving these problems, but they do not intend to use it because we haven't the necessary knowledge yet.

When we focus more in detail on <u>company's competencies</u>, we can see that 22.3 % of the companies report either that no one from their personnel is working with HPC or that **no one has skills appropriate to work with HPC**. Here we identify our next basin of SMEs that need help in gathering sufficient knowledge about HPC usage and application. Companies that work with HPC report, that their personnel is working with HPC is equipped with: HPC Code Development: Linux Shell Scripting (e.g. BASH, CSH, ZSH, etc.) (13.3 %), HPC System Usage: Basic Linux skills (i.e. Linux shell (e.g. BASH), SSH, etc.) (10.6 %), HPC Code Development: Programming Languages (e.g. C, C++, Fortran, etc.) (10.1 %), HPC System Administration: Parallel File Systems (e.g. Ceph, Lustre, Hadoop FS) (9.6 %), HPC Code Development: Linux Shell Scripting (e.g. BASH, CSH, ZSH, etc.) (7.4 %). The majority (23.0 %) of enterprises fall into the category of "no opinion" regarding the issue of demand for training in one of the following skill categories. Other companies report that their personnel have **demand for training in one of the following skill categories**: HPC Code Development: Scripting languages (e.g. Python, Perl, etc.) (10.1 %), HPC Code Development: Programming Languages (e.g. C, C++, Fortran, etc.) (8.4 %), HPC System Administration: Parallel File Systems (e.g. Ceph, Lustre, Hadoop FS) (7.9 %), HPC Code Development: Numerical Libraries (e.g. BLAS, LAPACK, PETSc) (6.2 %). Generally, enterprises believe that HPC infrastructure and/or equipment could **not** be used by other companies (71.6 %).

Regarding the issue of company's cooperation and networks, 70.5 % of enterprises believe that cooperation with science/industry could foster the HPC usage and their organisation development. The majority of the companies in our sample has **not** been involved in international projects related to HPC (67.2 %). The one that were involved report mainly private projects (10.3 %), followed by EU projects such as PRACE, SESAME, FORTISSIMO, IoT and Big Data related projects and some others. Among SMEs only a small proportion of companies does take part in any cluster or network related to HPC (n=7). The majority of enterprises appreciate the importance of cooperation in HPC related aspects among National research centres the most (M=4.0), followed by Foreign research centres (M=3.8), National enterprises (M=3.8) and Foreign enterprises (M=3.8). Generally, 38.7 % of enterprises report that they are aware that also other companies in the field use HPC, 21.5 % believe this is not the case, while 39.8 % does not have relevant information to believe so.

Our next survey among HPC provider and competencies centres aim to establish their infrastructure, competencies and motivation in the field of HPC. Data yield results that are going to be summaries and compared to enterprise's needs, expectations and competencies in the field of HPC in order to establish a gap between the needs of the SMEs operating as TIER I and II suppliers in the electronic and automotive sectors and the infrastructure, competencies and motivation of HPC providers and competence centres.

When we focus on general information about providers (n=47), in the sample we have 80.9 % public centres, 12.8 % private centres and 6.4 % of the organisations constitutes a private centre in a non-profit organization. In general, within the only one department or part of the whole organization deals with HPC (83.0 %), the majority of organizations has been working on HPC solutions for more than 5 years (some even from the 90's) (61.7 %) on daily (48.9 %), weekly (12.8 %), monthly (10.6 %) basis. Providers mostly rely on open source (33.0 %), developed in-house (28.3 %) or bought (24.5 %) software applications and infrastructure related to HPC, they focus on parallel computing (42.9 %), supercomputers (28.6 %), grid computing (23.1 %), they serve engineering (30.4

%), research and education (16.5 %)[24], electronics (13.9 %), automotive (11.4 %), aero spatial industry (7.6 %), 46.8 % of organisations has 10 or less employees from the academic and technical staff working on HPC.

When we focus more in detail on providers' needs, we can see that the degree of HPC development in DANUBE area is the highest regarding the degree to which universities equip students with the necessary knowledge to work in HPC (M=2.8), within the availability of skilled human resources (M=2.8), availability of competitive public funding (e.g. direct public funding, grants, awards, baseline funding) (M=2.6), the degree of science-public authorities' cooperation related to HPC (M=2.6). While, SMEs believe that the degree of HPC development in DANUBE area is the most prominent in the field of availability of commercial HPC infrastructure (M=3.1), degree of science-industry cooperation related to HPC (M=2.9), availability of skilled human resources (M=2.9), the degree of science-public authorities' cooperation related to HPC (M=2.9). On the other hand, there is still some place for improvement within HPC prioritization in legislative documents and strategies (M=2.4), availability of free HPC infrastructure (e.g. public funding) (M=2.4), availability of private funding for R&D related to HPC (M=2.3) as stated earlier.

In general, all the statements dealing with the degree of HPC development in the DANUBE area were assessed relatively low (around 3 or lower) on the scale from 1 (very poor) to 5 (very good). Nevertheless, the gap between what SMEs and providers on the other side believe is evident. The largest gap can be spotted among the availability of commercial HPC infrastructure and the degree of industry- public authorities cooperation related to HPC where private companies rang them higher. This probably means, that HPC providers and competencies centres are less aware of what it is going on the free market or how developed it is in the DANUBE area. The gaps are big also among the availability of private funding for R&D related to HPC, the degree of awareness about HPC benefits, degree of science-industry cooperation related to HPC and HPC prioritisation in legislative documents and strategies, in all cases SMEs rank the degree of development higher.

According to HPC providers, the need to adopt or integrating/using HPC is the highest within fields of **testing ideas faster** (M=4.3), **improving the quality of products/services** (M=4.1), **increasing competitiveness** (M=4.1). According to enterprises, the need of the companies in integrating/using HPC is the highest within: **training for the employees in the field of HPC** (M=3.6), **finding well**

24 Research and education is not an industry itself, but due to a prevalent response among option other, we included it as a category itself.

trained human resources (M=3.5), **finding partners from business sector to collaborate with** (M=3.5), **awareness and knowledge about possible applications and the potential of HPC technologies** (M=3.5), **access to the infrastructure** (M=3.5).

Less important factors in integrating/using HPC:

- according to companies are regulatory and tax environment to improve conditions for investment in HPC (M=3.3), access to infrastructure (M=3.3), securing funding for HPC (M=3.3),
- according to providers are going to the market faster (M=3.7) or Supply chain optimization (M=3.5).

Providers rate all the possible needs to integrating/using HPC higher than SMEs, the only exception is in testing ideas faster. Large scale data management, reduced costs and going to the market faster are the needs where the gap between providers and SMEs is largest.

Top 3 problems related to the use of HPC within the organisations of providers are: **lack of funds** to support development based on HPC (20.8 %) closely linked to **high costs of using HPC** (13.9 %) and **finding well prepared human resources** (14.6 %). Here we can make the comparison with SMEs, where same top 3 problems were mentioned: **high costs** of using HPC (16.5 %) connected with the **lack of funds** to support development based on HPC (16.1 %) and finding well prepared **human resources** (14.9 %). In both cases one quarter of companies both SMEs and providers have the common problem of finding well prepared human resources on the market. The biggest gap between providers and SMEs among the lack of/minimal information and knowledge about HPC, from where we can deduce, that SMEs experience a much deeper lack in knowledge about HPC compared to providers, which is of course expected. However, providers or competencies centres, experience a much bigger problem in lack of funds to support development based on HPC and limited interaction with SMEs compared to SMEs. On the other hand, high costs of using HPC are experienced by both, slightly more from SMEs.

The majority of the providers (38.2 %) will acquire HPC resources to solve **computational problems**, while 14.5 % of providers know how HPC could help them in solving computational problems, but they do not intend to use it because it's expensive, compared to 26.1 % of enterprises with the same issue. 12.6 % of providers know how HPC could help them in solving these problems, but they do not intend to use it because we haven't the necessary knowledge yet – compared to 19.8 % of companies with the same issue, 7.3 % do not intend to use HPC resources to solve computational problems, 18.2 % are not aware of computational problems. Among other reasons there is a lack of know-how, not fully used available HPC resources, HPC is firmly established – regular replacement cycles, support all of the projects in need of HPC resources at a decent service level, using our HPC resources. Providers are more eager, compared to SMEs, to use HPC resources to solve computational problems are doing not have an opinion regarding the issue. On the other hand, SMEs are aware how can HPC could help them solving computational problems, but it is too expensive for them or do not have necessary knowledge yet.

Providers believe that the best option for the theme of a course dedicated to their stuff/researchers is Programming (e.g. Performance Programming, Parallel Architectures, Shared Memory Parallelism, Distributed Memory Parallelism (i.e. Message Passing) and Practical Parallel Programming etc.) (n=15), Basics: general sense of HPC infrastructure & HPC tools (n=13), Big Data Analytics (n=9), Courses on Performance Analysis Tools and Performance Optimization (n=9).

When we focus more on providers or competencies centres, we can notice that providers report, that their personal working with HPC is equipped with: HPC Code Development: Programming Languages (e.g. C, C++, Fortran, etc.) (11.2 %), HPC Code Development: Linux Shell Scripting (e.g. BASH, CSH, ZSH, etc.) (10.2 %), HPC System Usage: Basic Linux skills (i.e. Linux shell (e.g. BASH), SSH, etc.) (10.2 %). On the other hand, companies that work with HPC report, that their personnel is working with HPC is equipped with: HPC Code Development: Linux Shell Scripting (e.g. BASH, CSH, ZSH, etc.) (13.3 %), HPC System Usage: Basic Linux skills (i.e. Linux shell (e.g. BASH), SSH, etc.) (10.6 %), HPC Code Development: Programming Languages (e.g. C, C++, Fortran, etc.) (10.1 %), HPC System Administration: Parallel File Systems (e.g. Ceph, Lustre, Hadoop FS) (9.6 %), HPC Code Development: Linux Shell Scripting (e.g. BASH, CSH, ZSH, etc.) (7.4 %).

The biggest gap between providers and companies is in the fact that 22.3 % (compared to 1.7 % of providers) of the companies report either that no one from their personnel is working with HPC or that **no one has skills appropriate to work with HPC**. Others slight differences can be also observed. SMEs are more inclined towards HPC Code Development: Programming, Scripting Languages, HPC System administration: Parallel. Providers on the other hand focus more on HPC Code Development: Message Passing (here we can observe the greatest gap between SMEs and providers), HPC Code Development: Linux Shell Scripting and Administration, HPC System Usage: Resource Managers. Same amount of effort is putted in HPC System Usage: Basic Linux skills.

The biggest discrepancies between SMEs and providers. However, we do not yet have a clue wheatear the skills that the SMEs personnel does not have is really needed in everyday work. That is why we move to the next comparison where we tried to establish the gap between acquired skills and desired skill level in the field of HPS competencies.

The majority (23.0 %) of enterprises fall into the category of "no opinion" regarding the issue of demand for training in one of the following skill categories. Other companies report that their personnel have **demand for training in one of the following skill categories**: HPC Code Development: Scripting languages (e.g. Python, Perl, etc.) (10.1 %), HPC Code Development: Programming Languages (e.g. C, C++, Fortran, etc.) (8.4 %), HPC System Administration: Parallel File Systems (e.g. Ceph, Lustre, Hadoop FS) (7.9 %), HPC Code Development: Numerical Libraries (e.g. BLAS, LAPACK, PETSc) (6.2 %). The discrepancy where the demand exceed their competencies is HPC Code Development: Numerical Libraries, Message Passing, Profiling and Debugging.

Among providers a technical HPC infrastructure that is available varies between Linux Clusters (37.6 %), HPC resources (29.4 %), Cluster Computing (28.2 %), Grid Computing (25.9 %), technical infrastructure for parallel computing (24.7 %), Supercomputer (21.2 %), shared memory processing capacities (21.2 %). The majority of the providers in our sample has been involved in EU projects (38.2 %) and non-EU projects (30.9 %), as well as private projects (14.5 %). Compared to SMEs, where 67.2 % of companies have not need involved in international projects related to HPC, among providers this percentage is much lower (16.4 %). Providers report that they mainly prioritize in their HPC work in the following areas: Highly scalable methods for modelling and simulation that can exploit massive parallelism and data locality (n=19), Data-intensive HPC (n=16), new programming models and tools, targeted at massively parallel and heterogeneous environments (n=12). Areas that remain in the shadow are: low-energy computing from both an architectural and application perspective (n=6), decoupling application development from HPC (n=6), technologies to support new and emerging applications which require robust HPC with real-time capability (n=11).

Regarding the issue of <u>provider's cooperation and networks</u>, the majority of providers appreciate cooperation in HPC related aspects among National research centres the most (M=4.5) and by foreign research centres (M=5.4), followed by national enterprises (M=3.7) and foreign enterprises (M=3.7). Among providers 23.4 % cooperate with national enterprises, 6.4 % cooperate with foreign enterprises, 8.5 % cooperate with national and foreign enterprises. They believe that cooperation with the industry for the future development of their organisation is important or very important (29.8 %) and that they could help enterprises to meet their needs through HPC by: help them to carry out simulations and/or modelling of complex processes (n=17), help them to analyse or develop large datasets (n=17), help them to conduct large-scale research projects (n=17), help them to store large amounts of data for future analysis (n=16), help to develop new products or to redesign products (n=15). Most providers agree that enterprises can use their HPC infrastructure only if we are partners in a project/network (29.8 %), 10.6 % agree to share their HPC infrastructure against payment or both for payment and for free, 10.6 % of providers use HPC infrastructure only for internet research, 38.3 % of providers do not have an opinion related to the topic.

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HPC as an Object of Intellectual Property and a Tool for IPR Management

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Abstract: HPC can play a crucial role in managing large amounts of data, especially when many users are involved; such as in simulation based engineering work, testing prototypes in virtual environment and optimisation of manufacturing process. HPC can support the organisation's business processes and in this chapter we focus on HPC support inside the intellectual property rights processes as business processes. At the same time HPC can be a field of new discoveries and inventions, thus an area for which intellectual property rights may be applied for.

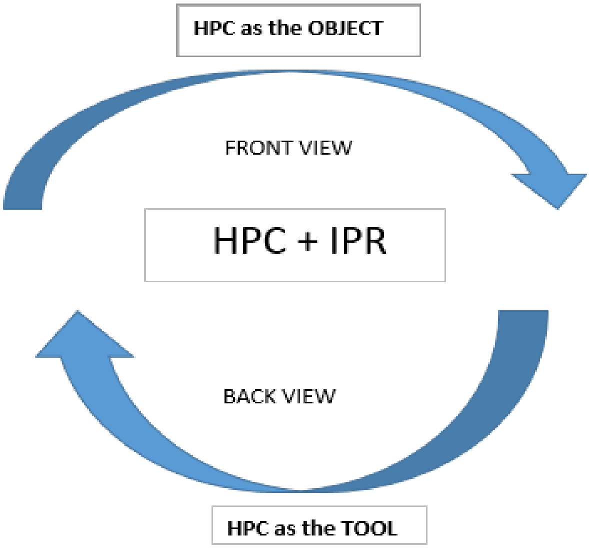
Keywords: HPC, big data, IPR process management, intellectual property, patents

1. Introduction

High performance computing is "the practice of aggregating computing power in a way that delivers much higher performance than one could get out of a typical desktop computer or workstation in order to solve large problems in science, engineering, or business" (Sravanthi et al., 2014). It is also important whenever several users attempt to solve a computational problem simultaneously.

Gilder's (2000) "microcosm" is now ending and in its being replaced by the age of "telecosm" in which HPC plays an important role. The influence of computers and their components remains strong in this environment, with high performance computing (HPC) or supercomputing having the potential to support this new environments' transformation of organisational changes. This is due to the fact HPC can help supersede problems that are be caused by immobile data (*ibid.*): data that is non-accessible, non-linked or without enough processing support to use it immediately inside processes in organisations. Established and born out of the previous era of "microcosm" the new emphasis on (intra and inter-firm and organizations') networking and collaboration efforts is put into the forefront. This has given rise to the notions of so-called network firms (Castells, 2010). To support these collaboration efforts and the networked society, intellectual property rights will also be of key importance (Modic, 2018).

Figure 1: HPC and IPR conceptual model



In this networked society of interlinked data and interlinked organisations the role of the HPC can be seen as double, HPC can be an object, with HPC or HPC-derived solutions needing protection. Alternatively, HPC can be a tool for better IPR intelligence that can power the business decisions related to IPR management and the management of technology transfer processes.

2. The HPC and IPR Telecosm of the Danube Region

According to the findings of the InnoHPC project (InnoHPC, 2018a) the HPC infrastructure in the Danube Region consists of 74 HPC providers across the

Danube region: 80.9 % being public centres, 12.8 % private centres and 6.4 % non-profit organisations. The 'microcosm' of the (super)computing support is thus by now well-present in the Danube region.

15.8 % enterprises in the InnoHPC (2018a) report that if they would have access to more freely available HPC infrastructure they would work with larger/more complex data or models, with 34.7 % responding maybe they would do so. Furthermore, the companies use HPC inter alia: to solve problems that couldn't be addressed through other means (26.6 %); to address problems more efficiently, faster, at the lower cost (24.5 %); to develop new products or services (22.3 %); to improve business innovation process (10.6 %); and for research and testing (3.2 %). *Companies are thus using HPC (InnoHPC, 2018b) now much more for R&D purposes (42.9 %) than for large scale data management (11.7 %), sending a mixed signal for a cross-cutting field such as that of IPR management.*

On the other hand, the providers could help enterprises to meet their needs through HPC by helping them to: carry out simulations and/or modelling of complex processes, analyse or develop large datasets, conduct large-scale research projects, store large amounts of data for future analysis, develop new products or to redesign products (InnoHPC, 2018a).

In automotive industry, as research of Hafner on Slovenian automotive suppliers (2018) shows, HPC is used for simulations and optimisations. For example, a representative of larger company reported: *"We use simulations mainly for various FEM analyses for material testing and construction solutions. This is all being tested now in virtual environment. We also use simulation models – Abacus and the like, and this software, of course, requires high performance computers"*. A manager of a start-up enterprise on the other hand states that in the current project they were using HPC from Italy: *"Now we were cooperating in a project where we used HPC from an Italian HPC centre because we had some demanding optimizations of various assemblies, different physics. The aim of this project was to develop a model that would be equivalent to the model which needs HPC – that is, a model that can have a domestic, internal HPC, a smaller cluster"*.

Case studies done in USA also demonstrate the importance of HPC across all industrial sectors since the application of simulation is critical to industrial innovation. The computational needs of such simulations are much higher than those of single-scale analyses as well as the software needed is much more complex (Shepard et al., 2013: 16). Not only in engineering, HPC is useful whenever we have to analyse big data. For example, Belle et al. (2015) research the possibilities of big data analytics in healthcare practices and research.

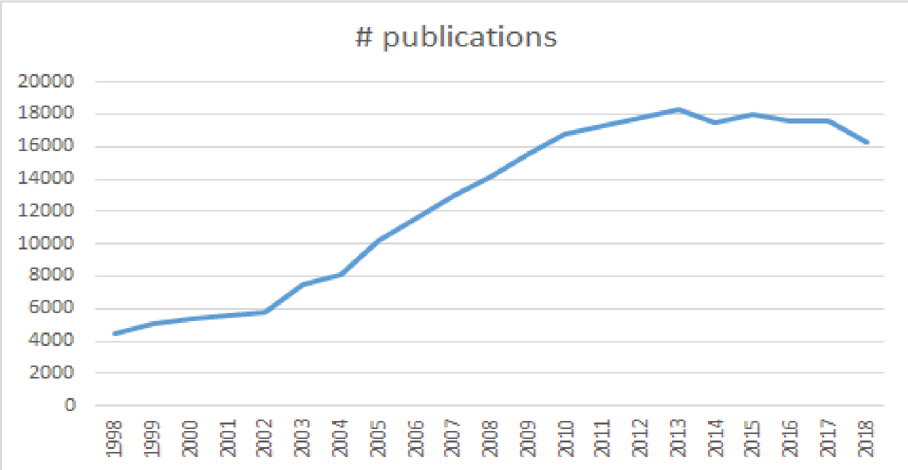
While searching for articles connected with IPR databases and the use of HPC in Google Scholar, we can mainly find US software patents. However, since data on IPR is almost exponentially growing, we believe this will soon become a systemic issue for HPC. For example, the European Patent Office's (EPO) database PATSTAT is currently hosted in Wharton Computing's HPC (Wharton, 2019). Why does the EPO operate with its database on HPC in the U.S.A.? Possibly, as European Commission (2018a) noted "the EU does not have the most powerful machines that some of their applications require. As a result, European HPC users are increasingly processing their data outside the EU. This situation may create problems related to privacy, data protection, commercial trade secrets, ownership of data. None of the EU supercomputers are currently in the global top 10 and the existing ones depend on non-European technology. This brings an increasing risk for the Union of being deprived of strategic or technological know-how for innovation and competitiveness". For this reason, the European Declaration on High-Performance Computing was launched in 2017 and signed by European countries – among them there are also the EU Danube region countries – committed to upgrading European computing power. In July 2018, the European Parliament supported the Commission's proposal to create a European High Performance Computing Joint Undertaking which started to operate in November 2018 in Luxembourg (ibid.).

The above leads us to conclude that combining the use of HPC with the potential of the innovation and in particular IPR data can bring new business and research intelligence, which, in turn, support the European Commission's goals. IPR data and related data is fast-growing complex big data, hence the support of HPC when mining this data is important. With this we get a closed-ended loop, leading from intelligence gathered with the assistance of HPC to support the generation of further HPC outputs in the Danube region.

3. Front view: HPC as the object

HPC can be an object of IPR. We first take a look at the publications involving the query "high performance computing" or "high performance computer" in the title or text, using Google Scholar (February 6th, 2019). Interestingly, the number of publications has flattened out since 2012.

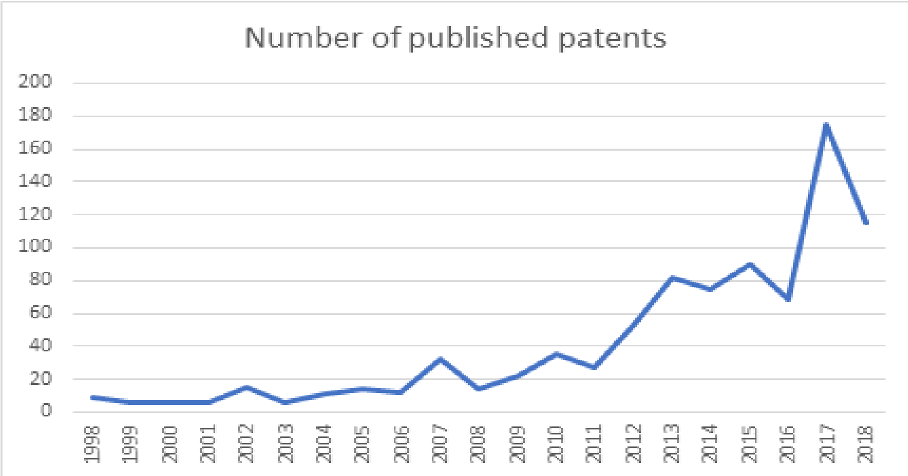
__Figure 2: Publications in HPC__



Source: Espacenet, 2019, own calculation

Furthermore, HPC is less frequently an object of invention as someone would expect. However, the number of HPC related patents is growing. On January 28, 2019 there were 925 published patent documents in a worldwide database Espacenet with exact keywords "high performance computing" or "high performance computer" in title or abstract of the patent document. In a chart below there are 874 patents published on this subject in last 20 years (from 1998 to 2018) while seven more were published so far in 2019 and 44 before year 1998.

Figure 3: Patents in HPC



Source: Google Scholar, 2019, own calculation

First patent with application number US19780866686 was filed in the USA by company IBM in 1978 and introduces multi-instruction stream branch processing mechanism. There are 93 published documents of international PCT applications up to this date (January 28, 2019). First ten applicants are listed in Table 1 below. Two independent inventors are listed among them, so surprisingly the research field is not open only to big corporations, but to small entities as well.

Table 1: Major HPC applicants

Name	Number of patents
INTEL CORPORATION	10
ORACLE INTERNATIONAL CORPORATION	10
SILICON GRAPHICS INTERNATIONAL CORP.	10
SAUDI ARABIAN OIL COMPANY	5
ARAMCO SERVICES COMPANY	4
DAVIDSON, Shannon, V.	4
RAYTHEON COMPANY	4
BALLEW, James, D.	2
BULL SAS	2
HEWLETT PACKARD ENTERPRISE DEVELOPMENT LP	2

Source: PATENTSCOPE, 2019

In eleven of these 93 documents universities are the only applicants or the patent was filed in cooperation with companies (a joint patent). There are only two patents from applicants with the residence in the Danube region, both are German applicants from Bavaria. This would imply that the Danube region entities are not in the forefront of HPC related development and that the EU strategies in this field have not yet delivered a major change. However, that does not preclude Danube region companies from utilizing, to the best of their advantage and following IPR related regulations, HPC offerings in various fields, including that of IPR process management.

4. **Back view: HPC as the tool for IPR process management**

There is an understanding that *HPC can and does contribute to improved innovation processes, including in optimizing business processes* and predicting market data analytics (Sterling et al, 2018). Modic and Damij (2018) have argued that *IPR processes are business processes, constituting of the Back-office and Front-office*. They claim that whereas Back-office activities are dealing with the legal and administrative dimension, Front office activities explore how IPR can benefit the company. Thus, as IPR processes are business processes, that have both a more technical, administrative component, as well as a more market, strategic oriented one, we explore how HPC can influence the IPR processes.

IPR data is big data, since its characteristics are high volume, high variety, and high velocity of changes (Ciccatelli, 2017). The surge of intellectual property is mirrored in rising IPR numbers with dissemination (and exploitation) efforts dependent upon not only the available data, channels and skills (Modic et al., 2019), but also on the understanding which parts of IPR processes can be supported by HPC solutions.

However, one also needs to take into account the intricacies of IPR, hence many important players are mainly talking about *augmented intelligence* (Fleischman, 2018) or augmented expertise (White, 2018) and not (self-standing) *artificial intelligence,* when discussing the role of computer-supported systems, such as HPC and artificial intelligence in the field of IPR. Nonetheless solutions, like IBM Watson, seem to also be a game-changer in this area. Watson identified compounds for which the patent protection has already lapsed. Pilot results suggest that Watson can accelerate identification of novel drug candidates and novel drug targets by harnessing the potential of patent (and connected) big data (Chen et al., 2016). The IBM team believes the insights provided by Watson technology are to be used as a guide, i.e. as augmented intelligence – which is capable of ingesting, digesting, understanding and analysing data and can be harnessed in various elements of IPR processes: from evidence of use, to prior art, patent landscapes and portfolio analysis (Fleischman, 2018). If the technology was widely available with all its features, this could present a significant change.

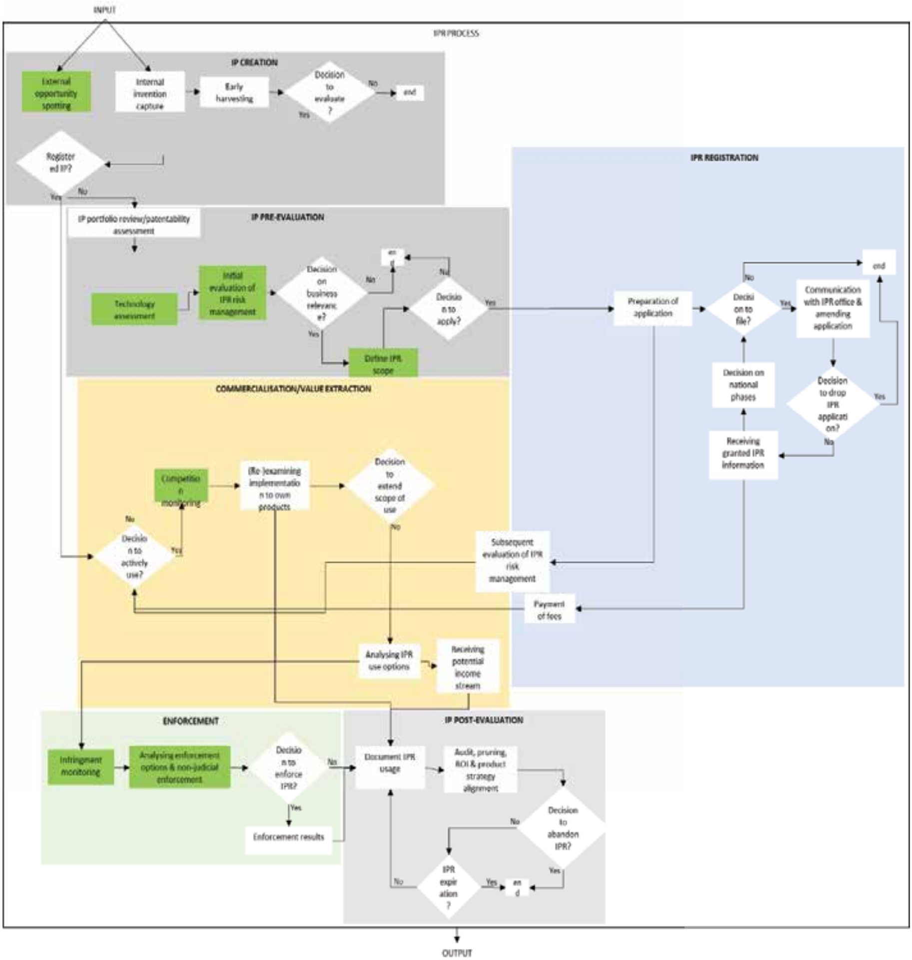
It is however HPC that enables the future of augmented intelligence and big data analytics in IPR. This also brings us to the fact that having in-house HPC capacities is still mostly reserved for the biggest (resource rich) companies, whereas smaller entities will depend on other providers to access the HPC infrastructures; with one of them being solutions like the one provided with the InnoHPC project. *Yet, to be able to truly harness them for their IPR processes, first we have to find out in which parts of the processes HPC can be exploited to support IPR analytics in order to improve harnessing IPR big data.*

Below we present a modified and upgraded IPR (mid-level)[25] process flow, based on Modic and Damij (2018). The flowchart aims to present the key links between specific activities as well as their flow (parallel or sequential). *The IPR management (IPRM) process consists of six sub-processes.* IP Creation sub-process are where the IPRM process begins and where the key goal is the early harvesting of technologies later becoming the object of IPRs. In the IP Pre-evaluation sub-process, a number of questions are answered in terms of coreness, crowdedness, alignment with product strategy (considering IP market options) and IPR evaluation leading to decisions on both market relevance as well as whether or not to apply for a patent or keep the technology as a trade secret. The IPR Registration sub-process is directly connected to

25 The flowchart above depicts a mid-level overview of a typical IPRM process as the overall flow chart showing more detailed activities is too complex (and is broken down into various sub-processes).

dealings with the IP offices. The next sub-process is the Commercialization, depicting various activities connected to either using IPR as negative rights and as insurance for freedom-to-operate or utilizing them on the IPR markets. The last two sub-processes are Enforcement and Post-evaluation. The first makes sure that the theoretical comparative edge the IPR brings is not in jeopardy in practice. The second one ensures the pruning of the IPR portfolio takes place (providing the basis for maintaining or dropping individual IPR). *As seen below HPC can be harnessed in several parts of the IPRM sub-processes.*

Figure 4: IPR process flow with HPC intensive sub-processes



The following tasks inside indicated (Fig. 4 in green) activities can benefit from the use of HPC capacities: collecting data for research, prior art search, freedom to operate search, technology trends' analysis and competition monitoring. These are big-data-heavy and/or collaborative tasks.

The task of *collecting data for research* is part of the IP creation sub-process and precedes the internal innovation capture step as an input. There are two elements that suggest the support of HPC capacities in this step. Firstly, there can be large amounts of data to be processed and secondly, this data needs to be interconnected. This activity is even more important for technology transfer offices in public research organisations than for big companies and SME. The task of the *prior art search* before applying for IPR (patents, industrial designs, trademarks) takes place inside the IP creation sub-process, as the activity of the preliminary state-of-the art search as well as it is a task inside the activity of technology assessment and Defining IPR scope activity (both part of the IP pre-evaluation sub-process). Here the cooperative nature of the processes comes to the forefront alongside of the need to combine and speedily process large amounts of IPR data combined with other research and business intelligence data. The tasks of the prior art search can and need to be done, especially in larger organisations by different individuals – these will also want to have a cooperative responsive platform at their disposal to avoid doubling the efforts.

The freedom to operate search is part of the initial evaluation of risks or so-called clearing process. It represents an essential moment, since it can prevent unnecessary spending of time, cost and other resources of already protected inventions aiming at the company's target markets. In other words: the freedom to operate search tests the invention in question, and the connected right to appropriate the derived value from it. This moment is especially important for SME and industrial followers (generic drugs manufacturers are typical example), however less so for industrial leaders or public research organisations (the latter because they do not own manufacturing facilities).

Technology trends' analysis is according to Modic and Damij (2018) an activity inside the risk assessment. In larger companies this can be done by the IP coordinator together with marketing employee. At the same time this business intelligence task can render new ideas inside the External opportunity spotting activity. Again this is thus a collaborative activity executed on the basis of big data analytics, hence HPC support can bring efficiency gains.

Competition monitoring and infringement monitoring are part of the *Commercialisation/Value extraction* and the *Enforcement sub-processes,* respectively. The idea is on one hand to follow the competitors' applications and other related activities on the other hand identification of infringements. Large firms, SMEs and research organisations benefit from those activities.

Beside identifying the relevant parts of the IPR process where HPC can help achieve efficiency, it is also to be noted is that the software development process, or “workflow” for HPC application development may differ profoundly from traditional software engineering processes. For example, one scientific computing workflow, dubbed the “lone researcher”, involves a single scientist developing a system to test a hypothesis. Once the system runs correctly and returns its results, the scientist has no further need of the system. This contrasts with standard software engineering lifecycle models, in which the useful life of the software is expected to begin, not end, after the first correct execution (Johnson and Paulding, 2005). Fortunately, there is an emerging interdisciplinary community involving both HPC and software engineering researchers and practitioners who are attempting to define new ways of measuring high performance computing systems (ibid.), ways which take into account not only the low-level hardware components, but also the higher-level productivity costs associated with producing usable HPC applications.

As a consequence, a specific research gap becomes visible: Is the use of HPC in business processes really as beneficial as assumed or predicted? If yes, how to measure the application of the HPC innovation within business processes, and particularly, what are the benefits within the intellectual property management processes? How can the benefits of HPC application in IRP processes be measured? *We believe much is still to be done in this field, to truly understand the real potential of HPC inside business processes, and in particular for IPR management. Identifying the parts of this processes, as done is the chapter, however represents the very needed first step to this direction.*

5. **Conclusion**

High performance computing systems are becoming mainstream due to decreasing costs and increasing numbers of application areas with computation and/or data intensive processing. In this chapter we first conceptualized HPC in relation to the IPR, focusing on HPC as the object. However, one needs to understand that today the hardware engineering is hardly a bottleneck, especially for the implementations connected to IPR. The challenges now lie in the software engineering supporting the uses (Johnson and Paulding, 2005), as well as in understanding the utility of new IPR informatics offerings (Modic and Damij, 2018; Modic et al., 2019); in terms of where and when they may be exploited. Though the value of using the HPC in business processes is not fully explored yet, nor it is among seven areas of “scientific, industrial and societal challenges” the EuroHPC initiative defines (European Commission, 2018b), we tried to expand the understanding of utility in this chapter, depicting when and in what parts of the IPR management process flows HPC could bring competitive advantages. We can assume that with development of new techniques and software tools in the field of augmented/artificial intelligence (machine learning and deep learning), that are important also in the field of IPR and will need sufficient hardware support, HPC systems will become critical to the overall competitiveness of companies in the Danube region.

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Transnational HPC Infrastructure in the Danube Region

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Abstract: A bottom-up needs assessment analysis for the Danube region (incl. interviews with business experts, focus groups and analysis of HPC infrastructure) has shown the following: 1. there is a critical mass of SMEs with the need to use HPC; 2. the applications include business process simulation and optimization, testing products in virtual environments etc.; 3. HPC provides the opportunity for transnational product co-creation and consequently formation of transnational industrial value chains; 4. HPC providers form academia are focused on using the HPC infrastructure to deal with basic science, creating a lack of HPC supply for SMEs. Hence, we need to conduct in-depth review of HPC capabilities on supply and user side and explore opportunities of its applications to increase efficiency of innovations, co-creation and development of transnational value chains. The development of InnoHPC Lab will offer transnational institutional infrastructure with all relevant training and collaborative tools, linking interested partners and providing structured access to HPC capabilities across the Danube Region.

Keywords: InnoHPC Lab, HPC infrastructure

1. Introduction

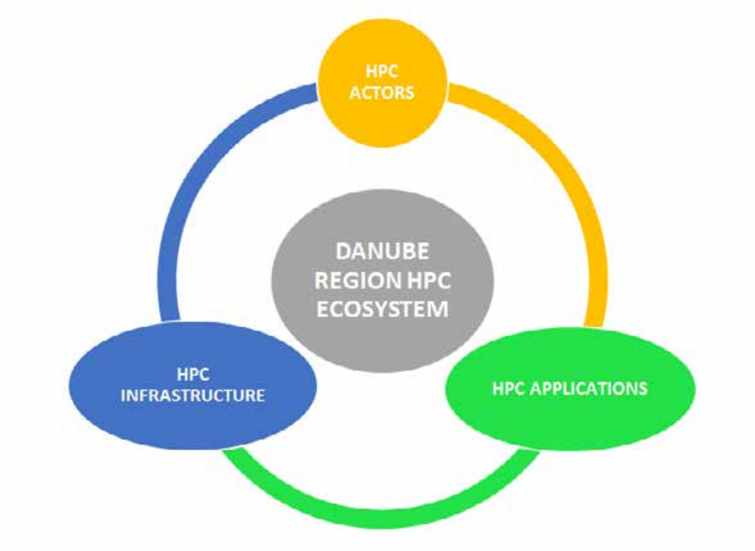
High Performance Computing (HPC) plays an important role in stimulating Europe's economic growth. That means HPC is one of the tool that allows industry and academia to develop world-class products, services and inventions in order to maintain and reinforce Europe's position on the competitive worldwide area. The ETP 4HPC describes HPC as a crucial in addressing grand societal challenges and describes the role of HPC as "Today, to Out-Compute is to Out-Compete" (ETP4HPC, 2019). Nowadays, HPC is used in specific HPC research centres and not at all in large enterprises. One of the important needs of HPC is to become more pervasive across the entire industry, including SMEs (Small and Medium-sized Enterprises). It is known that Europe represents a significant sector of the world's available HPC resources, but only a slice of technology and infrastructure is developed in Europe. Other regions, as Danube Region, invest considerably more in new technologies, architectures and software for HPC systems, gaining a substantial competitive edge over Europe.

The re-industrialization goals of the EU have in recent years been upgraded to emphasize the need for digital transformation of European companies (HPC-EUROPA3, 2019). According to the Report of the Strategic Policy Forum on Digital Entrepreneurship (EC) (Commission, 2019) digitalization of European manufacturing can contribute to 15 % to 20 % growth by 2030. But the problems related to establishing a dialogue between European businesses and technology platform providers, increasing the supply of new, highly specialized skills and establishment of new centres of digital transformation excellence. Furthermore, there is a clear need to provide for a European world-class HPC capability, both on the supply and user side. Despite some valuable initiatives, European HPC is still fragmented in terms of funding and critical mass applications. Also, not all countries in Europe have the capacity to build and maintain such infrastructure. Pooling and rationalizing efforts at the European Union level as well as regional levels, such as inside the Danube region, is therefore a necessity, according to EC HPC Communication (2012).

Hence, at the level of Danube region was developed InnoHPC Lab to improve the efficiency of innovation in the region by connecting HPC providers, business support organizations, higher education institutions (HEIs), research institutions (RIs) and policy-makers in a transnational HPC laboratory. It aims to improve framework conditions for transnational co-design in developing knowledge-intensive innovative high value-added products.

InnoHPC Lab diffuse HPC as a general-purpose technology capable to enhance innovative capabilities of enterprises by increasing access to existing HPC infrastructure and providing integrated services. Inside the European Single Digital Market, HPC is seen as a strategic resource for Europe's future, so the excellence in HPC applications by developing (new) HPC applications and dissemination of this knowledge is crucial. But successful utilization of HPC also depends on the (predominantly) academic HPC providers' understanding the needs of the businesses, especially SMEs, on the businesses' ability to understand and identify the opportunities provided by HPC, and on the willingness of both actors to cooperate. InnoHPC Lab will hence develop capacity building tools to enhance knowledge and skills required to efficiently use HPC in innovative processes, recognizing the co-operative dimension of these processes. These tools focus on both HPC providers and beneficiaries, by building entrepreneurial skills of HPC providers and increasing enterprises' ability to understand and detect opportunities provided by HPC. This directly correlates to the need detected inside the digital transformation of companies to establish dialogue between companies (and especially SMEs) and the HPC providers by creating a HPC ecosystem (see figure 1) (ETP4HPC, 2019).

Figure 1: Danube Region HPC Ecosystem



2. InnoHPC Lab across the Danube Region

The area covered by the EU Strategy for the Danube Region stretches from the Black Forest (Germany) to the Black Sea (Romania-Ukraine-Moldova) and is home to 115 million inhabitants. Participating countries are: 1. EU Member States: Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Romania, Slovakia and Slovenia, 2. Accession Countries: Bosnia and Herzegovina, Montenegro and Serbia, 3. Neighbouring Countries: Moldova and Ukraine (The Danube Region, 2019). Thus, InnoHPC Lab was developed in the framework of InnoHPC (High-performance Computing for Effective Innovation in the Danube Region) project funded under Interreg Danube Transnational Cooperation Programme, supported by European Union funds (ERDF, IPA) to create transnational HPC virtual laboratory – a network of HPC providers, business and innovation support organizations, HEIs, RIs located in the Danube region – for co-designing knowledge-intensive innovative products with high value-added in transnational value-chains.

This network considers qualitative and quantitative development of not only the available hard HPC infrastructure and competencies, but also intangible aspects that can either hinder or lubricate transnational cooperation. In other words, the InnoHPC Lab connects SMEs and business associations and clusters, HPC providers, regional development agencies and business support institutions in order to intensify transnational cooperation in development of high value-added and technology-intensive products and lead to more effective research collaboration and increased innovative outputs of enterprises, especially SMEs, utilizing the existing hard HPC infrastructure and soft competences for faster development of new products and commercialization of scientific expertise. InnoHPC Lab provide access to actors who offer tailor-made and transferable technology and skills necessary for knowledge-intensive and high value-added entrepreneurial activities (InnoHPC-Partners, 2019).

The vision of the InnoHPC Lab is to connect and utilise currently dispersed HPC capabilities within the Danube region in a unique cooperation space. The main goal is to foster entrepreneurship and innovation based on HPC in the Danube region by serving as a catalyst between HPC providers and enterprises for exploring unconventional ideas for new opportunities that could enhance Danube business environment and engage a wider range of stakeholders in collaborative problem-solving activities. The mission of InnoHPC Lab is to create value by establishing a collaborative and competence exchange community between HPC providers, business support organizations, higher education institutions (HEIs), research institutions (RIs) in the Danube region and to offer joint transnational access and support to enterprises, especially SMEs, in development of innovative high added-value products and services (InnoHPC-Partners, 2019).

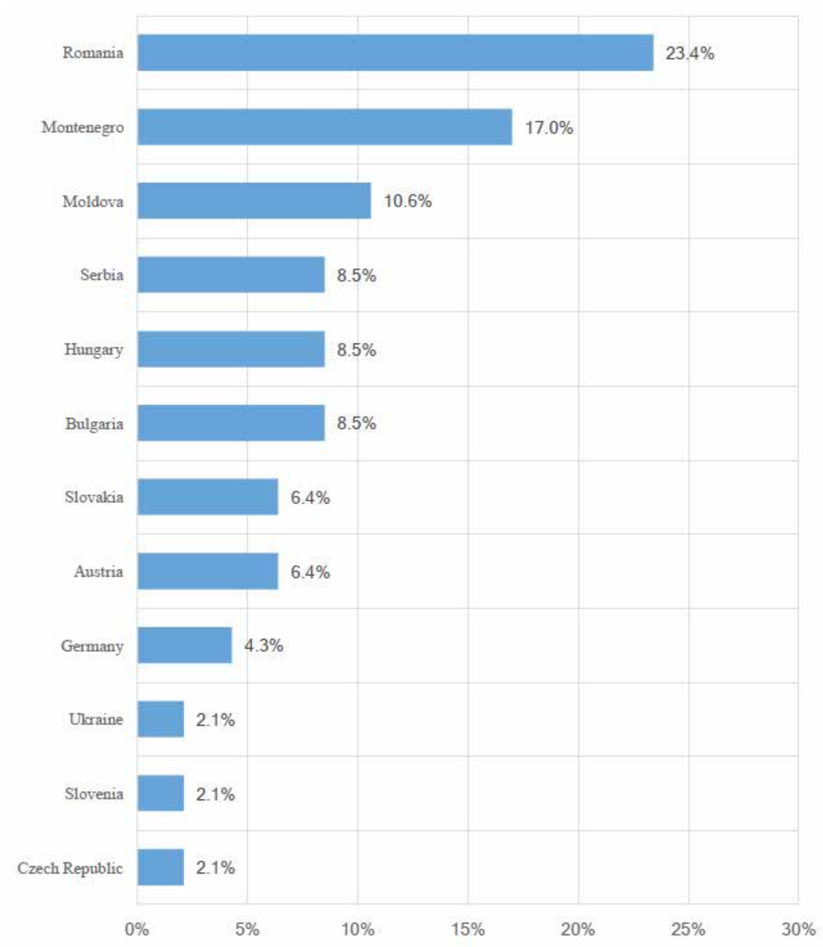
Figure 2 describes a brief map which listing the 17 contact points from 13 countries as part of comprehensive list of integrated services provided by InnoHPC Lab members. All the comprehensive details of contact points can be found in InnoHPC Lab Contact Points document on the project website or on InnoHPC Lab platform (http://www.innohpclab.fis.unm.si).

Figure 2: InnoHPC Lab contact points across Danube Region

3. InnoHPC Lab Services Framework

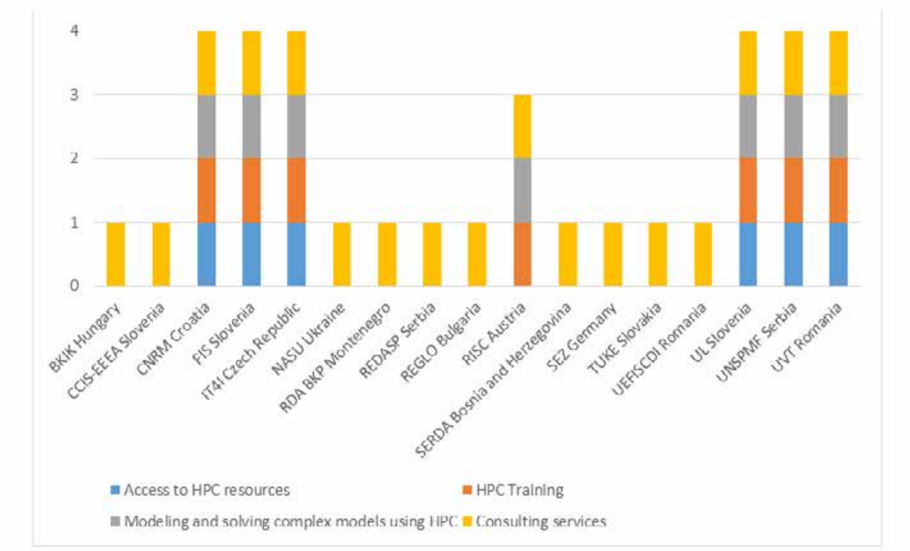
In the research conducted in 2017 at the level of Danube Region by InnoHPC project members (InnoHPC-Partners, 2019)was developed a Regional HPC capacity report with detailed and systematic assessment of competencies and opportunities of HPC applications for the electronic and automotive industry and assessment of awareness and entrepreneurial spirit of academic institutions and presents the analysis of the data collected from HPC providers and competence centre to ensure a consistent use of the tool across all regions. The benchmark parameters used to design the Regional HPC capacity report are derived from the parameters and characteristics identified from the three phases of work: desktop research, semi-structured interviews and workshops with HPC actors – covered 23.4 % of the companies from Romania, 17.0 % were from Montenegro, 10.6 % were from Moldova. In total, we received 47 responses from the providers of HPC infrastructure from all-over the Danube area, constituted by public centres (80.9 %), 12.8 % of organisations are a private centre inside a company, while 6.4 % of the organisations constitutes a private centre in a non-profit organisation as shows the following figure.

Figure 3: Respondent Countries of the Danube region (n=47)



Based on the work done in 2017, were designed the comprehensive lists of specific services along with a brief clear and concise description of each service written in a non-technical language. Services offered by InnoHPC Lab members have been split into four categories, categories might help future clients to find what they need more easily (see figure 4).

Figure 4: InnoHPC Lab specific types of services



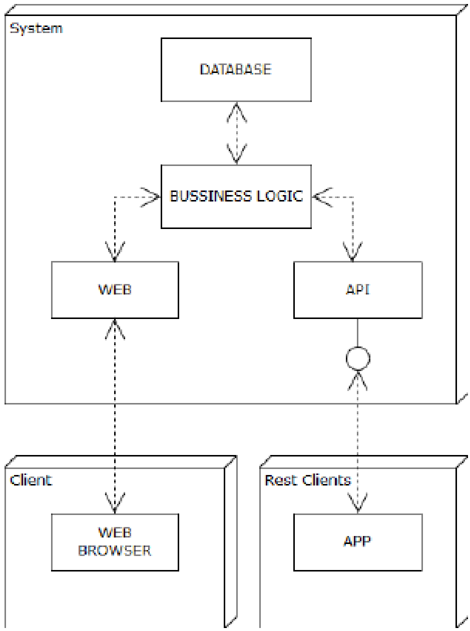
The first category of services is access to HPC resources – HPC infrastructure offered by InnoHPC Lab members and contains services for clients that already have the code or software and knowledge of using the HPC infrastructure, so they would only need the HPC infrastructure to run it. Even in this scenario, some human power is needed to realize the access to the infrastructure. There are some challenges that have been identified related to this category of services. Public institutions cannot just offer infrastructure to SMEs for free. However, it can be offered for free for a test period after which a contract detailing the future engagement may be developed. The second group lists HPC training offerings, three target groups have been identified. The first would be the students that can get experience during studies and then take the knowledge to a future SME. The second group might be the research institutions seeking the expertise in the HPC field and the third one would be SMEs interested to directly use HPC equipment, specific solutions and software monitoring and optimization tools. One other kind of training has been identified – training for funding within the HPC field. The third category lists services related to modelling and domain knowledge, as well as solving complex models using HPC equipment. These services include human power within HPC competence centres capable of helping SMEs in solving problems described by the SMEs using HPC equipment. In this setting, an SME client does not have the code or software to solve their problems, or they have a code that is not well optimized. Services in this category also include investing time and human power and includes further costs. Finally, the fourth category includes consulting services, mediation between academy and industry and making use of understanding the roles and needs on both sides. Through this category the expertise, training, consulting, support and service for HPC problems is offered. Furthermore, to have a clear process of how a SME or a HPC provider will be able to approach the InnoHPC Lab and how the request gets handled, was designed the communication tool between users and information exchange as describes the figure 5.

Figure 5: InnoHPC Lab protocols for collaborative tools

4. InnoHPC Lab Platform

InnoHPC Lab platform provide the design and set-up of a web platform. This multi-purpose platform is proposing to provide tools to gain transnational access to HPC infrastructure for the purpose of supporting innovative process through simulations of business processes, manufacturing or services, tools for sharing meta-solutions (guidance, frameworks for implementation, success stories, lessons learnt, etc.), and collaborative tools (discussion forums) enabling peer and mutual learning exploiting, as well as search for possible partners, communications with HPC experts. Hence, it encourages development of transnational linkages between innovation actors, leading to transnational clusters. In the end will provide the implementation of the holistic service in the form of the InnoHPC Lab and unified access to infrastructure layer for the benefit of the Scientific Communities (Oleksiak, et al., HPC-Europa: towards uniform access to European HPC infrastructures, 2005). The underlying layers include networking, computing (HPC, Grid, and Cloud), storage, and standard interfaces to these (V. Dimitrov, 2018). The following figure describes in general lines InnoHPC Lab platform architecture.

Figure 6: InnoHPC Lab platform schema



Web application have been developed in ASP.Net Core MVC because of a multiplatform usability. Web interface must contain all necessary functionality and it will be fully dynamic. OpenAPI was used for easy integration of information to other external platforms (RSS feeds readers, etc.). Web platform and used API must use secure form of communication based on HTTPS protocol standard and the result solution is based upon open-source software and tools (Oleksiak, et al., 2006). Current infrastructures at the level of HPC resources available of InnoHPC Lab across Danube Region are in the following countries: Croatia, Czech Republic, Slovenia, Romania and Serbia.

Figure 7: Current infrastructures available of InnoHPC Lab

5. Conclusion

HPC is not a minor obscure technology. The ability to efficiently process huge amounts of data dramatically increases innovative capabilities. It can be applied to develop, redesign and test products in virtual environments, optimize production and delivery processes, store and process large amount of data etc. Since physical proximity plays lesser role in utilization of HPC - it can be accessed and operated remotely – it provides excellent opportunity for transnational co-creation and technology transfer without the need for extensive investments in expensive hardware infrastructure in all parts of the Danube region. Hence, the main objective of InnoHPC was to improve the efficiency of innovation in the Danube region by connecting HPC providers, business support organizations, higher education institutions (HEIs), research institutions (RIs) and policy-makers in a transnational HPC laboratory. It aims to improve framework conditions for transnational co-design in developing knowledge-intensive innovative high value-added products.

InnoHPC will increase transnational cooperation in the Danube region, connecting enterprises, HPC providers (HEIs and RIs), national and regional policy-makers and business support. Enterprises will be able to utilize distant infrastructure for effective innovation. Remote access and tailor-made services will promote technology transfer and transnational clustering, improving inclusion of less developed regions in high-tech and knowledge intensive development thus allowing the pooling and rationalizing efforts inside the Danube region.

Policies and projects targeting Danube region, especially its least developed parts, traditionally tend to draw on poorly-defined advantages and are trying to focus on supposedly unique cultural and natural heritage of the region. As a consequence, they often support low value added and labour intensive activities and, ironically, equip participants with skills that make them even more likely candidates for out-migration. Such projects contribute to a vicious circle of underdevelopment. Instead, InnoHPC will provide tailor-made and transferable technology and skills necessary for knowledge-intensive and high value-added entrepreneurial activities. Furthermore, it will do so without the need for expensive investments in hard HPC infrastructure, as it can be accessed remotely.

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Part II

National Case Studies

Austrian Innovation Performance and High Performance Computing Applications

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Abstract: Austria has been classified into the group of strong innovators according to the European Innovation Scoreboard. Firstly, the results of desktop research, interviews and workshops are presented in this article. Secondly, survey results from public and private centres as well as micro-companies from automotive and electronic sector are presented here. They all use open source high performance computing (HPC) software applications. Existing HPC application is mostly oriented towards science. Academic community in the Austrian research centres and universities have much knowledge about HPC (etc. the Vienna Scientific Cluster and the Austrian Centre for Scientific Computing). The most relevant conference for the scientific area of HPC is the Austrian HPC meeting. SMEs are the weakest and still barely visible actors in the Austrian innovation policy. The general awareness and uptake of HPC by the Austrian companies, especially SMEs, is quite low, as they do not see advantages of using HPC in the process of digitalisation. Companies find it hard to work together with their competitors. Promotion of education, training and research for Industry 4.0, creations of knowledge- and research-intensive business start-ups, as well as an acceleration and an integration of the digital transformation's awareness into companies' strategies, have been recommended. More effort should be put also in attracting young talented experts.

Keywords: high-performance computing, digitalization, innovation, factories of the future, Industry 4.0, automotive industry, electronic industry, Austria, Danube region.

1. Overview of the Austrian innovation performance

EU member states have been according to the European Innovation Scoreboard (Hollanders, Es-Sadki 2018) classified into four performance groups based on their average performance scores: innovation leaders (with innovation performance well above the EU average), strong innovators (with performance above or close to the EU average), moderate innovators (their performance below the EU average) and modest innovators (with performance well below the EU average). Performance of innovation systems has been measured by an average performance on 27 indicators divided into four main types of indicators and ten innovation dimensions presented in Table 1.

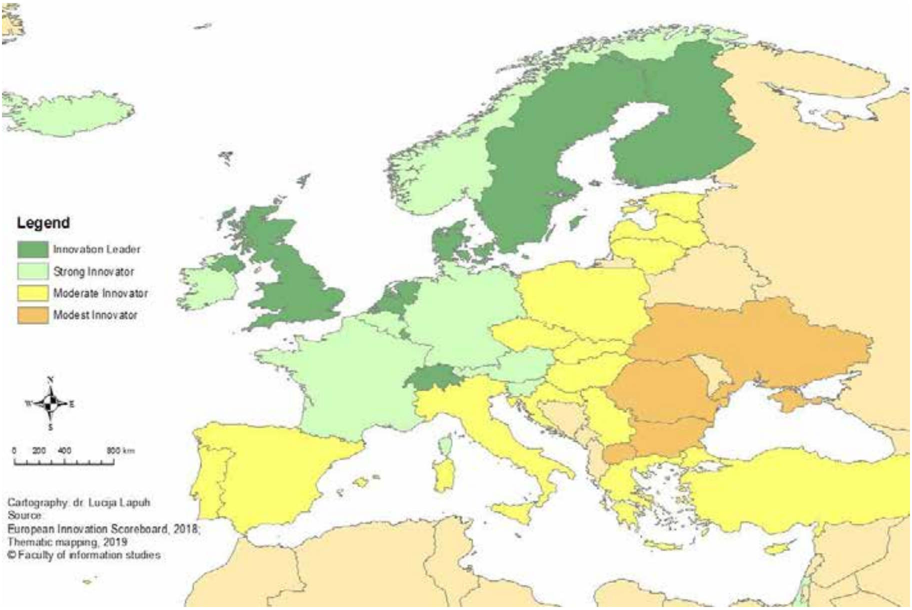
Table 1: Performance of innovation systems has been measured by indicators divided into four types of indicators and ten innovation dimensions

framework conditions	investments	innovation activities	impacts
• human resources • attractive research systems • innovation-friendly environment	• finance and support • firm investments	• innovators • linkages • intellectual assets	• employment impacts • sales impacts

Source: Hollanders, Es-Sadki 2018.

Austria has been classified into the group of strong innovators beside Belgium, France, Germany, Ireland, and Slovenia, whose performance is between 90 % and 120 % of the EU average (presented on Figure 1). Performance of Austria increased strongly (for 9.0 percentage points) between 2010 and 2017, in particular due to a strong performance increase in 2016 (EU improved by 5.8 percentage) (Hollanders, Es-Sadki 2018).

Figure 1: Performance of European and neighbouring countries' innovation systems.



The following paragraph presents more focused overview of ten innovation dimensions focused on Austria. Performance in Attractive research systems declined between 2016 and 2017 for two member states: France (-0.9 %) and Austria (-0.3 %), while the EU average increased at that period by 1.2 %. Performance in Innovation-friendly environment decreased between 2010 and 2017 for Austria (-4.2 %), on the other hand the EU average increased by 33.8 %. Sweden is the overall leader in Firm investments, Germany ranks second, and Austria third. Compared to 2016 performance declined for 16 member states, with the strongest decline for Austria (-14.1 %). Intellectual assets and Linkages are the strongest innovation dimensions in Austria. Performance in Linkages reflects well the overall classification into four performance groups. The Innovation Leaders are represented amongst the top group of countries, together with Strong Innovator countries Belgium, Austria, Germany, and Slovenia. For ten Member States, performance increased between 2010 and 2017. The highest rate of performance increase is observed in Austria (23.1 %), Lithuania (19.6 %), and Ireland (17.1 %). Employment and Sales impacts are the weakest innovation dimensions in Austria. Strong Innovators perform below the

EU average in Employment impacts. Austria perform below the EU average in Sales impacts.

If we look more closely at the indicators GDP per capita, the turnover share of SMEs, and the value added share of foreign-controlled enterprises are well above the EU average; the turnover share of large enterprises is well below the EU average (Hollanders, Es-Sadki 2018).

2. Appraisal of High Performance Computing (HPC) situation

Appraisal of High Performance Computing (HPC) situation is presented in the following chapter according to the collected data from publicly available sources and through online search (InnoHPC's desktop research) (Regional HPC capacity 2018). Three Austrian supercomputers are located on the list of 500 most powerful commercially available computer systems. One is located at the University of Vienna (the Vienna Scientific Cluster) and the other two are hosted by companies (Top 500 List 2018).

2.1. Appraisal of HPC situation in the scientific institutions

The Vienna Scientific Cluster hosts two systems ("VSC-2" and "VSC-3"). The Gregor Mendel Institute of Molecular Plant Biology by Austrian Academy of Science in Vienna has a HPC Cluster named "MENDEL" (https://www.gmi.oeaw.ac.at/about-us/scientific-facilities/scientific-computing/).The Austrian Centre for Scientific Computing hosts two systems ("mach" at University of Linz, "leo3" at University of Innsbruck). At the University of Linz are dealing with high performance computing at the Research Institute for Symbolic Computation of University Linz and at the Institute for Computational Mathematics of University Linz. Johann Radon Institute for Computational and Applied Mathematics (RICAM) by Austrian Academy of Science – located in Linz – are dealing with high performance computing. In Innsbruck are dealing with HPC at the Institute of Mathematics, Numerical Analysis at University of Innsbruck (with own Research Centres for High Performance Computing and Scientific Computing) and the Medical University of Innsbruck owns a cluster for Bio informatics (Research Infrastructures Database in Austria of the Federal Ministry of Science, Research and Economy). Furthermore, the University of Salzburg has two clusters ("Doppler-Cluster" and "Gaisberg"). There are several university institutes, who are dealing with high performance computing, etc.: Institute of Science and Technology Klosterneuburg and Institute for Mathematics and Scientific Computing at University of Graz and many more institutes, who deal with HPC in the area of bioinformatics, medicine, physics, chemistry, microelectronics, etc. Generally, some of the supercomputers are dedicated to bioinformatics or medicine in particular. The infrastructure is open to all thematic areas but dedicated only to scientific work. Central IT-services are responsible for the universities' HPC infrastructure (Regional HPC capacity 2018).

To sum up, in the scientific area, the Vienna Scientific Cluster and the Austrian Centre for Scientific Computing are most relevant institutions in Austria. The most relevant conference for the scientific area of HPC is the Austrian HPC meeting, which is hosted by the Vienna scientific cluster (Regional HPC capacity 2018).

2.2. Appraisal of HPC situation in the industry R&D

The general awareness and uptake of HPC by the Austrian companies, especially SMEs, is quite low. In the course of the InnoHPC project's desktop research, no effective use of HPC between Austrian SMEs have been reported (Regional HPC capacity 2018).

Two Austrian companies participated and provided anonymized input in the online survey on "SMEs demands and needs" carried out by the SESAME NET project. Both companies have satisfactory experience of working with external HPC providers. Any direct demand for training in HPC related topics has not been indicated from the answers of both participated companies. However, those two responses cannot be regarded as being representative for the general situation in Austria (Regional HPC capacity 2018).

2.3. Programs and projects dedicated to HPC

Austria is involved in the following EU wide projects on HPC (Regional HPC capacity 2018):

- Partnership for advanced computing in Europe PRACE,
- Exascale Compound Activity Prediction ExCAPE,
- Network for sustainable ultrascale computing NESUS,
- Mont Blanc,
- Epigram etc.

In the course of the first three calls of the PRACE SME HPC adoption programme in Europe (SHAPE), no applications from Austria have been received in the first call, consequently no projects from Austria have been awarded. Possible reasons for this may be according to the InnoHPC desktop research (Regional HPC capacity 2018): 1) lack of advertising in Austria, 2) insufficient reach of selected Austrian advertising communication channels, 3) lack of awareness, interest and/or demand for HPC by Austrian SMEs or 4) already sufficient coverage of HPC demands by regional HPC resources and/or providers (Regional HPC capacity 2018).

The public funding agency in Austria does not offer any specific programs dedicated to HPC for companies.

It is assumed that the company "AVL List GmbH" is dealing with HPC, because it is part of the EU-wide projects Fortissimo and Mont Blanc (Regional HPC capacity 2018). The following companies, whose work was presented at the Austrian HPC meeting, were identified to possibly work in the area of providing HPC competencies to customers (Austrian HPC meeting 2018): Catalysts GmbH, Materials Center Leoben, DCS Computing GmbH and Medizinkraft solutions GmbH. Institute for Mathematics and Scientific Computing at University of Graz is also partner in EU project Mont Blanc (Regional HPC capacity 2018).

3. Innovation actors active in HPC

3.1. HPC needs and competencies for enterprises

Two micro-companies from automotive and electronic sector were included into this research. Both of them have the R&D department. One of them has been using HPC solutions for less than three years in R&D to meet business requirements and to solve problems that couldn't be addressed through other means. Windows Vista is used to access HPC. Direct benefits of using HPC in companies are increased competitiveness and productivity.

Lack of financial resources to integrate HPC in the current work is a reason for the company not to use HPC solutions, as they are considered expensive. The company which is not using HPC will maybe integrate HPC in the next 12 months to meet the business requirements (Database of enterprises and HPC providers, 2018).

Availability of free HPC infrastructure in Austria is estimated as poor, on the other hand is the availability of commercial HPC infrastructure estimated as good. Availability of competitive public funding as well as of private funding for R&D related to HPC is reasonable. In Austria is a poor awareness about HPC benefits and a fair degree of cooperation related to HPC between science-industry, industry-public authorities and science-public authorities. HPC prioritisation in Austrian legislative documents and strategies is estimated as not good.

Regarding needs about using HPC or integrating it there is a medium need for securing funding for HPC, high need to find partners to collaborate with from business sector, academia and research centres and high need to access infrastructure. A company can use HPC to meet business needs by developing new products or redesigning products and creating computer visualisations that explain research results. A very important potential reasons to adopt HPC or to expand the use of HPC are improve the quality of products or services and testing ideas faster. Top problem related to the use of HPC between Austrian companies is finding well prepared human resources. If companies have access to more free HPC infrastructure (sort of public funding), they will work with larger and more complex data or models. If HPC training in the sector of activity they operate in is available, they will consider this option for the development of their business (Database of enterprises and HPC providers, 2018).

Participating companies are not involved in international projects related to HPC. They consider the national research centres to be important. Cooperation between science and industry can foster the HPC usage and the organisation development. Based on their opinion and knowledge other companies in their fields use HPC (Database of enterprises and HPC providers, 2018).

3.2. HPC providers' competencies

Two public centres and one private non-profit centre from Austria participated in the research. Only a department or part of their organisation deals with HPC for more than 5 years on daily basis. They all use open source HPC software applications, while two of them use also bought and developed in house infrastructure. Parallel computing and supercomputers are HPC areas organisations are mostly focused on. Organisations' HPC infrastructure is used only in academia (Database of enterprises and HPC providers, 2018).

Those surveyed rated the availability of free HPC infrastructure in Austria as fair and the availability of skilled human resources as good. Related to HPC there is a fair degree of science-industry cooperation and a good degree of science-public authorities' cooperation. Increasing competitiveness and testing ideas faster are important reasons to adopt HPC or to expand the use of HPC in organizations.

Organisations' staff would be interested to participate in the following programming courses: Performance Programming, Parallel Architectures, Shared Memory Parallelism, Distributed Memory Parallelism (i.e. Message Passing) and Practical Parallel Programming (Database … 2018).

Two out of three in the survey participated companies are involved in international projects related to HPC and cooperate with industry in HPC related aspects, none of them with enterprises. They appreciate on average importance the cooperation in HPC related aspects with national and foreign enterprises and with national research centres (Database of enterprises and HPC providers, 2018).

4. HPC Benchmark

The following section presents the common strengths and weaknesses of Austria identified by analysing the results of the semi-structured interviews by the InnoHPC team (Regional HPC capacity 2018).

4.1. High Performance Computing and Innovation Profile

4.1.1 *Application of HPC in industrial R&D*

Academic community in the Austrian research centres and universities have much knowledge about HPC. Austrian industry is strongly relying on modelling and simulations for enhancing their products in many different areas. As companies are rather traditional, the industry sector is not very engaged to rethinking their software, therefore the upgrade towards using HPC takes longer. Austrian companies do not see advantages of using HPC in the process of digitalisation, also as the HPC's definition is unclear. Security is still a very important topic and therefore companies might not trust to the use of HPC. Communication and knowledge exchange have to be improved to enhance interdisciplinary cooperation and its efficient use, as well as bringing new users to the area of HPC (Regional HPC capacity 2018).

4.1.2 *Strengths and weaknesses concerning collecting, processing and disseminating HPC information*

There is enough easily accessed HPC information available for universities, which are publicly promoting their successes and development. Funding is possible through many programs, which are not directly covering HPC topics. Networks, such as clusters, offer possibilities finding potential partners. Centred access to HPC related information is missing, etc. a web page containing all needed HPC information. There is neither a clear overview of HPC resources, applications and competences available. A gap regarding knowledge exchange between universities and industry exists. As HPC is not really in the mind-set of the companies, it is difficult for researchers to find partners in industrial sector (Regional HPC capacity 2018).

4.1.3 *Strengths and weaknesses concerning applications of advanced information and communication technology (ICT) tools for R&D in enterprises from automotive and electronics industries*

Some companies in Austria have in order to stay competitive strong focus on R&D, therefore they are innovative and open for the use of advanced ICT tools. Existing clusters as e.g. the Automobil Cluster in Upper Austria and in Styria, as well in electronics the Silicon Alps Cluster in the South of Austria contribute also in connecting research with industry by creating an innovation chain. Few or no cooperation exists between industry and academia for enhancing and improving the use of HPC for industrial R&D. Industry has a very weak access to the existing tools, additionally special tools for HPC are not used (Regional HPC capacity 2018).

4.1.4 *Potential HPC application's orientation towards industrial R&D*

Existing HPC application is mostly oriented towards science, but autonomous driving area would be one example where HPC orientation is towards industry. The research work done so far has not really been applied in industry as a transfer of information from research centres, HPC providers and competence centres to companies is limited, underdeveloped and inefficient. Information on possible HPC's applications and case studies in industry would be welcomed for companies to get to know which problems can be solvable with HPC as the use of HPC in industry is very limited (Regional HPC capacity 2018).

4.2. Institutions

4.2.1 *The role of the public authorities and intermediary organizations for using HPC*

Several public free of charge trainings have been organized in Austria. On the other hand, funding available for infrastructure is limited not only to academia but also to industry. There is no support in rising an awareness for using HPC provided from public authorities. Intermediary organisations (e.g. technology transfer offices) are available in Austria, but not very much involved in the activities regarding HPC. Only a few cooperative activities exist between industry, public authorities and academia, for which is available limited funding budget (Regional HPC capacity 2018).

4.2.2 *Capacity to attract talented people*

Austria provides talented people with a good potential to influence national activities. In general, it is hard to attract students for technical studies. On the field of HPC professionals work mostly within academic institutions' research groups. Austria is not attracting enough foreign talented professionals with HPC competencies due to unnoticeable HPC marketing and too low academic budgets. More effort should be put in attracting young talented experts from abroad. Professional development and cooperative projects for achieving excellence have to be established internationally as national resources are not developed well enough. Alliances with industry are rare (Regional HPC capacity 2018).

4.2.3 *Capacity to retain talented people*

Some companies are using as a communication language besides German also English and are trying to be attractive employers by organizing interesting events for their employees. Some other countries are more attractive and open to retain talented people than Austria, which is experiencing also a brain drain. Many HPC experts from Austria have because of better career prospects migrated to foreign institutions. The official authorities and universities do not put enough effort to retain those talents inside the country (Regional HPC capacity 2018).

4.2.4 *Regional and national innovation policy*

It is estimated that the Austrian innovation is going into the right direction as money is spent on innovation topics. The innovation policy view is perceived as too broad and national strategy not well developed. Other stakeholders should be included into discussions about improvements (Regional HPC capacity 2018). SMEs innovativeness is promoted by directed research, which is complemented with a tax reduction (Database of enterprises and HPC providers, 2018). SMEs are the weakest and still barely visible actors in the Austrian innovation policy, even though they often do something in this domain. SMEs are not aware of benefits using HPC. In Austria it is not easy to fund a start-up – if you fail with a start-up, it is very difficult to come back. Long-term vision exists, but funding is limited (Regional HPC capacity 2018).

4.3. Networks

4.3.1 *Networks' organization and their contribution to the implementation of HPC in industrial R&D*

Strong cooperative academic community, which is willing to collaborate with industry, exists in Austria. This community is internationally well connected and open for international cooperation. Researchers from different research areas regularly exchange their knowledge on HPC and support further development. There are clusters and multi-sectoral networks in Austria, HPC specific is the Vienna Scientific Centre. No network exists in Austria anymore in the context of HPC as the international membership of PRACE was cancelled due to a budget decision. Cross-border networks should be improved (Regional HPC capacity 2018).

4.3.2 *Cooperation between stakeholders active in innovation and technological policy*

Collaboration between companies and research centres is well developed, but there is not much cooperation between other stakeholders. Austrian companies are not likely to cooperate between each other. Key actors from an academia have a possibility to influence the national policy developments. Direct communication between policy makers and key actors from academia is not well established and decisions are not always made in coordination with experts (Regional HPC capacity 2018).

4.3.3 *Cooperation between stakeholders active in innovation and technological policy and actors outside Austria*

Good network exists between national key actors in academia and international initiatives. Chance for collaborations are unreliable as the membership in international initiatives is strongly limited by budget constraints and national funding (Regional HPC capacity 2018).

4.3.4 *Trust between stakeholders and entrepreneurs active in innovation and technological policy*

Excellent level of trust exists in the academia and research. Competition regarding the available budget and missing collaborative approaches limit the trust between stakeholders active in innovation and technological policy (Regional HPC capacity 2018).

4.4. Cognitive Frames

4.4.1 *Population's culture and attitude concerning creativity, entrepreneurship and new technologies*

The entrepreneurship skills are on a high level in Austria. Creativity and technical excellence is one of the key strengths of Austrian culture, R&D topic is nowadays present in the news. Upper Austria in particular is quite conservative and not that open minded. Distrust is in new technologies and economic risk-taking is preferably avoided. Economic failure as crashing a start-up is regarded as a shame, consequently the fear of failure strongly limits entrepreneurship (Regional HPC capacity 2018).

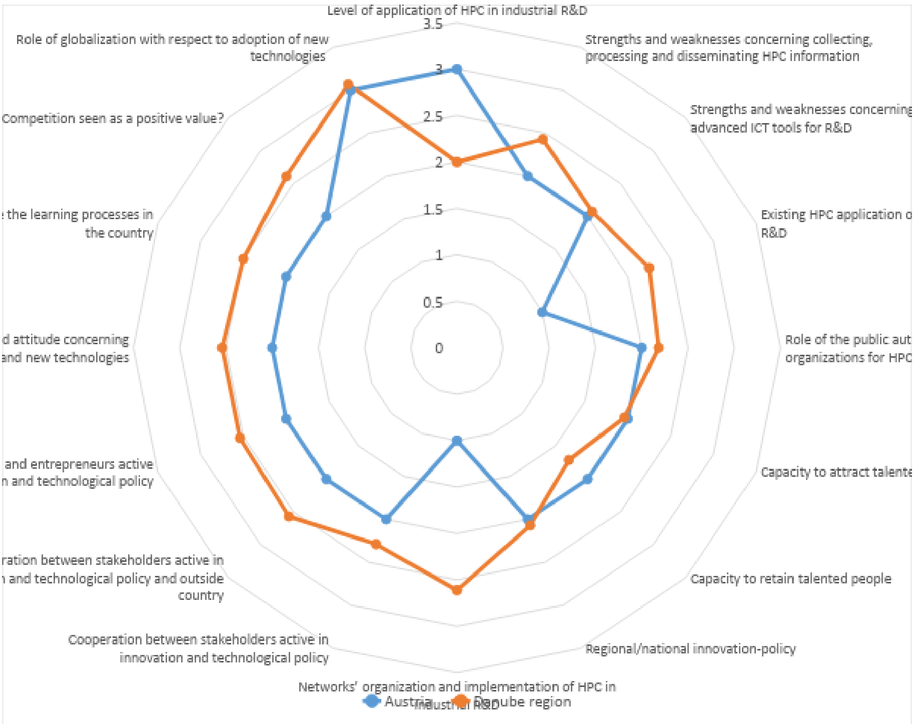
4.4.2 *Competition's value*

Entrance examination is missing for the undergraduate school system. Not enough pupils decide to go to the university. Less of them decide for technical subjects also as math is not one of the favoured subjects in schools. Gender unequal participation is strongly present with lower participation of women. The learning process at the university level is efficient and their professors are professionals. Creativity in not enough supported. Failure is in the business environment not seen as a chance for learning (Regional HPC capacity 2018).

4.4.3 *The role of globalization with respect to adoption of new technologies*

Some companies find that the competition fight is very important and therefore some collaborative work is achieved, but still very few. Companies find it hard to work together with their competitors, they prefer consensus and negotiation. Competition between different organisations has led to dispersed infrastructure and dispersed budget on the academic level for HPC. In recent years with the construction of The Vienna Scientific Cluster a national HPC competence centre was established. The strong focus on the national capital regarding investments is not optimal (Regional HPC capacity 2018).

Figure 2: Overview of scores on a range of 1–4 (four being maximum / most desirable) assessing strengths and weaknesses of HPC and innovation for Austria compared to countries of Danube region



Source: Regional HPC capacity 2018

It is seen that Austria performs in general worse than is the average of countries from the Danube region. Austria positively stands out for the level of application of HPC in industrial R&D and capacity to retain talented people.

5. Recommendations for activating innovation potential

5.1. Promotion of education, training and research for Industry 4.0

Industry 4.0, which is defined as the digitalization and integration of the entire value chain and which follows the mechanization, electrification and automation, changes requirements for qualification and competencies (Database of enterprises and HPC providers, 2018). For innovation potential activation more focus should be put to the fields of natural and computer science, as well as on digital competencies and MINT subjects (mathematics, computer science, natural sciences and technology), starting already from elementary school on. Interdisciplinarity in the education system should be fostered (Digital Transformation 2018). Knowledge transfer centres have to be established at universities to strengthen financial competency and entrepreneurship (Strategy 2011). Co-operation between science and business, which have to be increased and focused on excellence and sustainability, is important to prepare existing and future employees for Industry 4.0, so that they can also make their requirements meaningful and contribute to the success of digital transformation. Enterprises should support their employees in education and training on topics relevant to Industry 4.0 (Digital Transformation 2018).

For activating and increasing company's research and innovative performance access to academic high-tech resources, laboratories and HPC data centres have to be provided. Firms' access to external resources have to be improved. The involvement of Austrian companies, scientific and research facilities in EU and international programs has to be fostered. Enterprises have to be supported in securing intellectual property. Initiatives have to be developed to strengthen human potential in the area of applied research, inter-sectoral and international mobility (Digital Transformation 2018).

5.2. Business start-ups

Knowledge- and research-intensive business start-ups have to be created and administrative hurdles reduced (Strategy 2011). A legal framework to increase the equity capital of young technology and growth-oriented enterprises have to be created. A new disruptive business model cannot simply be built up within the old business model due to target conflicts. Instead, companies should better separate business units from the core business, concentrating only on the growth opportunities of the disruptive business, such as a start-up within an established company (Digital Transformation 2018).

A high relevance for SMEs that lack an own research, development and infrastructure is a pilot factory at the technical university (TU) of Vienna. The pilot factory combines basic research, application-oriented research in cooperation with industry, research-oriented teaching and continuing education. Its' hardware and software can be used for cooperative development projects (Database of enterprises and HPC providers, 2018).

5.3. Digital transformation

According to the Digital Economy and Society Index (DESI) Austria ranks 10th according to other European states. The Digital Economy and Society Index shows that the EU is making progress in digital, even though more efforts and investments will be needed to make the most of the digital opportunities (Database of enterprises and HPC providers, 2018).

Awareness of the digital transformation should be accelerated and integrated into companies' strategies. Politics should support business innovations with public funding (Digital Transformation 2018). Support for the digital transformation of SMEs is the program/initiative "Digital SME" ("KMU Digital") of the Federal Ministry of Science, Research and the Economy and the Austrian Economic Chambers. The initiative provides direct business support on several levels and with a multitude of instruments (Mattauch 2017).

IT strategy sets some fundamental principles. For instance, each company should decide at the very beginning of the digital transformation that either it prefers to build, host and maintain its own server and/or HPC infrastructure and to train and pay for own IT experts, or, secondly, prefers more cost effective way and outsources IT infrastructures into third-party HPC data centres or, thirdly, a hybrid solution, where some IT infrastructures are maintained always in house, but more expensive IT resources are rented from third-party HPC data centres and use only on demand. Digital transformation requires sensible regulations, especially data protection (Digital Transformation 2018).

5.4. Data strategy in value-added networks

Companies have to follow a development, preserve competitiveness and have an influence on the establishment of technical standards between stakeholders in their value-added network. Every company should design and evolve a data strategy for itself and, if necessary, coordinate it with partners in the value-added network. A proactive strategy to ensure in-house IT and data security is a must for companies who want to secure their place in successful value-added networks (Digital Transformation 2018).

6. Conclusion

Austria, with an innovation performance around the EU average, is classified according to 27 indicators into the second best group of European countries, named the strong innovator. The HPC applications in Austria are mostly oriented towards research centres and universities, much less to industry. Open source HPC software applications, which are already used by both academia and industry, have a greater potential for further use to speed up the process of the digitalisation in this country. There is also a greater potential of more cooperation between companies.

As the samples in this survey on the use of HPC between providers and companies from automotive and electronic sector is relatively small, the obtained results from questionnaires may not represent the countries' entire situation.

More effort should be intended in rising the companies' awareness of the advantages of a work process digitalization and the inclusion of HPC. Promotion of education, training and research for Industry 4.0 will be beneficial for fostering the innovation performance and the use of HPC, creations of knowledge- and research-intensive business start-ups, as well as an acceleration and an integration of the digital transformation awareness into companies' strategies. Consequently Austria can remain competitive and advanced in the even more digitalised societies.

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National Case Study Bosnia and Herzegovina

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Abstract: Bosnia and Herzegovina is underdeveloped country in terms of HPC infrastructure, with a low level of HPC usage. In general, industry in B&H use digital technology but straggled behind the developed world. Technological backwardness is especially relating to the technology and technical systems of the future such as technology of new materials, information technology, communication technology, new production technologies and techniques, new energy technology, biotechnology, and modern and intelligent manufacturing systems.

Keywords: Bosnia and Herzegovina, HPC, innovation performance, digital transformation of industry

1. Overview of country innovation performance

Bosnia and Herzegovina (B&H) is the South-east Europe country that submitted the application for EU membership in 2016 and is currently awaiting the approval of the candidate status. Country has 3.5 million inhabitants. GDP per capita is 4572 euros with a 10-year average annual GDP growth of 1.8. Unemployment rate is 25.6 %. Annual allocations for innovation amount to 0.2 % of GDP which is much lower than the EU average. Bosnia and Herzegovina – together with Albania, Kosovo and Montenegro-is for a very first time included in the European Innovation Scoreboard for 2018. These countries cannot yet be included in comparative EU analyses, and for Bosnia and Herzegovina currently data are available from international data sources for 10 indicators, although some data are still not available or expected from the first innovation survey.

Table 1: European Innovation Scoreboard 2018 – Bosnia and Herzegovina[26]

ATTRACTIVE RESEARCH SYSTEMS	
International scientific co-publications	94.0 (2015)
Top 10% most cited publications	3.3 (2014)
INNOVATION-FRIENDLY ENVIRONMENT	
Opportunity-driven entrepreneurship	1.2 (2017)
FINANCE AND SUPPORT	
R&D expenditure in the public sector	0.21 (2014)a
FIRM INVESTMENTS	
R&D expenditure in the business sector	0.05 (2014)
LINKAGES	
Public-private co-publications	1.05 (2014)
Private co-funding of public R&D expenditures	0.016 (2014)
INTELLECTUAL ASSETS	
Trademark applications (absolute numbers)	9 (2017)
	31 (2017)
Design applications (absolute numbers)	1 (2014)
SALES IMPACTS	
Medium and high-tech product exports	22.4 (2017)
Knowledge-intensive services exports	14.9 (2015)

According to The Global Competitiveness Report 2018[27] of the World Economic Forum, Bosnia and Herzegovina is ranked 91 out of 140 countries in competitiveness in 2018. When it comes to "Pillar 12 Innovation capability", Bosnia and Herzegovina is 114th out of 140. In terms of cooperation, university-industry collaboration is at 122th place. Compared to EU countries and neighbouring countries such as Croatia, Serbia, Montenegro, the B&H innovation performance as well investments in innovation are far below satisfactory and enough. Competitiveness of Bosnia and Herzegovina economy is directly proportional to the degree of investment in research and development.

26 Source: (European Innovation Scoreboard 2018, Table 3: Data availability Western Balkan countries, page 29, 2018)

27 Source: (The Global Competitiveness Report 2018; Klaus Schwab, World Economic Forum, pages 107–109; 2018)

2. Appraisal of HPC situation in Bosnia and Herzegovina

Sarajevo Regional Development Agency SERDA, whose mission is to support the development of the business environment in BiH, seen participation in the implementation of the INNOHPC project as an opportunity for improving knowledge and business infrastructure for SMEs in BiH.

SERDA accepted the partnership in the project with the fact that B&H is a country with a long tradition and great experience in the automotive industry. Volkswagen produced passenger cars and commercial vehicles in a factory near Sarajevo until the 1992, while the companies "Kosmos" from Banja Luka and "Soko" from Mostar produced buses. War in the early 1990s heavy damaged industry of the country and post-war period broke this tradition, but not broke the comparative advantage of B&H in terms of qualified labour force from B&H.

In the last ten years, the Bosnia and Herzegovina's industry records dynamic development and an export of 90 percent of its production to 30 countries around the world. There are cca. 60 companies in the country engaged in the production of parts for vehicles, nearly all are private owned, and many of them are with invested foreign capital. Mostly are metal processing production facilities, and there is also important export of textile and leather seat covers. The industry still has great potential for development. B&H companies from the automotive sector produce a wide range of parts and components, such as motors and gears and its parts, metal precise parts, drive shaft, braking systems, couplings, control systems, pumps, filters, electric parts for vehicles, textile products and leather, alloy wheels, batteries, and various small parts such as springs, screws, tubes, and components of metal, rubber or plastic. When it comes to the electronics industry in B&H, it is very underdeveloped.[28] Concrete activities in Bosnia and Herzegovina within the InnoHPC project started with desk research and semi-structured interview with relevant actors conducted in the first half of 2017.

The obtained results did not encourage. The brief appraisal regarding HPC in Bosnia and Herzegovina was as follow:

1. There is NO HPC centres or similar in Bosnia and Herzegovina (B&H), so there is no institution that deal with.
2. Within the existing legal framework there are no adequate legislations to regulate in detail the specifics of the HPC.
3. In academia super computers and HPC are present in terms of topics within faculties subjects and some project (exp. human genome project),

28 Source:www.fipa.gov.ba (Agencija za unapređenje stranih investicija u Bosni i Hercegovini, 2012)

etc. (thanks to enthusiasts). Some electrical engineering faculties were linked in grid network within some EU funded project.

4. Regarding industry, there were few weak rudiment forms of super computer use (in a form of grids). Also, there was an initiative for use of super computers in the Hydro Meteorological Institute of B&H.
5. Generally, the application of HPC is very underdeveloped. People/ organizations/sectors very rare use modern digital technologies such as HPC-mostly some partial and weak use of academia, telecoms, freelancers.

Research initially showed us that, in general, industry in B&H use digital technology, but straggled behind the developed world. Technological backwardness is especially relating to the technology and technical systems of the future such as technology of new materials, information technology, communication technology, new production technologies and techniques, new energy technology, biotechnology, and modern and intelligent manufacturing systems.

The some of the main cause of this are the lags due to the 1990s war, the specific country structure, inadequate legislation, lack of material and technical and financial resources, and insufficient scientific research in B&H.

We were surprised by the fact that B&H does not have HPC infrastructures although it has two preconditions for establishing HPC centres – a good geographical position, network of optical fibres, and good supply of electricity, which are the prerequisites for work of supercomputer.

Even though we knew Bosnia and Herzegovina have not achieved significant progress in the digitalization of industry as well as the implementation of HPC, it has surprised us that Bosnia and Herzegovina companies do not use a lot the HPC infrastructure that exists in the EU and may improve their business performance.

However, as continued with our activities, we realized that participation in InnoHPC project was more than necessary for us to find the way to open the door and demystify the HPC in the Bosnia and Herzegovina entrepreneurial space.

Although B&H do not have HPC infrastructure and although initially were discouraged and somewhat confused, it motivated us to identify our advantages through the InnoHPC project, adopt the knowledge and experience of our partners, connect with relevant partners and stakeholders so that we can further support our companies in improving their business.

3. Innovation actors active in HPC

In Bosnia and Herzegovina there is no innovation actors active in HPC. Through research, some actors (faculties, technology parks and other relevant centres) were identified to be potentially active in HPC.

The main areas where exist the possibility of application of HPC as well innovation is automotive industry, pharmaceutical industry, telecommunication industry, metal industry- production of machines, hydro meteorological branch, media, etc.

4. HPC Benchmark

During the June 2017 in Bosnia and Herzegovina were conducted interview with companies in order to catalogue HPC needs in firms, analysing capacity and institutional absorption capacities.

The sample consists of 6 companies on the market of Bosnia and Herzegovina that work in automotive industry. In the sample defining process, participation of businesses of all sizes (2 large, 1 medium, 1 small and 2 micro companies) were considered in order to make an adequate comparison and to examine HPC usage in the context of these companies. Aiming to illustrate actual use of HPC technology in the country, a broader approach was preferred, so 3 additional companies which work in automotive industry, but they have manufacturing facilities outside the country also surveyed.

The survey revealed low level of awareness and knowledge of HPC technologies and their potential and possible applications.

While conducting the survey, we found out there are companies in Bosnia and Herzegovina which use HPC solutions. They manufacturing system follows the just-in-time model, which requires continuous and strictly synchronized delivery of parts to minimize inventory and optimize speed and quality of production.

Although these three companies are legally registered in EU countries and there, they have production plants, they are still members of domestic group and their R&D department, IT department, administration and management are located in BIH, including many key customers.

However, survey findings related to those companies show their HPC usage is mainly in R&D and large-scale data management (3 out of 3) but in manufacturing/production process (2 out of 3). They emphasized increased competitiveness, reduced costs and faster time to work as the biggest benefits of HPC.

In line with this, they opted for HPC implementation because of both external (e.g. tax incentives, legislation, customer request) and internal drivers (e.g. efficiency in addressing problems such as lower cost; faster time to solution, new product/service development).

All interviewed companies, even these companies, which have used HPC system, indicated need for education and capacity building. Regarding the HPC, they expressed interest for training in following skill categories: HPC System Administration- Parallel File Systems (e.g. Ceph, Lustre, Hadoop FS) – 33,33 %; HPC System Administration- Resource Managers / Job Schedulers (e.g. SLURM, TORQUE, etc.); HPC Code Development: Scripting languages (e.g. Python, Perl, etc.);HPC Code Development:-Programming Languages (e.g. C, C++, Fortran, etc.); HPC Code Development- Version Control Systems (e.g. SVN, GIT, etc.) –22,22 %;HPC Code Development: Numerical Libraries (e.g. BLAS, LAPACK, PETSc); HPC Code Development- Message Passing (i.e. MPI); HPC Code Development- Profiling and Debugging tools (e.g. Intel VTune, Allinea Tools, etc.) HPC System Usage- Basic Linux skills (i.e. Linux shell (e.g. BASH, SSH, etc.); HPC System Usage- Resource Managers / Job Schedulers (e.g. SLURM, TORQUE, etc.).

Technical skills of the personnel of companies who dealt with HPC are mostly: HPC System Administration- Parallel File Systems (e.g. Ceph, Lustre, Hadoop FS); HPC Code Development- Linux Shell Scripting (e.g. BASH, CSH, ZSH, etc.); HPC Code Development- Scripting languages (e.g. Python, Perl, etc.); HPC Code Development- Programming Languages (e.g. C, C++, Fortran, etc.); HPC Code Development- Version Control Systems (e.g. SVN, GIT, etc.); HPC Code Development-Message Passing (i.e. MPI).

Lack of financial resources, knowledge and HPC related skills are among main reasons why companies do not use HPC. Specifically, lack of funds is the main obstacle to SMEs usage of HPC. Also, the most of interviewed companies stated that their customers not require to use HPC.

There is no available public or private funding for HPC including R&D related to HPC or free HPC infrastructure. Considering lack of relevant legislative documents and strategies, establishment of HPC supportive environment should be given high priority.

However, most surveyed companies recognize potential in use of HPC solutions especially when it comes to new products development or their redesign, but also process optimization and innovation. Accordingly, majority of respondents indicated that increase competitiveness and improved the quality of products/

services represent important and/or very important potential reasons to adopt HPC or to expand the use of HPC.

Furthermore, survey shows companies perceive that cooperation with science/ industry could foster the HPC usage and organisation development as well. Specifically, they value most cooperation in HPC related aspects with enterprises, including both national and foreign, and then research-oriented institutions. In B&H, the largest part of the funds for research and development are invested in scientific research based on theoretical or experimental work without no direct application in the industry, while a very small percentage are invested in development (professional) research, which have an impact on the progress of the industry in Bosnia and Herzegovina.

Cooperation and external links ensure new and specialized knowledge, technology goods and services. The use of external knowledge sources is especially important in terms of extremely rapid growth of highly specialized knowledge. Companies' own capabilities are insufficient to meet the increasingly demanding environment, so using external resources and capabilities they significantly enhance their innovation capacities especially when it comes to process improvements and innovations.

In short, this is the overview of the current situation in Bosnia and Herzegovina taken **from the industry point** of view:

- HPC processes is not part of B&H industrial R&D
- Companies have limited capacity to access HPC (money limit)
- There is no a coherent, structured information management system/ process that covers collecting, processing, disseminating and monitoring needs concerning HPC relevant information such as funding opportunities, potential partners, available know-how, technologies, etc.
- No marketing on HPC usage
- No institute/laboratory on HPC usage
- No trainings on HPC usage

At the end of 2018, a workshop was held in Sarajevo with representatives of SMEs, industry, IT professionals and representatives of the education sector, where the results of the research and the activities undertaken under the INNOHPC project were elaborated. On this occasion, the following were defined: **Bosnia and Herzegovina lags behind EU countries in terms of HPC use.** In Bosnia and Herzegovina is extremely low level of awareness and knowledge about HPC technologies among business. Lack of financial resources, knowledge and relevant skills are the main reasons why domestic companies do not use HPC technologies. The lack of financial resources is especially evident within small and medium-sized enterprises. Need for education and capacity building is highlighted. There is no relevant legal or strategic framework, it is necessary to work on building an environment that will be stimulating to intensify the application of HPC technologies. Cooperation between industry and science could improve the application of HPC technologies**.** Clear indicators that concrete support mechanisms for implementing HPC technologies are needed**.**

5. Recommendations

Bosnia and Herzegovina have to fulfil many preconditions to approach completely to the process on digital transformation, and largely lags in the context of digital transformation of industry compared with the EU and neighbouring countries. The greatest number of preconditions, and the basis for all other steps is the adoption of appropriate legislation in this field.

The document "Policy on informatics society development in Bosnia And Herzegovina 2017–2021"[29] set up goals which well correspond with the results of the research conducted within the InnoHPC project. So, some of the recommendations at level of Bosnia and Herzegovina are as follow:

1. Establishment of the unique digital market through activities such as adoption of new legislative legislation that support the establishment of a unique digital market. Furthermore, simplifying the distribution of creative content and improving the protection of intellectual property rights on the Internet, Support and promote a unique digital market in Bosnia and Herzegovina and EU, Improving the domestic telecommunications market, etc.
2. Establishing the framework for interoperability and standards which implies the implementation of legislation on ICT interoperability, guidelines for ICT standardization and public procurement as well approach to the European framework for interoperability.
3. Stimulating confidence and security of private networks and data and strengthen the fight against cyber-attacks on information systems and critical infrastructure, as well maintain the EU platform to combat cybercrime. Also, this implies development of cybernetic security strategy.
4. Establishing fast and ultra-fast Internet access needs adoption and implementation of broadband legislation, means for broadband high-speed

29 Source: (www.mkt.gov.ba Ministarstvo komunikacija i prometa Bosne i Hercegovine, 2018)

access, Adoption of BH policy and spectrum strategy and development of an action plan for broadband implementation.

5. Strengthening digital literacy, knowledge and e-inclusion by providing guidelines for the advancement of digital literacy and ICT competence of citizens of Bosnia and Herzegovina
6. Application of ICT in addressing key challenges of Bosnia and Herzegovina society but one of the key recommendations in the contest of the HPC and digital transformation of industry is to **encourage investment in research and innovation**. This should be realized through adoption and implementation of the BH Cloud Computing Strategy based on the European Framework for Cloud Computing. Also, set up more business-friendly environments for beginner entrepreneurs is crucial. Furthermore, focus should be on the development of photonic, robotics and future internet public-private partnership on High Performance Computing. Introduction of an action Plan for the Development of the Electronic Industry and increase Investments in High Performance Computing are also necessary.

6. Conclusion

Compared to EU countries and neighbouring countries such as Croatia, Serbia, Montenegro, the B&H innovation performance as well investments in innovation are far below satisfactory and enough. Competitiveness of Bosnia and Herzegovina economy is directly proportional to the degree of investment in research and development.

There are cca. 60 companies in the country engaged in the production of parts for vehicles, nearly all are private owned, and many of them are with invested foreign capital.

HPC processes is not part of B&H industrial R&D. Companies have limited capacity to access HPC (money limit). There is no a coherent, structured information management system/process that covers collecting, processing, disseminating and monitoring needs concerning HPC relevant information such as funding opportunities, potential partners, available know-how, technologies, etc. There ae no marketing on HPC usage, no institute/laboratory on HPC usage and no trainings on HPC usage. In Bosnia and Herzegovina there is no innovation actors active in HPC. Through research, some actors (faculties, technology parks and other relevant centres) were identified to be potentially active in HPC.

There is no relevant legal or strategic framework, it is necessary to work on building an environment that will be stimulating to intensify the application of HPC technologies. Cooperation between industry and science could definitely improve the application of HPC technologies. Clear indicators that concrete support mechanisms for implementing HPC technologies are needed.

One of the key recommendations in the contest of the HPC and digital transformation of industry is to encourage investment in research and innovation. Participations in transnational projects, such as InnoHPC project, are more than necessary for B&H to find the way to open the door and demystify the HPC in the Bosnia and Herzegovina entrepreneurial space.

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High Performance Computing Development in Bulgaria[30]

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Abstract: This article analyses recent developments in the infrastructure and organization of the High Performance Computing (HPC) in Bulgaria. The major actors in the process from the providers' side are the Institute of Information and Communication Technologies of at the Bulgarian Academy of Sciences and the High Performance Computing Lab at the Technology Park in Sofia.

The focus of the analysis is on the opportunities for cooperation between active HPC providers and the SMEs in the automotive and electronics industries in Bulgaria. In addition, the article presents Strengths, Weaknesses, Opportunities and Threats related to the use of HPC applications in the country. Finally, yet importantly it summarizes some recommendations regarding Digital Transformation of the Bulgarian Industry.

Keywords: High Performance Computing, Digital Transformation of Industry, Innovation, Research and Development, Supercomputer Applications

1. Bulgaria's innovation performance

According to the European Innovation Scoreboard 2018, Bulgaria is a modest innovator. Over time, performance has not changed relative to that of the EU in 2010. The group of modest innovators includes Member States (MS) that show a performance level below 50% of the EU average. Besides, the summary innovation index shows that the performance of Bulgaria declined by 1.5 percentage points over the period 2010 – 2018, leading to a widening of the performance gap between the country's innovation performance and the average innovation

30 This publication is based on the results obtained in the framework of the project High-performance computing for Effective Innovation in the Danube Region (InnoHPC), DTP-1-260-1.1, funded by Danube Transnational Program of the European Union, 2017–2019.

performance of the EU member states. Bulgaria's performance in 2017 was below the performance level in 2010 (European Innovation Scoreboard, 2018).

The explanation of these facts could be found in the low innovation activity of companies in Bulgaria because of insufficient cooperation between the governmental agencies, business organizations and universities or research centres. In addition, the innovation activity is limited by the inefficient investments in research and development (R&D) as share of GDP. Furthermore, there is a lack of adequate business environment and infrastructure for innovations. Finally, there is a complicated access to sources of funding and weak investment activity in the country.

2. Appraisal of the HPC situation in Bulgaria

This part of the article outlines the High Performance Computing infrastructure in Bulgaria. Taking into consideration the general level of its economic development, the country has comparatively well-developed HPC infrastructure. There are many national and international initiatives related to HPC application.

Two clusters of HPC providers are the most important in the country. The first, and the best developed one, is structured around the Institute of Information and Communication Technologies of the Bulgarian Academy of Sciences (IICT – BAS). There is a specialised structure named Advanced Computing and Data Centre, which is dealing with HPC (Margenov, 2015).

According to the renewed National Roadmap for Research Infrastructure, the IICT-BAS is a scientific coordinator of two research infrastructures: 1) National Centre for high performance and distributed computing; 2) CLaDA-BG: Infrastructure for Bulgarian Language and Cultural Heritage Resources and Technologies (Bulgaria national roadmap for research infrastructure 2017-2023, 2017). In 2015 the Advanced Computing and Data Centre was expanded with new multifunctional high performance computing complex AVITOHOL (Website of Advanced Computing and Data Centre at IICT-BAS).

One of the best examples of integrated HPC Infrastructure, not only in the country but also in South Eastern Europe (SEE), is the National Centre for HPC and Distributed Computing (NC4HPC&DC). The financial coordinators of the Centre are the Ministry of Education and Science and the Ministry of Transport, Information Technology and Communications. The scientific coordinator is the IICT-BAS.

The Consortium for supercomputers applications was established in 2009. It includes Sofia University "St Kliment Ohridski", Technical University – Sofia, Medical University – Sofia, National Institute of Geophysics, Geodesy and Geography Bulgarian Academy of Sciences and the Institute of Mechanics – Bulgaria Academy of Sciences.

The consortium for supercomputer applications closely cooperates with the Association National Centre for Supercomputing Applications (NCSA), which represents Bulgaria in Partnership for Advanced Computing in Europe (PRACE) (Web site of National Centre for Supercomputing Applications, Bulgaria).

The Consortium for distributed (Grid and Cloud) applications was set up in 2004 and updated in 2012. It includes the Institute for Nuclear Research and Nuclear Energy - BAS, Sofia University "St. Kliment Ohridski", the Technical University – Gabrovo, the Institute of Molecular Biology "Roumen Tsanev" – BAS, the National Institute of Geophysics, Geodesy and Geography - BAS, the Institute of Mechanics – BAS and the Institute of mathematics and Informatics – Bulgarian Academy of Sciences (Atanassov, 2018).

The IICT-BAS is the scientific and technical coordinator of the Centre of Excellence (CoE) on Supercomputing applications, as well as the coordinator of the SuperCA++ (Website of the Project Centre of Excellence on Supercomputer Applications).

The HPC is regarded as strategic means for resolving problems in the industrial design, production and the management. The major current task is the more efficient management and exploitation of the existing HPC capacities by expanding their application. The infrastructural components in the step-by step resolution of the task are the building and functioning of the CoE Supercomputer Applications (SuperCA++), the Bulgarian Grid Consortium and the Bulgarian Research and Educational Network (BREN) (Website of the Bulgarian Research and Education Network Association).

The second major research and technology cluster, dealing with HPC applications in Bulgaria, is structured around the High Performance Computing Lab opened in 2017 at the T+IN Technology Park in Sofia (Website of Nestum Cluster. HPCLab@SofiaTech Park).

The main motor of the establishment of this HPC lab was the Monte Carlo Group at the Nuclear Physics Department, University of Sofia "St. Kliment Ohridski" (Karaivanova, Atanasov and Gurov, 2013).

The mission of the Lab is to deliver reliable and sustainable computing resources and services. They are expected to facilitate the use of HPC and to meet the small-scale and mid-range computational demands of the scientific research community in the academic institutions and high-tech Small and Medium Size Enterprises (SMEs) located in the country and in the SEE region. Thus, the laboratory is intended to support computational science, in which interdisciplinary teams of scientists consider fundamental problems in science and engineering that require computation and have broad scientific and economic impacts. Main activities and research at the HPC Lab are Global climate modelling, carbon materials, astrophysics, computational biology and Nano medicine; highly scalable methods for modelling and simulation that can exploit massive parallelism and data locality.

The lab team helps the users to understand what hardware, software and methodologies are available and which are appropriate for their needs (Proykova, 2018).

In addition to the research and applied activates of the two major clusters of HPC providers in Bulgaria, one should add also some education and training courses in HPC application. For example, the Monte Carlo Research Group provides Master courses in HPC at the Faculty of Physics of the Sofia University. In addition, the IICT-BAS is active in the Partnership for PRACE training events organised every year with Bulgarian participation (Website of PRACE). Finally, yet importantly, the IICT-BAS organised a special session on HPC and big data: algorithms and applications in June 2017 in Bulgaria. The session was focussed on current research using High-performance computing and data-intensive computations in field of Life Sciences, Climatology and Digital Cultural Heritage.

3. Innovation actors active in HPC in Bulgaria

This section of the article focuses on the opportunities for cooperation between active HPC providers and the branches of automotive and electronics industries in Bulgaria.

The automotive industry is one of the fastest growing industries in the country. Approximately 170 companies operate in Bulgaria, producing components and systems for the leading international automotive brands. The total revenue generated by the automotive industry in 2017 was close to Euro 2.5 billion and represents 5 % of Bulgaria's GDP. (Economic.bg, 2018).

The opportunities for HPC application in the automotive industry has been discussed actively over the last years. For example, an international Conference in Sofia on HPC Support for R&D in the Automotive Industry discussed several key parameters for HPC Simulation. Among them are Cost & Time Reduction at the

Design, Development, Production, Marketing Phase and Maintenance Phase. The following traditional technical challenges for HPC have been on the agenda: Computational Fluid Dynamics; External Flows; Internal Flows; Structural Mechanics; Crash; Stability; Combustion; Chemical Processes and Reacting Flows, etc. (Resch, 2013).

During the large-scale International Conference Automotive Forum Sofia 2018, major topics of discussion covered Electric mobility of the Future; Aluminium Battery Cases for Electric Vehicles; Automotive Technologies from the Future, etc. (Automotive Forum Sofia, 2018).

The electronics industry in Bulgaria has experienced steady growth, as production volume increased almost 4 times from 2000 to 2010. In 2010 the revenues were over Euro 1.5 billion, which is the highest level since 1990. Currently the industry, which includes Information Technology and Electrical Engineering and Electronics, employs about 45 000 people in 2300 companies. The sector has been developed on the basis of an ecosystem of multinational and local firms (Website of Invest Bulgaria).

The electronic industry in the country is generally export oriented. Approximately 75% of the products are for export (Electronic manufacturing in Bulgaria, 2017).

With a few exceptions, the firms are branches of foreign companies. This situation with the ownership explains the relatively low level of applications of HPC in their work since the relevant HPC simulations and other R&D activities are done as a rule abroad.

Briefly, in spite of comparatively well-developed HPC infrastructure in Academia, the level of interrelation and cooperation between the HPC providers and the industry is a task that still needs to be resolved.

According to the benchmark, conducted within InnoHPC project, Bulgaria along with Croatia, Moldova, Montenegro and Romania is among the HPC underdeveloped countries in the Danube region (InnoHPC project High-performance Computing for Effective Innovation in the Danube Region, 2018). The major reason of this relatively low level of cooperation is the limited needs and competences in the companies for using HPC. Another reason is the strong presence of foreign companies, which usually do R&D in their home countries.

4. **HPC Benchmark**

This part of the article builds on the description of the general HPC situation in Bulgaria, presented in the previous sections, and goes deeply in the analysis of the Strengths, Weaknesses, Opportunities and Threats (SWOT) related to the use of HPC applications in the country.

The analysis is based on the data collected via interviews and workshops carried out by REGLO with experts from the national HPC centres and potential users from automotive and electronics industries. The results are structured using SWOT analysis. Table 1 summarises the main strengths, weaknesses, opportunities and threats with respect to the use of HPC in the automotive and electronics industries in Bulgaria.

Table 1: Strengths, Weaknesses, Opportunities and Threats related to the use of HPC applications in Bulgaria

Strengths	**Weaknesses**
• Strong HPC infrastructure is available in the Academia. Bulgaria has a state-of-the-art supercomputer Avitohol with appropriate software available on it. • Bulgaria has experts with very good knowledge of HPC, with experience in development and use of HPC applications. • Several dozen specialists from the software industry have been trained to work with high-performance multiprocessor systems. • There is a tradition in using HPC, mostly in Academia. Efforts to disseminate knowledge, funding opportunities, etc. towards industry are performed within the context of many EU and national research projects. The Bulgarian academic institutions are well positioned in Europe, being members of relevant strong consortia in the field. • There are many investors in the automotive and electronics industries, e.g. the members of the Automotive Cluster Bulgaria and Electric Vehicles Industrial Cluster Bulgaria, which are leaders in industrial R&D and innovation. • On the national level, many networks exist. For example, ICT cluster Bulgaria, the Bulgarian Branch Chamber - Machine Building, etc. On the European level, active are SESAME network, FORTISSIMO, ETP4HPC, HiPEAC, etc. • There are some good practices of innovative training/learning in HPC, which could be followed. The IICT-BAS organizes suitable HPC courses and HPC training with invited lecturers from abroad. • Ambitious national programs for support of HPC providers and for intensification of the HPC applications in the industry.	• There are still few industrial companies that effectively cooperate with Academia in the area of HPC. • The price of HPC is still high for the Bulgarian Academia and industry (very high licensing costs). • There exists weak demand of HPC services from the industry because most foreign companies implement R&D in their countries. • Sporadic efforts are being made to assist and encourage businesses to use the European supercomputing infrastructure. • Many of automotive and electronics companies do not have R&D departments in Bulgaria to create innovative products. • Insufficient level of education does not allow enough practical skills. • Micro, small and medium-sized businesses are facing difficulties in securing funds for investments in innovation and technology. • The national networks are not closely linked to the European ones. The HPC in industrial R&D is still not among the main priorities of the national networks. • There is a lack of national innovation ecosystem based on innovation and technology infrastructure, such as Science/Tech parks, incubators/accelerators, Experimental Research and Innovation Infrastructures, e.g. Smart City zones, etc. • The mismatch between business needs and interests of the universities.

Opportunities	Threats
• There is a centralized channel (National Contact Points, Ministry of Education and Science) for collection, processing, and dissemination of information related to HPC opportunities at national and European level. • The HPC can be used in several scientific areas that Bulgaria has good potential for development such as earth sciences; weather forecast; Nano-technology and Nano-sciences; fundamental research in low-dimensional materials, like graphene; quantum information – quantum computing, etc. • Pan-European Research Infrastructure on High Performance Computing (HPC – Europe) established a strong international network that inherited many connections between the major stakeholders. • Bulgaria has a national policy in the field of technological innovations for the period 2014-2020. • There is a National Strategy for Smart Specialisation. • Technology transfer offices were established. • Open calls from the National Innovation Fund target cooperation between industry and science. • The long-term objectives of the central and local governments focus on achieving smart growth, especially regarding research and innovation. • There are high-tech factories and plants for the production of engine parts, chassis, braking systems, electronic components and seals, mainly built with foreign investment combined with the potential of local engineers and IT developers, and lower production costs.	• A handful companies in Bulgaria are highly developed to need HPC applications. In order to implement HPC in industry, it should be developed (for instance, Airbus branches in France and Germany use the most developed HPC centers to solve various problems starting from fuel consumption optimization to new wing profiles). • Lack of sustainable financial support for R&D and innovation in Bulgaria, including HPC applications. • Some strategic decisions are made on a short notice, without sufficient feedback from the society and without taking into account the opinion of the Academia. • Poor cooperation among national stakeholders in the HPC; • Low level of education and insufficient number of IT specialists; • Lack of adaptive capacity and flexibility among existing clusters and networks to the rapidly changing environment.

The results from the SWOT analysis of the data presented in the table 1, leads to the following conclusions.

First, despite all difficulties for innovation development, Bulgaria has a national policy in this field, including an ambitious program for development of the HPC in the country.

According to the strategic documents for the period 2014-2020, the administration is focussing the attention on the development of the innovation potential in the areas leading to competitive advantages and increasing the benefit of domestic products and services. In addition, Bulgaria has a National Strategy for Smart Specialisation with clear priorities, including ones related to HPC, e.g. ICT and Mechatronics.

Second, Bulgaria has good potential for development of HPC in several scientific areas such as earth sciences, weather forecast, Nano-technology and Nanosciences, fundamental research in low-dimensional materials, like graphene, quantum computing, etc. In addition, many business clusters and academic networks exist at national and EU levels that can promote the advantages of HPC applications in the industry. Many Bulgarian researchers have been educated and trained in internationally recognized HPC centres.

Third, there are many investors in the automotive and electronics industries, e.g. the members of the Automotive Cluster Bulgaria and Electric Vehicles Industrial Cluster Bulgaria, which are leaders in industrial R&D and innovation, including Industry 4.0. Some good cooperation lines with Academia have been established, e.g. in Sofia, Plovdiv, Varna and Ruse.

Fourth, the biggest issue with respect to the HPC application in the industry is related to interrelation between the HPC providers and the potential users. Currently the extensive use of HPC is still not in place in the automotive and electronics industries. There are opportunities, but they are not fully utilized. The HPC is partially used in the finance – banking & trading, as well as for movie rendering and game development. The organizations using HPC are still restricted mostly to a number of academic institutions. Currently, about 1-2% of the companies are interested in accessing HPC services, mainly from the ICT sector.

However, the demand for HPC applications from the business organizations is fast-growing, e.g. in relation to the needs of big data analytics, simulations and real-time data processing.

The shared opinion among experts was that the relatively low technological level of the enterprises in Bulgaria, both in the automotive and electronics industry, is the major obstacle hindering the use of HPC in the industry. There is low innovation activity of companies in the country because of insufficient cooperation between business, Academia and the universities, small as volume and inefficient investment in R&D and innovation, and lack of adequate environment and infrastructure for innovation. Other relevant factors are the low quality of education at all levels of the educational system and the massive emigration of the best-qualified young IT specialists. Finally, yet importantly, the price of HPC services is still high for the SMEs.

Fifth, enhancing interrelation between public authorities, technology transfer offices and business is the crucial point in the implementation of national innovation policy for the development of HPC. The experts were unanimous that the lack of coordination and cooperation among different stakeholders is one of the main obstacles for the development of the Bulgarian innovation system. The existing system of administration, intermediary organizations and business do not work in conjunction. In addition, there is no synergy in the work of the administration responsible for the economy development and for the education. Therefore, the experts maintain that it is necessary to strengthen the innovation capacity of the enterprises and development of an environment for research and innovations by supporting existing and effective structures and organizations.

The prospects of the introduction and the use of the HPC applications in Bulgaria mostly depends on the implementation of national innovation policy and action plan, as well as boost of R&D in the field of high tech in the country. The long-term objectives still need refinement in relation to building a national R&D and innovation ecosystem, closely linked to the European one.

Sixth, among the most important threats for the development of HPC in Bulgaria are: 1) lack of effective national policy, strategy and action plan for innovation and R&D; 2) continuing trend of low innovation index and low technological level of the Bulgarian enterprises; 3) insufficient financing for the national science and technology structures, as well as innovative SMEs; 4) low quality of education and the massive emigration of the best qualified young IT specialists, and 5) lack of coordination and cooperation among different stakeholders.

5. Digital transformation of the Bulgarian Industry: current state and recommendations for improvement

The situation with the current achievements in digital transformation of the Bulgarian industry is not favourable. According to the Digital Economy and Society Index (DESI) 2018, Bulgaria occupies 26th place out of the 28 EU Member States in the ranking of digitalization progress in the EU. Overall, Bulgaria has retained its ranking from last year with some slight improvements to its score. Compared to 2017, Bulgaria made progress in connectivity and the availability of digital services. In particular, digital public services improved, resulting in an increased number of e-government users. Bulgaria's main challenges relate to the very low level of digital skills among its citizens and the low integration of digital technologies by businesses (Digital Economy and Society Index, 2018).

The problem with the delay in the process of digitalization in Bulgaria could be resolved by implementing several tasks and undertaking some practical steps that are summarised in the following rows.

The first task is related to enhancing digital connectivity. This means to increase the number of the broadband subscribers; to foster the subscriptions for mobile broadband; to accelerate the 4G coverage; to increase the take-up of fixed broadband; to give priority to the deployment of broadband in rural areas; to follow the European call for the deployment of 5G networks; and to make the best of the European data.

The second task is to upgrade the human capital. To implement this task, Bulgaria has to make digitalization of the economy a part of the educational mainstream; to raise the share of the STEM (Science, Technology and Mathematics) graduates; to legally regulate and recognize the training provided by the IT companies for students; to support personal and institutional initiatives for acquiring digital skills; and to make digital trainings obligatory part of the professional development.

The third task is to foster the use of Internet in the country. The implementation of this task means to accelerate the development of the infrastructure for Internet banking; to carry out educational programs on Internet shopping; to intensify the use of music, videos and games via Internet.

The next task is related to integrating digital technologies in the business sector. This means to support the SMEs selling via Internet; to promote the use of cloud computing by the enterprises; and to provide incentives for increasing the e-commerce turnover.

Finally, yet important task is related to digitalizing public services. There are several steps that need to be undertaken in order to implement this task: 1) to follow strictly the Roadmap for implementation of the Strategy for the Development of e-Government for the period 2016-2020; 2) to continue the homogenization of the legislation and the policies in the field of electronic governance; and 3) to consequently combine the development of Open Data policies with the policies and practices for data protection and robust cyber security.

6. Conclusions

This article discussed recent developments of HPC applications in Bulgaria and the interrelations between HPC providers and the industry with particular focus on automotive and electronics.

The biggest difficulty in this regard is the transfer of well-developed academic ideas into the industrial praxis. This is a problem, which was often discussed during the expert interviews and seminars, and it is related to technological underdevelopment, scarcity of financial resources and low level of awareness regarding benefits from the application of HPC in the automotive and electronics industry.

The study identified some of the most important strengths, weaknesses, opportunities and threats with respect to the use of HPC applications in the country. Obviously, there is room for improvement, but in the same time, there are some positive developments.

To be precise, the traditions in HPC in Bulgaria, the comparatively well-developed infrastructure in the Academia and the will on behalf of the state institutions, gives ground to anticipate real prospects for the country to become a HPC hub in SEE. Of course, this very promising development requires hard work at all levels of organizational structures and enhanced cooperation among the stakeholders in the field.

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National Case Study for Croatia

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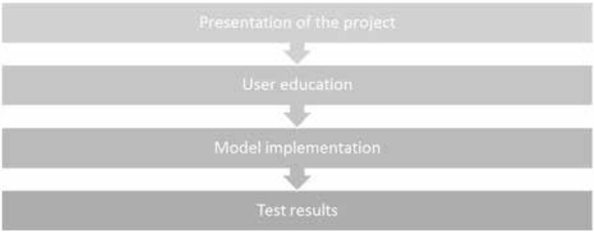
Abstract: In this paper, two examples of utilizing HPC for industrial purposes are described. The first example is describing procedure of HPC-based car modeling and simulations. This modeling is performed in collaboration with Rimac automobili, Croatian automotive company. The second example is HPC-based vehicle route optimization. This optimization is performed in collaboration with OmniOpti, Slovenian software company. In both cases, significant boost of performances can be noticed if HPC is utilized.

Keywords: modeling, simulations, HPC

1. Introduction

In recent years, numerous projects were performed with aim to utilize HPC for solving various complex problems in science and industry [1–13]. All projects have begun with project description and presentation. After determining project goals, users from industry or scientific institutions are educated for HPC usage. Education is performed with aim to optimize HPC programming process. After education, users have implemented models and/or algorithms into HPC. Software solutions implemented on HPC are then tested. Tested results are than compared with real data or conventional computer models, as shown in Figure 1.

Figure 1: Project execution process



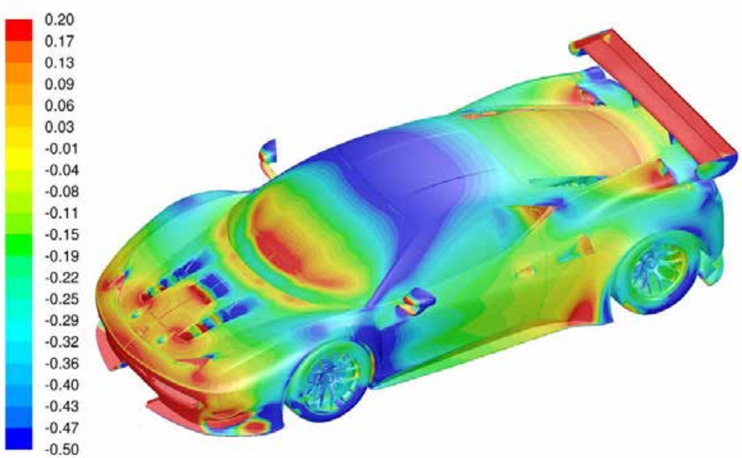
In this success story, two examples of implementing HPC for solving problems in industry are presented. First, collaboration with Rimac automobile industry is presented. The second example is one of the HPC usages in vehicle route optimization.

2. Rimac Automobili

2.1. Problem Description

Rimac Automobili is a Croatian company for the production of electric vehicles founded in 2009. Rimac Automobili has developed and introduced the electric car, Concept One, which later went into serial production [14]. When designing a new version of this car (Concept Two), the need for HPC modeling and complex simulations of the new car model.

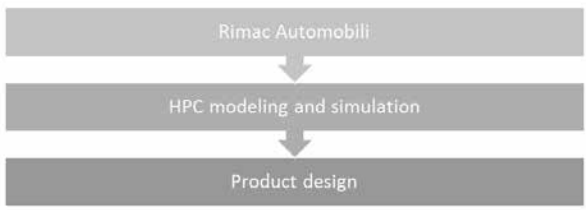
Figure 2: Example of HPC-based car modeling



2.2. Solution

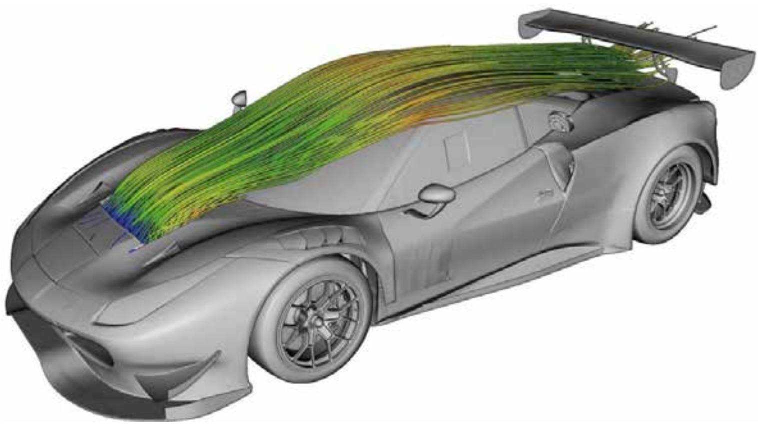
Simulations of the new car model were performed on the HPC in order to get the optimum design of the car with respect to the airflow when driving at different speeds. HPC simulation provides results closer to the real driving performance than those obtained through the use of conventional computers. Examples of such simulations are shown in Figure 2 and Figure 4.

Figure 3: Process of HPC utilization in collaboration with Rimac Automobili



When executing complex simulations of a new car model, open source software solutions were used, which enabled good integration of complex simulation models with HPC architecture. HPC utilization process is shown in Figure 3.

Figure 4: Example of HPC-based car aerodynamics modelling



3. OmniOpti

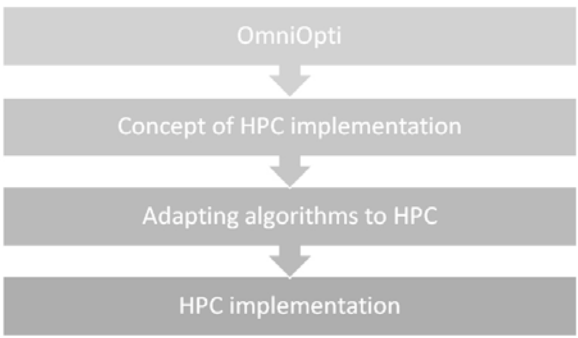
3.1. Problem Descriptio

Nowadays, rising trend of trading in goods can be noticed. Modern era companies are aiming to maximize their profit by utilizing more cost effective trade and transport systems. One approach is to use complex computational systems and optimization algorithms. Optimization algorithms are often too demanding for classical computer structures, so the application of high-performance computers imposes itself as a possible solution. One part of this problem is a delivery vehicle route optimization problem [15]. OmniOpti, company that is performing optimization of delivery vehicles routes, has approached us to examine the possibility of applying HPC to optimize the route of delivery vehicles and examine the cost-effectiveness of the whole process. The main challenge in solving this problem by using HPC was to adapt existing algorithms to format that can be used in HPC. All algorithms used for vehicle route optimization problem where written sequentially in Java. For these reasons, the solution for converting existing vehicle route optimization algorithms.

3.2. Solution

As a first step in adapting the existing optimization algorithms written in Java to be executed by HPC, an automated approach using the existing libraries has chosen. This is achieved by using Java2Python library for converting code written in Java into Python code. As addition to this software, Pydrone library is used for semi-automated code parallelization. Alternatively, an approach with creating new optimization algorithms by using OR-Tools. OR-Tools is a library created by google and it can be used for creating various optimization algorithms in Python, C++, C# and even Java.

Figure 5: Process of HPC utilization in collaboration with OmniOpti



Possibility for using HPC for vehicle routing optimization problem is tested at University of Rijeka. Utilization process is shown in Figure 5. Obtained results have shown that there are various possibilities for using HPC in vehicle route optimization and that the best results are achieved if optimization algorithms proposed by OmniOpti are utilized. Using HPC for vehicle route optimization problem will enable the use of faster and cheaper delivery systems.

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National Case Study for Czech Republic

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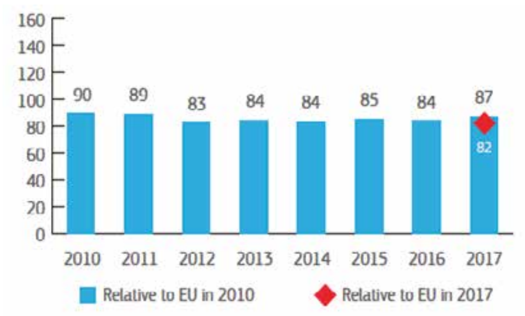
Abstract: Despite the fact that HPC technologies are rather new in the Czech Republic and their uptake by companies, especially by SMEs, is not that high, those technologies are seen as a very important not only by those who are currently using them but also by the Czech government. HPC is seen as one of the main pillars of the digital transformation of the Czech industry and as such receives more attention and support not only from European Commission but also from national governments including Czech government. This forms a good basis for bigger expansion and utilization of the HPC technologies among the companies, especially the SMEs, in the Czech Republic in their Research & Development activities as well as a tool for innovation of their products and services.

Keywords: Czech Republic, HPC case study Czech Republic, InnoHPC project

1. Overview of country innovation performance

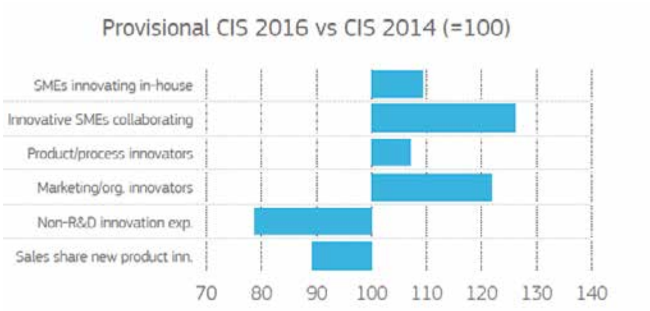
The Czech Republic in term of the innovation performance is seen as a moderate innovator [1]. Country innovation index declined over the time relative to that of the EU in 2010 (see Figure 1 for reference [1]).

Figure 1: Country innovation index over time [1]



Among the strongest innovation dimensions belongs employment impacts and company investment. On the other spectrum, finance and support, and intellectual assets ate the weakest ones. Provisional CIS 2016 data show improved performance for four indicators and reduction of performance for two of them comparing to 2014 (see Figure 2 [1]).

Figure 2: Provisional CIS 2016 data [1]



2. Appraisal of HPC situation

There are several public institutions operating High Performance Computing (HPC) and grid infrastructure in Czech Republic. IT4Innovations national supercomputing center [2], CESNET – MetaCentrum [3] and CERIT-SC [4].

The IT4Innovations national supercomputing center, VSB – Technical University of Ostrava is the only public center providing services to researchers from both academia and industry as well is. The other HPC systems are either owned by private companies for their internal use (SKODA Auto [5]) or systems available only for academicals research [3] [4].

2.1. Public HPC providers

IT4Innovations national supercomputing centre is the strategic research infrastructure in the Czech Republic. In the framework of the National supercomputing centre, the most powerful supercomputing facilities in the Czech Republic are being built and excellent research in HPC technologies is performed. The mission of the centre is to deliver scientifically excellent and industry relevant research in the fields of HPC. IT4Innovations research activities are distributed into 5 laboratories:

- Parallel algorithms research lab
- Advanced data analysis and simulations lab
- Modelling for nanotechnologies lab
- Big data analysis lab
- Infrastructure research lab

IT4Innovations is part of the National Roadmap for Large Infrastructures for Research, Experimental Development and Innovations prepared by the Ministry of Education, Youth and Sports of the Czech Republic, as one of the three large e-infrastructures in the country. IT4Innovations currently operates two supercomputers, Anselm (94TFLOPS, installed in summer 2013) and Salomon (2PFLOPS, installed in summer 2015). Besides operating the infrastructure and offering its resources, IT4Innovations provides regular training for the HPC community and offers MSc and PhD studies in the field of HPC.

Services provided by IT4Innovations comprise from renting of computational cycles, through contractual research to the collaborative research and helping companies, especially SMEs, to search for opportunities to fund research activities from national and international grants. IT4Innovations also organizes trainings and workshops available for participants from industry. IT4Innovations has joined ETP4HPC (European Technology Platform in the area of High-Performance Computing) [6] and represents the Czech Republic in the European research infrastructure PRACE (Partnership for Research and Advanced Computing in Europe) which is the unique institution joining national supercomputing centres in Europe [7].

CESNET – MetaCentrum is grid infrastructure operated by CESNET Association. It comprises numerous computing clusters located at several sites and belonging to different subjects (CESNET owns about half of MetaCentrum machines). All are integrated into a unified environment with a common management of users and tasks. MetaCentrum offer users own developed programmes and tools for development as well as a wide range of commercial programmes from different scientific fields (e.g. chemistry, biology, mathematics, technology). The service is limited to the research purposes of academic staff and students of research institutions in the Czech Republic.

The national **Center CERIT-SC** (CERIT Scientific Cloud) offers storage and computing resources and related services, including support for their experimental use. Center CERIT-SC is created through transformation of the Supercomputing Center Brno (SCB), a part of the Institute of Computer Science (ICS, ÚVT in Czech) at Masaryk University (MU). Within the context of the national e-Infrastructure, Center CERIT-SC focuses on the highly flexible real time computing and storage resources provision. The virtualized computing and storage resources, available through novel interfaces combining grid and cloud environment, represent unique installation in the Czech Republic and even in the Central Europe and eventually even larger region. Center CERIT-SC offers two kinds of storage resources: High-capacity data storage (Hierarchical Storage Management, HSM) and Shared networked storage depot for work data. Development, management and operation of these storage resources are the responsibility of the Data Storage activity. Clusters of two kinds represent the computing resources of the Center: SMP (Symmetric MultiProcessing, nodes with more than 64 cores in with shared memory each) and HD (High Density, nodes with usually 20-16 cores sharing a single memory). Center CERIT-SC is also involved in the building of the European Grid Infrastructure EGI.

2.2. Use of HPC technologies by industrial sector

Uptake of HPC technologies by R&D in industrial sector is relatively low in Czech Republic. Companies which has experience with using HPC technologies are those recruiting from large multinational companies. Those companies are using either their own systems or systems shared by whole holding.

Many SMEs in the Czech Republic are not aware of the HPC technologies and how they could benefit from their use. The main obstacle in term of higher uptake of HPC technologies by SMEs in the Czech Republic is the fact that majority of those companies lack necessary capabilities in term of knowledge not only how to use HPC but also how to use techniques such as numerical simulation and modelling into their daily life. Another issue is that investment into R&D by SME is rather low, despite incentives from government.

3. Innovation actors active in HPC

HPC system in the Czech Republic are mostly available to the large multinational companies such as SKODA Auto [5], Varroc [8] or Hannon [9] to name just few. Those companies use HPC systems to innovate their product by performing numerical simulations using Computational Fluid Dynamic (CFG) of Computational Structure Dynamics (CSD) methods. Access to HPC for Small and Medium Enterprises (SME) is available only through IT4Innovations national supercomputing center which is the only public centre providing services to researchers from industry. With two cutting edge clusters, Anselm and Salomon, third system will be installed in first half of 2019, and five research labs covering a wide range of relevant areas; advanced data analysis, big data analysis, infrastructure research, modelling for nanotechnologies, and development of parallel algorithms and their use for industrial applications. IT4I as a Digital Innovations Hub [10] is well equipped and positioned to be a mayor innovator in the HPC in the Czech Republic. IT4I unique combination of technology, infrastructure experts, and researchers focused on the application of said technology to real world problems allows it to create truly bespoke solutions to today's problems.

4. HPC Benchmark

4.1. Application of HPC in industrial R&D in the Czech Republic

Uptake of HPC technologies by SMEs in automotive and electronic industry sectors in the Czech Republic is negligible. The reason is that majority of SMEs are manufacturing companies without R&D ambitions, or companies providing services to the large companies or car producers. Another reason is that HPC technology is relatively new to the companies in the Czech Republic. First HPC centre, IT4Innovations national supercomputing center, was established in 2011. That is the reason why that even companies which use computers and numerical modelling and simulations as a part of their R&D process don't have experts with sufficient knowledge in HPC. Another issue related to the lack of the knowledge and expertise is that SMEs don't see opportunities which HPC technologies brings despite the fact than they are able to identify their needs. Since IT4Innovations is very well established within HPC community on the international level and such could bring this technology to the companies. There is a big potential in applying of HPC technologies for those companies who are using numerical modelling and simulation as a part of their R&D processes. There are several success stories from other industrial sectors which serve as an example for SMEs in automotive and electronic industry how HPC could be employed.

4.2. Awareness raising

Information about HPC technologies, how those technologies could be employed by companies together with best practice guides and training courses are disseminated by IT4Innovations to the all stakeholders in the Czech Republic. IT4Innovation as a member of Partnership For Advanced Computing in Europe (PRACE) has access to the network of European HPC centres and such access to the information, best practice guides and training courses. Appropriate channels are used to reach different target groups. General public is targeted through social media and various events organized atIT4Innovation premises. Companies are informed about funding opportunities, potential collaborators and new technologies at events and during face-to-face meetings.

4.3. Application of advanced ICT for R&D in enterprises from automotive and electronics industries

Majority of SMEs in automotive and electronic industry in the Czech Republic are manufacturing companies without R&D ambitions, or companies providing services. Only the large companies are active in R&D, but in lot of the cases R&D activities takes place outside of the Czech Republic. Manufacturing companies are using ICT tools for their manufacturing processes. Advanced ICT tools such as CAD software or simulation packages are used by companies which design their own product. In the automotive industry, innovative trends of the last decade consist of employing advanced ICT technologies and using of new materials. New materials are used either to reduce cost or weight of the component.

Application of HPC technologies in automotive industry is limited only to the large companies who could afford to buy hardware and have trained employees. IT4Innovations provide access to HPC technologies to the SMEs but its main role is in serving researchers and scientists. As such majority of the HPC application and utilization is towards non-applied, or basic, research. Only small part of the computational capacity is dedicated towards applied research for collaboration between academia and industry, or for industry itself.

4.4. Capacity for attracting and retention of talents

The shortage of people with technical skills and expertise is a topic of discussions on national level for decade. Companies regardless of their size are calling for changes in educational system to address this issue but only little has been done so far. Technical universities are collaborating with companies on creating new study programs targeting required areas of interests. Together with companies, topics for final thesis and internships are offered to the students. But those initiatives are not sufficient and changes in higher educational system on the national level are needed.

Many companies are recruiting workers from abroad (countries such as Poland and Ukraine) but those are mainly for blue collar positions. There is no mechanism on the government level for attracting talented people. All the initiatives are left to the individual organisations, this applies for universities and research organisations as well.

Situation with capacity to retain talented people is very similar to the capacity of attracting talented people. There is no system per say on the government level, although there was an initiative several years ago to encourage talented Czech researchers and scientist to come back and create new research teams and pursue their research at Czech Universities or research institutes. There is no housing policy on government level, housing is left to the free market.

Because of shortage of people with technical skills and expertise, it is very difficult for SMEs to retain their best employees. Large companies could offer higher salaries and other benefits to the extend which SMEs could not afford. This situation is even more eminent for IT experts because those are wanted not only in automotive and electronic industry but also in ICT sector.

4.5. Role of globalization in adoption of HPC technologies in the Czech Republic

HPC is one of the new technologies which could be accessible from anywhere. All highly-developed countries around the world are investing into HPC which makes this technology more accessible even for SMEs. Those companies could use HPC without necessity of high investment. New technologies bring new opportunities and new markets for the companies. On the other hand, it puts pressure because they must be very responsive in term of adoption of new technologies to be able to keep up with the demand of the global market. The main challenge for SMEs in the Czech Republic is to get and retain experts who could keep up with newest trends. Through IT4Innovations SMEs have access to the several networks of HPC providers and experts such as Partnership for Advanced Computing in Europe (PRACE) or Supercomputing Expertise for Small and Medium Enterprises (SESAME Net) and High-performance Computing for Effective Innovation in the Danube Region (InnoHPC).

4.6. Role of the public authorities in HPC

Support for HPC technologies from government of Czech Republic is dated to 2011 when IT4Innovations national supercomputing centre was established. This centre was funded from the European funds, particularly the Operational

Programme Research and Development for Innovations (OP RDI). Between 2011 and 2015 The IT4Innovations Centre of Excellence project was co-implemented by the following 5 partners: VSB-Technical University of Ostrava, University of Ostrava, Silesian University in Opava, Brno University of Technology, and Institute of Geonics of the Czech Academy of Sciences. At present, the cooperation of these partners is continuing in the form of the IT4Innovations Excellence in Science project funded from the National Sustainability Programme II (NSPII), within the frame of which we are continuing in conducting excellent research in the field of supercomputing and embedded systems.

In 2018 Czech Republic has signed the EuroHPC declaration, becoming the 14th country to participate in the joint national and European effort to build together world-class computing and data infrastructures in Europe [11].

In the EuroHPC Declaration [12] describes agreement of countries to work together with the European Commission on acquisition and deployment of cutting edge HPC infrastructure. This infrastructure will be available for scientists from academia as well as from public and private sector across Europe. The EuroHPC infrastructure will raise Europe's capabilities and competitiveness.

4.7. National innovation policy

National innovation strategy (NIS) [13] of the Czech Republic was established on the basis of Government Resolution No. 77 on 26 January 2011. In this resolution Minister of Industry and Trade and Minister of Education, Youth and Sports were required to elaborate NIS as an integral part of the strategy of international competitiveness of the Czech Republic. The proposed NIS is based on the recommendations of the European Innovation Union Strategy [14], to support knowledge-based innovation activities in Member States, excellence in research, quality education and training activities, as well as the innovation activities carried out by the industry. NIS consist of four pillars comprising excellent research, cooperation between the business and research sectors in the transfer of knowledge, supporting innovative entrepreneurship and people as the bearers of new ideas and initiators of change. Specific measures for the NIS are elaborated in more detail in the project intentions within the pillars of the International Competitiveness Strategy. As a part of the measures mentioned above Innovations centres such as Moravian-Silesian Innovation Center (MSIC) [15], South Moravian Innovation Center (JIC) [16] or Central Bohemian Innovation Center (SIC) [17] were established by local governments as a part of the regional innovation strategies.

Research and development activities on the national level are supported by Czech government through several channels.

- There are two grant agencies
    - Czech Science Foundation (GACR - for basic research)
    - Technology Agency of the Czech Republic (TACR - for applied research)
- Grants on national level from by ministries
    - Ministry of Education Youth and Sports
    - Ministry of Industry and Trade
    - Ministry of Health

5. Recommendations

"Digital Transformation of Industry Guidelines" presents the recommendations for accelerating the digital transformation of the Czech Republic. Průmysl 4.0 (Industry 4.0) [18]

is a national initiative aiming to maintain and enhance the competitiveness of the Czech Republic in the wake of the Fourth Industrial Revolution. The concept was firstly presented during the 57th International Engineering Fair in Brno, September 2015 and approved by the Government of the Czech Republic on 24th August 2016. The Ministry of Industry and Trade plays a key role in the implementation process, however, there is a strong interdisciplinary cooperation between the ministries, social and industrial partners and academia [19].

The goal is to prepare not only the industry but the whole society for the economic and societal changes related to the fourth industrial revolution. P40 has a wide focus on the creation of business and social environment, in which the Czech economy can reach its full potential. At the same, the initiative aims to mobilise private sector, R&D and industry associations, and academia to actively participate in the implementation process [19]. The main points of Industry 4.0 initiative are listed in Table 1.

Table 1. Main points of the Industry 4.0 initiative

Digital transformation of Industry Guidelines at national level: Czech Republic	
Industry 4.0	Reskilling of workforce: new skills for Industry 4.0
	• To increase flexibility of labour market • To promote and support entrepreneurship, start-ups and spin-offs • To create system of complex monitoring of new jobs • To enhance educational and retraining system
	Stimulate applied research in new areas
	• To strengthen support of applied research by concentrating support for larger projects • Create new models for finance support of applied research with higher involvement of private funds • Create new evaluation system of research outputs suitable for applied research
	Accelerating of uptake of new technologies
	• To promote interdisciplinary theoretical R&D • To promote creation and operation of infrastructures for fast prototyping (FabLab, TestBed) • To promote joint ventures of companies and research organisations • To promote transfer of technologies from R&D institutes and companies • To promote R&D at companies
	Changes in educational system
	• Implement new trends and technologies (e-skills, IoT, IoS, IoM, robotics) into educational system on all levels • Intensive use of modern technologies (multimedia, interactive mobile applications, augmented and virtual reality, serious games) • Creation of new study cross disciplinary programs at universities (combination of engineering, IT and elector engineering subjects) • Creation and implementation of new financial model to increase private funding of educational activities
	Standardisation of technical norms
	• To be more involved in international bodies CEN, CENELEC, ETSI • Create advisory board at Czech Office for Standards, Metrology and Testing for Industry 4.0 • Involve experts from industry into standard preparation process • Increase availability of the standards for companies

6. Conclusion

Despite the fact that HPC technologies are rather new in the Czech Republic and their uptake by companies, especially by SMEs, is not that high, those technologies are seen as a very important not only by those who are currently using them but also by the Czech government. HPC is seen as one of the main pillars of the digital transformation of the Czech industry and as such receives more attention and support not only from European Commission but also from national governments including Czech government.

This forms a good basis for bigger expansion and utilization of the HPC technologies among the companies, especially the SMEs, in the Czech Republic in their Research & Development activities as well as a tool for innovation of their products and services.

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National Case Study in the Danube Region: Germany

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Abstract: This paper will conceptualize the national case study of Germany and outline forthcoming interdisciplinary research program. Germany has a leading role in the EU HPC-Community on the level of its economic development. It is concentrated in the Gauss Centres for Supercomputing (GCS), and provide both the European Tier 0 level Centres of HPC and the German National Tier 1 and Tier 2 level. Our main research was focused on HPC in automotive and electronic industry. In the paper are presented workshops' objectives of the research, main information's that we obtained from interviews and main recommendations of Industry Guidelines for Germany, based on the European Industry Guidelines. As we see the objective is the dissemination that German HPC infrastructures, competencies and web platforms are providing HPC access, integrated services, capacity building tools, and sustainability toolkit, to support durability of the final product of InnoHPC project.

Keywords: HPC case study Germany, Gauss Centres for Supercomputing, automotive industry, electronic industry, European Industry Guidelines, InnoHPC project

1. Overview of country innovation performance

This paper will conceptualize the national case study of Germany and outline forthcoming interdisciplinary research program. Europe is one of the worlds' centres of innovation. For European innovation strategy this means three objects: additional social innovation, more Europe and more organization. "Further development begins with a considerable strategy for the future, but should also be reflected in the economic success of Europe. Last was always embedded in functioning welfare systems" (Buhr & Stekhen, 2018, pp. 5). Principally when it comes in Europe to the digitalization of industry, it must be built upon a solid foundation. “The term Industry 4.0 has become equal for the industrial production of the future of Europe” (Buhr & Stekhen, 2018, pp. 3). Politicians should be conscious of the possibilities that a market for Industry 4.0 became leading, and they should work together to take a leading role in terms of methodical, but also common principles. The present research demonstrates what is Germany doing on the European level in order to use the potential of Industry 4.0 – especially High Performance Computing and the portray is focused on national programmes which support Industry 4.0. Germany belonged to the countries with the highest proportion of industry, and was the first country bellow European Commission that organised the first stakeholder forum under the slogan “Digitising European Industry” (Essen, January 2017) (Buhr & Stekhen, 2018, pp. 12).

2. Appraisal of HPC situation

Germany has a leading role in the EU HPC-Community on the level of its economic development. It is concentrated in the Gauss Centres for Supercomputing (GCS), and provide both the European Tier 0 level Centres of HPC and the German National Tier 1 (firms are the largest, wealthiest, and most experienced in the industry) and Tier 2 level (Mid-tier companies are still key players in the construction industry) (A portal open to German HPC centres, 2019). A number of medium-sized Centres are also organized in the Gauss Alliance (GA). One national Centres is positioned at Garching near Munich (LRZ) and the other in Stuttgart (HLRS). The third is Juelich (JSC) in North Rhine-Westphalia (Forschungszentrum Jülich – JSC, 2019). Together form Funding sources and management of HPC Centres are contributed by GCS and by the German Ministry of Education and Science (BMBF) (High Performance Computing in EU, 2018, pp. 123).

The BMBF is investing 100 million over 5 years for the D-Grid project to support HPC scientific collaborations especially in Danube region, and Germany contribute in resources to the PRACE programs. GCS represents Germany in the PRACE alliance and provides three of the current six Tier-0 systems of PRACE (High Performance Computing in EU, 2018, pp. 123; Joseph, 2015; PRACE Research Infrastructure, 2019; The High-Tech Strategy for Germany, 2019; Tier sites of the Worldwide LHC Computing Grid; 2019; Topology of the Worldwide LHC Computing Grid, 2019).

HPC in this strategic context is stared as main and very well developed need for technology developments aimed at scientific, technology leadership, and the integration of novel services. The Performance of supercomputing in Germany is presented by the market for HPC and has increased its presence on the global supercomputing stage, having unveiled one of the world's largest high-performance computing sites in the last few months and dedicating much of the country's HPC power to scientific research (KONWIHR, 2019).

With **the Gauss Centres for Supercomputing and the Gauss Alliance,** the structure of the German HPC Centres offers users from all scientific areas access to HPC (Gauss Centre – HPC Services – The Visualization Centres of GCS, 2019; Exception – HPC in Deutschland – Gauß-Allianz, 2019). They serve a wide range of industrial and research activities in various disciplines such as medicine, aeronautic, military sectors etc., with the specific consideration to the automotive and electronic industries and world-class computing and networking infrastructure. Each Centre (GCS) hosts supercomputer systems in the **multi-petascale performance range,** placing all three individual GCS institutions amongst the most powerful computing Centres in the world (in total, computing power of more than 20 Petaflops quadrillion performance operations per second is available) (MERIL, 2019; Europe's fastest supercomputer unveiled in Germany, 2019)

Availability of HPC can be addressed and rang from parallel programming paradigms, via dynamic load distribution, to energy-awareness, and scalability of algorithms and application.

It can be briefly mention that LRZ in Munich, houses the **SuperMUC** system (LRZ: SuperMUC Petascale System, 2019), which began operations in 2012 at a processing speed of 3 petaflops (CINECA - HPC portal, 2019; HPC, 2019; HPCwire, 2019). This was, at the time it entered service, the fastest supercomputer in Europe (EUR-Lex, 2019). For the efficient usage of HPC computing architectures, knowledge in the area of parallel programming and code optimization is indispensable LRZ offers regular training courses on various subjects in HPC (LRZ: Courses, Workshops, Tutorials and Training, 2019). In this area LRZ collaborates with the HPC group of the Erlangen Computing Centre and the Competence Network for Scientific High Performance Computing in Bavaria, and the partners within the GCS. GCS is one of the six PRACE Advanced Training Centres (PATCs) that started in 2012. Additionally, GCS proudly provides first class training opportunities for German and international researchers and scientists (PRACE Research Infrastructure, 2019). A large pool of trainer experts with a training experience of well over 300 trainer-years ensures a high quality of the comprehensive training program offered, which helps enable users of HPC infrastructures to maximize efficiency and research output on supercomputing systems (Gauss Centre – Training courses at GCS, 2019).

The HPC Centre HLRS in Stuttgart have the fastest computing system is **Hazel Hen** with a peak performance of more than 7,4 petaflops (HLRS High Performance Computing Centre Stuttgart, 2019). Hazel Hen is based on technology called Cray XC40 and was ranked the 8. fastest system of the world in the November 2015 on the TOP500 List. Hazel Hen is powered by the latest Intel Xeon processor technologies and the CRAY Aries Interconnect technology leveraging the Dragonfly network topology. The installation encompasses 41 system cabinets hosting 7,712 compute notes with a total of 185,088 Intel Haswell E5-2680 v3 compute cores. Hazel Hen features 965 Terabyte of Main Memory and a total of 11 Petabyte of storage capacity spread over 32 additional cabinets hosting more than 8,300 disk drives which can be accessed with an input-/output rate of more than 350 Gigabyte per second. With the installation of Hazel Hen, HLRS completed the last step of its system roadmap as defined with the current purchasing plan by the German Federal Ministry of Education and Research and the federal states of Baden-Württemberg, Bavaria (and North Rhine- Westphalia) (HLRS High Performance Computing Centre Stuttgart, 2019; The High-Tech Strategy for Germany, 2019).

Technology plus Innovation Network in Danube region, provides scientists with various computing clusters at the entry level (**bwUniCluster and bwForCluster**). Existing cluster structures benefit from efficient funding through the Federal Government's high-tech strategy "Excellence Cluster Competition". Larger companies, such as Mercedes-Benz, NVH CAE & vehicle concepts, can gain access to HPC through a different organisation: the GCS (Schriften_hpcc-bw_2004, 2019).

Our main research was focused on HPC in automotive and electronic industry, so in the next paragraphs we will mention some main information about the sectors; the Initiative Automotive SuperCluster in Danube region in Germany (DonauMotor) have associated core members: Fraunhofer-Institut für Produktionstechnik and Automatisierung IPA and Germany Landesnetzwerk Mechatronik BW, Germany (Industry-overview-electronics-microtechnology, 2019). Currently, five German companies and seven marques dominate the automotive industry in the country: Volkswagen AG (and subsidiaries Audi and Porsche), BMW AG, Daimler AG, Adam Opel AG and Ford-Werke GmbH. Nearly six million vehicles are produced in Germany each year, and approximately 5.5 million are produced overseas by German brands. Alongside the United States, China and Japan, Germany is one of the top 4 automobile manufacturers in the world and the Government of Germany is not long ago even more increased the investment in the supercomputing in the automotive industry (Industry-overview-electronics-microtechnology, 2019; The High-Tech Strategy for Germany, 2019). On the other side HPC in the electronic industry used the total recently tripled power of its supercomputer to develop for example more complete visualizations of seismic landscapes and run simulations at 10x times the resolution of existing oil and gas reservoir models. This new capability will enable more efficient upstream oil and gas exploration, as well as the discovery of reserves under more challenging geological conditions. Renowned as the production and R&D site of some of the world leaders in office machines and communications (Ezell & Atkinson, 2016, pp. 20). The home of a wide range of small and medium-sized companies, known for their technological superiority and export orientation-a centre for outstanding international newcomers. Recent trends in HPC are increasingly developing many-core GPUs to a good advantage through the use of such GPUs as a massively-parallel CPU co-processor to achieve rapidity up of computationally intensive EDA simulations (Electronic Design Automation (EDA)-NVIDIA, 2019) including "Verilog simulation, Signal Integrity & Electromagnetics, Computational Lithography, SPICE circuit simulation and more" (Information and communication technology by T-Systems, 2019).

3. Innovation actors active in HPC

Preliminary literature overview shows that the German supercomputing has evolved continuously and is constantly changing. We distinguish between service providers in the public space and service providers for the industrial area: Tier-1 level, Tier-2 level, and Tier-3 level (includes companies that take on the smaller projects). At the Tier-1 level, we find the GCS as described earlier. Together, the Centres provide services to all German researchers that require access to high-end systems (Tier sites of the Worldwide LHC Computing Grid, 2019). Access is controlled by a scientific steering committee, which awards CPU time based on proposals submitted through a portal. Services of GCS are provided in the following fields: access to high-end systems; support for porting and optimization; education and training; support for industrial use of supercomputing.

GCS has also established working groups to discuss and agree on major questions that affect the users of all the three Centres. Such working groups include the following: operational issues; security issues; industrial use issues; administrative issues and public relation issues (Gauss Centre - HPC Services - The Visualization Centres of GCS, 2019). At the same time, each of the Centres is focused on individual strengths. Together, they cover the whole landscape of application fields and most methodological aspects of supercomputing. Furthermore, at the national level, GCS helps to communicate with political decision makers and scientific funding agencies. At the same time, GCS acts as a European provider (Tier-0) in the frame of the European PRACE (Partnership for Advanced Computing in Europe) initiative. By providing CPU cycles to European scientists, GCS plays a major role in supporting Pan-European activities and projects. At the Tier-2 level, we find a collaboration of medium-sized Centres. The GA was established 1 year after the GCS and brings together Centres that reach out beyond their home organizations to support a regional user community. GA has started to coordinate these Centres and is to establish a central office in the near future. GA brings together both regional and topical Centres. This means that the needs of the Centres and their users are more diverse than is the case for GCS. Hence GA is working out methods to intensify collaboration and to provide all users in Germany with the same level of support (Gauss Centre – HPC Services – The Visualization Centres of GCS, 2019).

In the time of our project, we have the mission to meet, made surveys and group interviews in Germany, so in the Table 1 is listed the database of enterprises and HPC providers that responded the survey made or via e-mail or via telephone.

Table 1: A database of enterprises and HPC providers that responded the survey made or via e-mail or via telephone

No.	Country of the enterprise:	Name of the person who made a survey:	Name of the organisation in English*:	Type of organisation*:	Type of company*:	
	Respondents from: SMEs, TIER 1, SME, TIER 0, COMPETENCE CENTRE, TIER1, TIER 2					
	Enterprises					
1.	Germany	Anonymous	Enterprise in automotive sector	Micro-company (<10 employees)		
2.	Germany	Anonymous	Enterprise in automotive sector	Large enterprise (250 or more employees)		
3.	Germany	Person want to stay Anonymous	Enterprise in automotive sector	Large enterprise (250 or more employees)		
4.	Germany	Automotive Industry Name don't wont to mention	Enterprise in automotive sector	Large enterprise (250 or more employees)		
5.	Germany	HPC Company Association	Enterprise in automotive sector	Large enterprise (250 or more employees)		

6.	Germany	/	Both	Large enterprise (250 or more employees)		
	HPC Providers					
1.	Country, town, village of the HPC provider:	Name of the organisation in English:	Website:	Contact person:	Town/Village:	Type of organisation:
2.	Germany	Want to stay Anonymous	Http://www. prace-ri.eu/	Want to stay anonymous	Germany	A public centre
3.	Stuttgart	Want to stay anonymous	N/A	N/A	Stuttgart	A private centre (inside a company)

Source: own data

In the Table 2 is listed the database of the group interviews in the Germany.

Table 2: A database of the participants of the group interviews

No.	Respondents.
1.	Employee from company Hella, Stuttgart. It was made a Skype meeting. The employee doesn't want to be named. The employee is working in the automotive sector of the HPC enterprise.
2.	Personal meeting in Germany from commercial sector in automotive and electronic sector. An employee in Cray Computer Deutschland GmbH from Cray Computer DeutschlandGmbH. He was also a several years an employee on HLRS CC, so he was talking from both sides.
3.	Personal meeting in Germany from commercial sector in Automotive and electronic sector. An employee from company Sicos (SICOS GmbH – a spin-off of University of Stuttgart) and colleague of Manager Höchstleistungsrechenzentrum, Department of Applications & Visualization in Germany).
4.	An employee who is working and interviewed as a member of the "Communication system", so he does not want to be named. He is also working for an Institute for Advanced Simulation (IAS) in collaboration with Jülich Supercomputing Centre (JSC) and member of Prace. So he is an employee from "Institute for Advanced Simulation (IAS) – member of Jülich Supercomputing Centre (JSC).

Source: own data

4. HPC Benchmark

In the next table are outlined the main topics marked trough interview results and workshop within InnoHPC project.

Table 3: Main workshop objectives within InnoHPC project

Main workshop objectives within InnoHPC:
To share and validate the results of the needs and opportunities for HPC inside Danube region in relation to electronic and automotive sectors with focus on Germany.
To raise awareness and validate the results of the needs, opportunities for HPC technology application amongst SMEs in Danube region (Germany).
To select suitable suggestions for HPC development at Danube and national levels.
To gain understanding into HPC technology and application through orientation presentations.
Recommendations at national level:
Industry Guidelines at national level; to presented the research and development directions, competences and infrastructure, policy framework, network and cooperation of Germany.
More focus on R&D, find right firms to connect other powerful industries and business sectors (like medicine and aeronautic power industry), consolidate cooperation between the academy and SMEs, organizing trainings, courses for academia and SMEs, achieve good examples from European practices and successful stories from the global market.
Summary of input provided by stakeholders and speakers during the workshop discussion points included:
More important, current hype-topics, such as Machine Learning and Artificial Intelligence are dominating and attracting companies' attention.
Due to the dropping out of the EU-funded PRACE project, Germany has lost perceptibility in the sector of HPC on an international level.
German researcher, HPC expertise are hard to find or tend to go elsewhere outside from Germany.
German companies are very open to new technologies and willingness to assuming risks.
Access to information, funding-opportunities and HPC resources is easier for universities than it is for companies. The need for freely available information, e.g. through a central web-portal, is seen high.
Workshop Conclusions & Final Industry Guidelines at national level
HPC service should maybe in first place raise awareness for potentials of HPC and be easy to use and only in second stage offer advanced services.

Source: Workshop made in Austria, Linz, Feb. 2018

The final digital transformation of industry guidelines for Germany can be found in the next chapter.

5. Recommendations

In this chapter are presented main recommendations of Industry Guidelines for Germany, based on the European Industry Guidelines. As we see in Figure 1 there is designed a small relationship of the main guidelines that lead the Industry in Germany. Bellow the Figure 1 are presented the main touch points of Guidelines and some strategy innovations that are leading Germany to the top of the EU countries in digitalisation.

Figure 1: Digital transformation Guidelines for Germany in Industry

Table 4: Digitalization "made in EU"

Creating a gigabit network for Germany
• To have globally competitive telecommunications networks in Germany (by 20125) which offer gigabit/s transmission speeds both upstream and downstream, and which guarantee adequate capacity at all network levels, reliable real-time capability and the highest service quality. • To ensure in the short term that trade and industry in particular (Industrie 4.0, Smart networking, Smart services) have nationwide access to first-class networks and that rapid progress is made on rolling out gigabit networks
Steering in a new age of entrepreneurship
• To support Entrepreneur's fresh ideas and rethinking of commerce • To support their innovative skills with established companies and the networking which offers key opportunity for industry in Germany • To support start-ups, improve funding conditions, and promote cooperation between new and established companies
Creating a regulatory framework for more investment and innovation

• To evaluate legal framework with a view to digitalisation (and to see a modernisation of the European legal framework which provides a stimulus for a strong, growing Digital Single Market) • To take support and take account of some laws of special features of online markets, and merger control needs to be adapted both in the national and in the European context • To think about setting up regulatory “experimental spaces” for new technologies and business models
Pushing forward with smart networking in the core areas within our economy
• To construct comprehensive and systematic use of the digitalisation potential in the fields of energy, transport, health, education and public administration • To generate considerable efficiency gains and to stimulate macroeconomic growth (The Smart Networking Strategy was adopted by the cabinet in September 2017. Since then, a lot of information policies have been rolled out. For example, a “Smart Networking Initiative Germany” centre of excellence has been set up, and roadshows set in motion) • Strengthening data security and data protection • To ensure data security and data protection safeguard basic rights • To promote public acceptance, and also stimulate growth, because they require the development of new technologies and business models • To create our own security ecosystems (for hardware and software) • Enabling new business models for SMEs, the skilled craft sector and services • To help SMEs to succeed and grow in the rapidly changing conditions of a global data economy. In some sectors, such as the services sector, this initially involves measures to raise awareness of scope for digital development and resulting new value chains Utilising Industrie 4.0 to modernise Germany as a manufacturing base • To offer potential for more efficient, customer-oriented and resource-conserving production and for the creation of additional value added by means of new business models • To increase a goal to make Germany the leading supplier and user of Industry 4.0 – and as a result, it will be the most modern industrial location in the world • To achieve the leading supplier, is needed to enable SMEs to come to terms with Industrie 4.0. • Bringing research, development and innovation in digital technology to a competitive level • To significantly boost funding for research and development in the area of digitisation of the economy. In most areas of trade and industry, this funding is only one-tenth the amount of that provided for energy or aerospace

- To enforce in promotion of research and development projects at the precompetitive stage, address forward-looking topics in ICT early on
- To expedite the transfer of scientific results, including market-oriented cutting-edge technologies with substantial application potential
- Offering digital training to people at every stage of life
- To support digital education and training and provided it at all levels of the education system in the interest of innovative commerce, decent work and better participation in working life through better digital evaluation skills
- To take responsibility for people's own data
- Creating a digital agency as the central unit for implementing the Digital Strategy till 2025
- To overcome the fragmentation of tasks at federal level regarding digital economy issues, and to effectively support the implementation of German Digital Strategy
- To bring together the responsibilities along the entire digital value chain, to provide institutional backing for the implementation of the Digital Strategy (duty of the new "Federal Digital Agency" of the Economic Affairs)
- To strengthen the digitalisation expertise for the provision of neutral policy advice (in the short term, the capacities in the Bundesnetzagentur (Federal Network Agency) which focus on issues like Industrie 4.0, smart networking, standardisation, etc. will be increased;
- To expand market monitoring, so that we can better understand digitalisation processes and, if necessary integrate them into the regulatory system.

Source: White paper, 2017; Acatech, 2019; Bundesregierung, 2018

6. **Conclusion**

From the InnoHPC Project Handbook (2017) we found that "the main objective of InnoHPC project is to create transnational HPC laboratory for co-designing knowledge-intensive innovative products with high value-added in transnational value-chains". The objective is the dissemination that German HPC infrastructures, competencies and web platforms are providing HPC access, integrated services, capacity building tools, and sustainability toolkit, to support durability of the final product of InnoHPC project – InnoHPC Lab, with the intensive spreading into SMEs, Research departments in Companies, Universities, HPC Centres etc., in Germany. InnoHPCLab' challenge for the continuous operation of the InnoHPC Lab is going to be in raising awareness and marketing of the ecosystem InnoHPC Lab offers. After raising awareness, the second task of the InnoHPC Lab members is going to be in continuous supporting, collaboration and promotion of the InnoHPC lab and its services (Sustainability strategy and business InnoHPC, 2018; White-paper, 2017).

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National Case Study in the Danube: Hungary

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Abstract: The objective of this chapter is to provide a comprehensive analysis on the developments in the infrastructure and organisation of the High-Performance Computing (HPC) in Hungary. Because HPC greatly contributes to enterprises' research and development, it is important to indicate the key aspects by which industrial HPC use is hampered and encouraged. Thus, this chapter initially presents an overview of the innovation performance in Hungary followed by a detailed appraisal of the HPC situation in the country and a description of the innovation actors that are involved. These are important elements to be considered in order to propose recommendations, at the end of the chapter, that can help Hungarian firms benefit from the underused HPC infrastructure that is available to them.

Keywords: Hungary, HPC case study Hungary, InnoHPC project

1. Overview of Hungary's Innovation Performance

According to the European Innovation Scoreboard (2018), Hungary's innovation performance[31] is classified as a moderate innovator i.e. below the EU average (between 50 % and 90 % of the EU average). While the overall EU innovation performance between 2010 and 2017 improved by 5.8 percentage points, the performance for ten member states declined during that period, including Hungary whose innovation performance declined by a marginal – 0.1 % percentage points. Out of the 27 indicators for innovation performance in the European Innovation Scoreboard (2018), Hungary's employment and sales impacts are the

31 The performance of EU national innovation systems is measured by the Summary Innovation Index, which is a composite indicator obtained by taking an unweighted average of the 27 indicators

strongest innovation dimensions whereas innovators and intellectual assets are the weakest innovation dimensions.

2. Appraisal of HPC situation in Hungary

This section outlines the High Performance Computing (HPC) infrastructure in Hungary. Hungary has HPC service since 2001 provided by the National Information Infrastructure Development (NIIF) Programme under the Governmental Information-Technology Development Agency. NIIF serves as a framework for the development and operation of the IT infrastructure and provision of services for public education, higher education, research institutions and the general public in Hungary by providing them with[32]:

- an integrated computer networking infrastructure, and, on the basis of that,
- a wide range of communication, information, and co-operation services,
- leading-edge environment for networking applications, as well as
- advanced framework for content generation and provision.

The NIIF Programme is funded by the central state budget in close cooperation with Hungarnet[33], which is the association of users community. While the NIIF Programme plays a leading edge role in the development and introduction of most advanced networking technologies in Hungary, there are still a low number of enterprises which uses HPC for research and development. Accordingly, the special know-how of HPC usage generates a considerable gap between the potential users and HPC service providers. However, even with the efforts of the universities, who have installed HPC systems locally, that are trying to decrease this knowledge gap by creating small groups of specialists, these efforts seem to have lower effectivity than was expected in Hungary (InnoHPC project, 2018, D.3.2.3). Consequently, it highlights the need for parallel programming skills with intensive programming courses to be included in the universities' education programme not only for students having informatics speciality, but also for the majority of other specialities.

The service provided by NIIF includes scientific computation and data storage facilities which are based in five different locations throughout the country.

1. NIIF centre Budapest
2. University of Debrecen

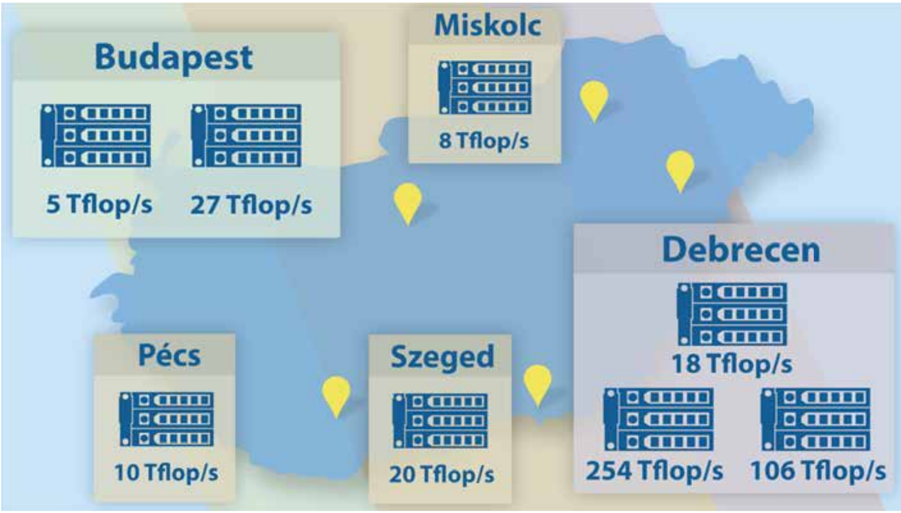
32 https://hpc.niif.hu/index_en.php

33 Hungarnet provides central information services and maintains a country-wide computer network for the academic community in Hungary https://www.ercim.eu/publication/Ercim_News/enw31/martos.html

3. University of Pécs
4. University of Szeged
5. University of Miskolc

Figure 1 presents the NIIF HPC resources available in the five locations. These supercomputers are operated by NIIF Institute staff under the supervision of the Programme Committee, and by the contribution of the Technical Committee[34].

Figure 1: NIIF HPC Resources



Source: HPC.NIIF.HU

The aim of these HPC systems is to provide high speed and high processing capacity services mainly to the Hungarian academic and higher education researchers. These various supercomputer architectures (see Figure 1) are available in different locations in order to support different types of scientific computing tasks. Through these HPCs, the latest development tools and scientific applications are made available for users. While the usage of the supercomputers is free for authorised users, any person or research group who wants to use the supercomputers needs to have a contract with the NIIF Institute in order to avail the services. New users who wish to have access to the supercomputers should request a HPC project on the HPC portal[35]. Once the project is accepted, invitations can be sent out for group members by the principal investigator of

34 http://www.prace-ri.eu/niifi-national-information/

35 The portal can be accessed here: https://portal.hpc.niif.hu/

the project. The main users of these HPC systems are the researchers, staff and students of the academic and higher education institutes. As regards a 'scientific contract of cooperation' between Hungarian and foreign organisations, members of foreign organisations may also gain access to use the Hungarian HPC resources. However, all the scientific results produced and papers published in national or international journals with these HPC systems must contain references acknowledging the Hungarian HPC national project. Although, these systems can be used for education and research at any of the five institutes mentioned above, they cannot be used for profit oriented development activity or software applications because of the financing policy of the HPC project.

Hungary is a member of the PRACE project[36] since 2005. PRACE seeks to strengthen the European users of HPC in industry through various initiatives and has a strong interest in improving energy efficiency of computing systems and reducing their environmental impact. PRACE ensures the wide availability of HPC resources on equal access terms. According to the European Commission (2012), PRACE has to be further strengthened to acquire the competence to (i) pool national and EU funds, (ii) set the specifications and carry out joint (pre-commercial) procurement for leadership-class systems, (iii) support Member States in their preparation of procurement exercises, (iv) provide research and innovation services to industry, and (v) provide a platform for the exchange of resources and contributions necessary for the operation of high-performance computing infrastructure. Additionally, an e-Infrastructure for HPC application software and tools needs to be put in place. It should further consolidate the EU's strong position in HPC applications by coordinating and stimulating parallel software code development and scaling, and by ensuring the availability of quality HPC software to users.

Accordingly, in order to conform to the EU HPC initiatives, Hungary HCP TIER 1 system is linked to the e-Infrastructure of PRACE. Additionally, in order to achieve the initiative of establishing Centres of excellence for the application of HPC in scientific or industrial domains that are most important for Europe (e.g. in the area of energy, life sciences and climate), Hungary has proposed a plan[37], both at national and international levels. Since, HPC Knowledge Centres should be virtual organisations based in the multi-field knowledge of the academic and higher education institutions, Hungary's plan to comply with EU HPC initiatives includes:

36 http://www.prace-ri.eu/

37 Based on D3.2.3 InnoHPC project, 2018

a. The transfer of HPC know-how should be managed both in online and offline modes. The Level1 of the HPC HelpDesk needs to be organised offline through a well-developed web based tool. At this level even the registered users may propose a solution to the request dispatched. On Level2, specialists with deep knowledge in a given domain process the request. On Level3, specialists in parallel programming answer the questions conceived by L2 people.
b. The HPC Knowledge Centre should offer a cost based HelpDesk service depending on the complexity of the question. Public users have access to all the L1 problems, such as chat channels. Flat rate subscribers to the service have access to L2 problem discussions. L3 problems are charged extra and need to be developed based on the opinion of the InnoHPC project members.
c. The subscribers to this HPC HelpDesk service may be from different countries and different sectors. It is not only researchers of academic and higher education institutes that may subscribe, but also researchers from different enterprises may apply to this service. By running this service for a scheduled time period (i.e. until the end of the InnoHPC project or later) an intelligent HPC knowledge database is created. This database may serve as a good information source for any new person starting to use the HPC services. It is necessary to share a small percentage of the national HPC processing capacities to the community included in the InnoHPC project to be able to use the existing HPC systems in practice.

4. Innovation actors active in HPC[38]

The usage of HPC services strongly influenced the R&D activity in several industry sectors in Hungary. These three major industry sectors are included in the National Research, Development & Innovation Strategy (2013-2020): a) pharma, b) automotive and c) electronics & information technology.

a. Pharma: High-performance computing can help pharmaceutical companies reduce the time they spend on research and development, but further deployment of the HPC is needed. The challenges facing informatics systems in the pharmaceutical industry's R&D laboratories are changing and the number of large-scale computational problems in the life sciences is growing and they will need more high-performance solutions than

38 D3.2.3 Regional HPC capacity report with detailed and systematic assessment of competencies and opportunities of HPC applications for the electronic and automotive industry and assessment of awareness and entrepreneurial spirit of academic institutions.

their predecessors. However, HPC is not a cure-all for the computational problems of pharma R&D and some applications are better suited to the use of HPC than others and its deployment needs to be considered right at the beginning of experimental design. For HPC to be useful in pharma R&D it should produce results that are rapid, accurate, and reproducible.

b. Automotive: HPC-based virtual prototyping and large-scale data modelling provide breakthrough insights that dramatically accelerate and streamline not only upstream R&D and engineering, but also downstream business processes such as data mining, logistics and custom manufacturing. Key stakeholder enterprises agree that HPC can dramatically boost their ability to innovate. Despite the energy industry's assertive use of HPC, best-in-class firms apply HPC beyond traditional upstream R&D functions more frequently.
c. Electronics & information technology: IT industry has emerged as a major contributor to the industry revenue as well as employment opportunity provider in the majority of countries. Major goals of the sector's development are to empower scientists and researchers with state-of-the-art compute facilities for their cutting-edge research in respective domains and to reduce redundancies and avoid duplication of efforts and investments.

4. HPC Benchmark

To share and validate the results of the needs and opportunities for HPC, a series of recommendations for HPC development at a national level are proposed. The analysis, to generate these proposals, is based on the data collected through a stakeholder's workshop for the InnoHPC project (D3.1). The InnoHPC project aims to enhance the HPC usage for SMEs in the electronic and automotive sector. In addition, the pharma industry is one of the three major sectors included in the National Research, Development & Innovation Strategy (2013-2020). Therefore, it is recommended to enlarge the list of sectors of the SMEs being potentially HPC users at the national level. Table 1 summarises the main weaknesses and opportunities with respect to the use of HPC in the pharma, automotive and electronics industries in Hungary.

Table 1: Weaknesses and Opportunities of HPC usage in Hungary

Weaknesses	Opportunities
Only a few Hungarian SMEs have information about the possibilities of HPC Therefore, adoption of HPC services by the industrial actors should be stimulated.	SMEs consider national level networking in HPC service usage as a realistic approach at the beginning. Later on the international collaboration may accentuated.
The collaboration between academic and industrial actors in HPC usage needs to be popularised at the strategic national level.	SMEs agree that the know-how of HPC usage is a critical aspect of spreading country-wide HPC services. It is considered a great opportunity to spread the results of the InnoHPC project in the next few years
There is a lack of information channels to SMEs in order to reach them with decisive important topics affecting their industry and businesses.	Experience of the HPC services usage exists at higher education and research institutions, but these results are concerning mostly basic research and not the applied research.
The collaboration in the academia sector is not strong because research projects are executed in parallel and isolated from each other.	The computation tendency of the SMEs could be increased by encouraging R&D&I projects by national level application programmes based on HPC usage.
There is a lack of information channels, which contain decisive information for SMEs.	New planned prototype services such as the test road in the city of Zalaegerszeg, the Industry 4.0 National Technology Platform and the start-up enterprises are examples, where the usage of HPC services are inevitable in the near future.

Source: InnoHPC, 2018, D3.1

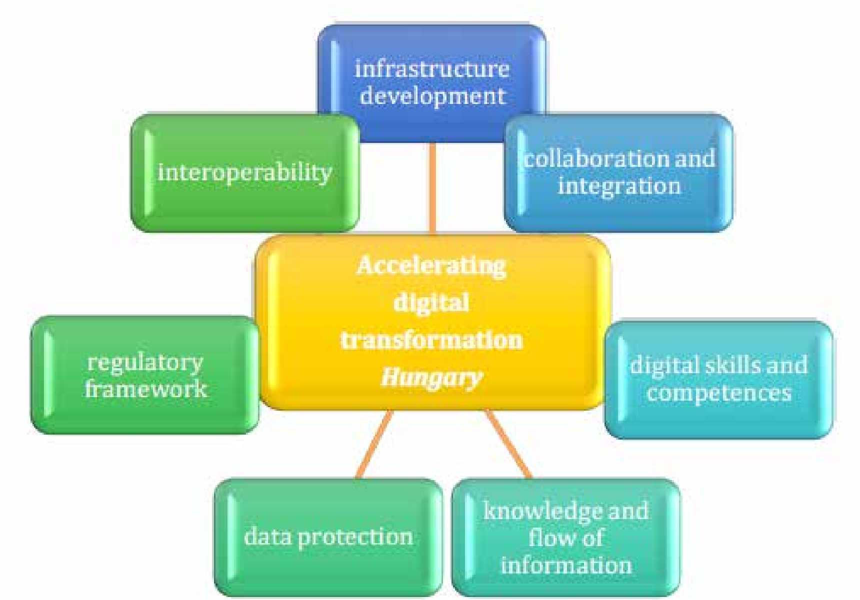
The results from the analysis of the data presented in Table 1 leads to the following conclusions. Firstly, there is a lack of information channels, which contain decisive information about the possibility of accessing HPC. Secondly, there are barriers for SMEs to use HPC. The hardware procurement (CAPEX) costs and/or operation expenses (OPEX) are high and the lack of expertise and resources makes it risky for the SMEs to procure their own HPC hardware. While these weaknesses were highlighted, the InnoHPC project was considered to be a great opportunity to spread the know-how of HPC usage as it was considered to be a critical aspect of the country-wide HPC services. Additionally, new prototype services in the Industry 4.0 National Platform are identified as potential HPC users in Hungary.

5. Recommendations

The main recommendation of active actors from both groups of interest in HPC has been designed taking into consideration the Industry Guidelines developed through the InnoHPC project[39]. The recommendations are presented in relation to the guidelines, in the following figure (Figure 2) and table (Table 2).

Acknowledging the need for a multilevel approach in implementation of strategies, the recommendations for accelerating the digital transformation of industry in Hungary is developed through desktop research, analysis of secondary data and legislation as well as stakeholder engagement through workshops across the Danube region. Figure 2 presents these recommendations for accelerating the digital transformation of industry in Hungary.

Figure 2: Recommendations for accelerating the digital transformation of industry in Hungary



Source: InnoHPC, 2018, D3.3.3

39 D3.3.3 Digital Transformation of Industry Guidelines

In order to assess the needs and opportunities for HPC in Hungary with a specific focus on SMEs from the pharma, electronic and automotive sectors, the present chapter deals with a set of specific guidelines for improving the framework. Thus, presenting a set of guidelines that can contribute to the improvement and change toward a digital industry in Hungary. The suggested guidelines are as follows.

Table 2: Recommendations for accelerating the digital transformation of industry in Hungary

Digital infrastructure
• Eliminate the potential bottlenecks in the segments of electronic telecommunications networks.
Digital competences
• Increase the spread of digital competences among the population and SMEs
Digital economy
• Reduce the shortage of ICT experts both in quantity and quality
• Increase the rate of IT use in domestic SMEs and their participation in the digital economy
• Encourage and support cooperation between educational institutions and ICT enterprises.
Digital state
• Establish and operate a stable and secure government IT background
• Put in place a legislative framework for the transferability of information communication technologies (ICT) in order to achieve interoperability
R+D+I
• Support innovation activities of knowledge and technology intensive ICT companies to develop marketable products
• Strengthen the co-operation culture and supporting its forms in R+D+I
• Support any closer co-operation between ICT companies and universities and research institutes, with special regard to increasing the efficiency of participation in tenders
• Support ICT cluster development
• Make adequate super-computing (HPC) capacities available for the R+D+I sector
Developing globally competitive knowledge bases
• Train researchers and creative professionals
• Strengthen globally competitive research centres

Strengthening intensive flow of knowledge

- Facilitate R+D and technology-based dynamism of medium-sized companies
- Integrate large enterprises based on R+D
- Establish an integrated, client-oriented, IT-based national innovation service system
- Support open, pre-competitive and social innovation co-operations

Improving efficient knowledge utilisation

- Boost innovative small firms
- Create dynamic collaborations and networks

Application of new and digital technologies

- Increase industry competitiveness
- Access and exploit market gaps

Energy and material efficient instruments and production methods

- Reduce dependency on raw materials and energy
- Increase the marketability of Hungarian products
- Use the most state-of-the-art technologies in production

Easing territorial disparities

- Employment creation in less industrialised regions
- Increase networks

Expanding employment opportunities

- Extend dual education

More efficient use of resources

- Produce higher value added products
- Provide high value added services
- Streamline the composition of energy use

Industry 4.0

- Use more digital technologies during production
- Produce “smart” products
- Support related R&D&I activities

Source: InnoHPC, 2018, D3.3.3

6. Conclusion

The objective of this Chapter was to provide a comprehensive analysis on the Hungarian experience with High Performance Computing (HPC) by explaining how this country has developed its infrastructure and organisation in order to enable the potential opportunities for both the public and private sector organisations. Such analysis led to an assessment of the HPC landscape in Hungary capable of identifying the main aspects related to this country's innovation performance, the HPC situation and the main actors involved, which are as follows.

Firstly, it was presented that the innovation performance in Hungary is moderate if compared to other EU countries. However, as levels of innovation performance improved for most of the European countries in recent years, they slightly deteriorated in Hungary. Secondly, the HPC situation was explained in consideration of the NIIF which, despite its capacity and capability to diffuse innovative knowledge, has not been successful specifically with HPC as the number of enterprises using this technology in the country is still very low. The universities that have HPC facilities have already attempted to tackle this issue with enterprises by implementing their own measures, however, with exiguous results as the main users are still people based in their own premises, such as students, staff and researchers. Thirdly, it was identified that the main industry actors active in HPC are enterprises from three specific industry sectors, namely pharmaceuticals, automotive and electronics & information technology.

In view of all these aspects related to innovation and HPC use, and also based on the needs and opportunities for HPC in Hungary, the following two conclusions were drawn: (i) the number of information channels that can diffuse knowledge on HPC is insufficient; (ii) barriers for SMEs to use HPC are high because costs are elevated and expertise is lacking. The InnoHPC project can support Hungarian enterprises, especially SMEs, with these issues to a great extent because it can serve both as an information channel for participating firms and also because it has the means to support the transfer of HPC knowledge and, consequently, expertise to public and private sectors in Hungary.

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National Case Study in the Danube Region: Moldova

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Abstract: Data on Moldova's innovation performance is relatively scarce, since the country is not covered by the European Innovation Scoreboard and there are very few studies assessing the current situation. There is however a Roadmap for improving the competitiveness of Moldova's economy, as well as National Innovation Strategy for 2012-2020. Overall, Moldova is regarded as a modest innovator, with a developing innovation culture. The present paper analyses the country's potential for enhancing the development of High Performance Computing (HPC), as well as the factors influencing this development on medium and long-term. The results – although based on exploratory research – offer useful insights on the actions and measures to be taken on long term to strengthen innovation performance and facilitate the development of HPC.

Keywords: Moldova, HPC case study Moldova, InnoHPC project

1. Overview of country innovation performance

According to a Peer Review of the Moldovan R&I system [1], carried out by the independent panel of PSF experts between November 2015 and July 2016, Moldova's innovation performance is still modest, being influenced by the relatively unstable political situation in the past few years, as well as by the country's slow transition to a market economy. The same report identifies ICT as a promising innovative sector that has gained weight similar to that of other Commonwealth of Independent States (CIS) countries. Moreover, the country has a relevant tradition of education and research, although cuts in education and research funding led to very low investments in these sectors over the past years.

The Roadmap for improving the competitiveness of Moldova's economy [2] indicates that the main obstacles to investment are of an institutional nature. Thus, lack of transparency and efficiency in the functioning of the public administration has a negative effect on innovation performance by reducing both the incentives and the opportunities for „productive entrepreneurship, investment and innovation".

In 2014, Moldova, together with five Western Balkan countries (Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Montenegro and Serbia) secured full access to the European Union's current seven-year research and innovation programme, Horizon 2020 [3]. Moreover, a background report prepared by the Centre for Social Innovation (ZSI) in Austria [4] shows that the innovation ecosystem has been evolving and that there is willingness to reform. At the time being, competence regarding public policies on innovation is shared between the Academy and Ministry of Economy.

There is an Agency for Innovation and Technology Transfer (AITT) which functions within the structure of the Academy and which currently finances Innovation & Technology Transfer projects, S&T parks and incubators, as well as innovation prizes and fairs. Moreover, the Organization for Small and Medium Enterprises Development (ODIMM) operating under the Ministry of Economy manages several instruments targeting innovation, including a credit guarantee fund.

AITT and ODIMM jointly implemented an innovation funding tool (ener2i Innovation Vouchers) developed under a EU FP7 funded project (www.ener2i.eu) and co-funded by CEI and Austrian Development Cooperation. An Innovation Voucher Competition (IVC) was designed to bring businesses and research organizations in direct contact; the Voucher money (€ 4,000) can be spent on R&D services (e.g. technology and market surveys, feasibility studies, etc.) and R&D activities (e.g. prototyping, travel for international knowledge transfer, etc.), and all applications are assessed by an international evaluation panel.

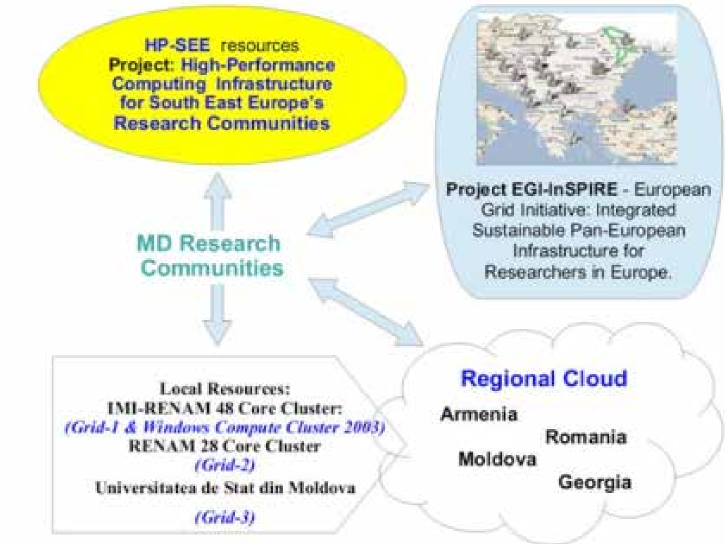
However, steps still need to be taken to increase productivity based on adjusting the existing modern technologies, development and implementation of innovations, and upgrading of own technologies [2].

2. Appraisal of HPC situation

In Moldova the work to create HPC infrastructures started recently due to participation in some international projects in the field, as SEE-Grid projects [5]. Historically, the first scientific computing resources began to develop from the initial deployment in 2006 of the first Grid cluster that was integrated in the regional South-Europe Grid infrastructure. Since this time Moldova has been actively involved in regional and European programs for cooperation in the field of scientific computing.

Moldova's participation in the regional project HP-SEE (HighPerformance Computing Infrastructure for South East Europe's Research Communities) allowed for local research and educational institutions to get access to regional HPC resources. Regional HPC infrastructure combines powerful HPC clusters and various supercomputers provided by project participants from the five countries involved in the project: Greece, Bulgaria, Romania, Hungary and Serbia. Regional HPC infrastructure is heterogeneous and includes supercomputers and clusters based on Intel/AMD CPU and GPU. HPC resources also include two supercomputers IBM Blue Gene/P installed in the Bulgarian Supercomputing Center of the Agency "Electronic Communication Networks and Information Systems" and in the Western University of Timisoara (Romania) [6]. The development of national scientific computing infrastructure in Moldova is coordinated by MD-Grid NGI (National Grid Initiative) [7]. The general scheme showing the evolution of the integrated computational infrastructure in Moldova is presented in the figure below.

Figure 1: The evolution of the integrated computational infrastructure in Moldova



No sound collaboration between academia and enterprises in the field of HPC was identified. Also only one company offering HPC solutions (S&T Mold) was identified. Thus, we may conclude that HPC is approached and used only in international projects and the main infrastructure and applications are developed inside this type of collaboration.

The Industry Guidelines developed through the InnoHPC project revealed that Moldova does show some advantages in what regards HPC development, such as the fact that most university graduates possess digital skills to activate in the information society. However, a series of weaknesses may also be identified, such as:

- Insufficient development of human and institutional skills within the system of research, development and innovations
- Lack of an open model of governance in the field of research, technologies and innovations
- Existence of some barriers in implementing the academic and professional mobility determined by a large number of formalities for access in the teaching and scientific activity

- Low position of the Republic of Moldova in international ratings on Information Society
- Poor quality of information in the basic registries of the country (e.g.: State Registry of Population, etc.) and outdated technologies
- Low productivity per employee in the IT sector

Thus, action should be taken to reduce these shortcomings, while capitalizing on the country's current unexploited potential.

3. Innovation actors active in HPC

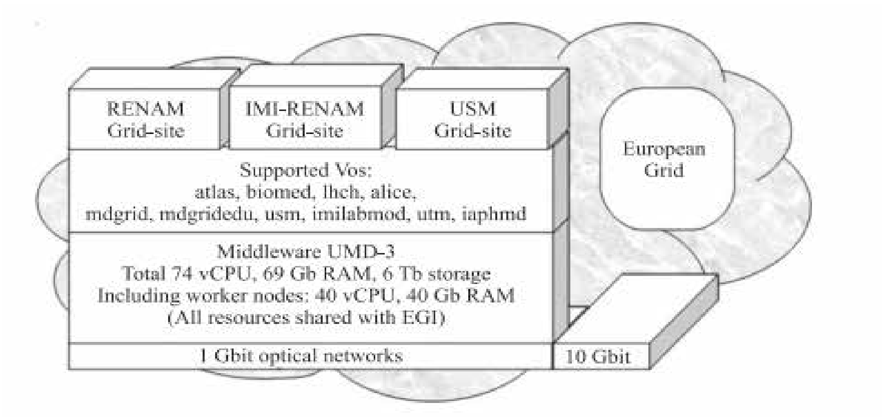
The availability of HPC hard infrastructure and soft competencies in the country, including experience and thematic focus, was analysed based on a preliminary literature review, desktop research and focus groups with HPC Moldavian actors, like universities, SMEs, and HPC providers.

The National Scientific Computing infrastructure is based on using specialized parallel architectures for running complex applications and integrates the following components [6]:

- grid distributed computing infrastructures;
- HPC cluster systems;
- scientific clouds;
- libraries and software packages for parallel algorithms design and programming;
- instruments for complex applications development, debugging, and porting.

At present grid infrastructure in Moldova unites three sites and has well-determined perspectives for its further enlargement, as presented in the figure below. NGI is offering R&E PKI operational support, providing federated identity management as well as other specific informational and computational services [6].

Figure 2: Grid Infrastructure in Moldova



Support from international projects allowed for the development of national high-performance computing resources in Moldova. A high performance computing cluster with parallel architecture was installed in the State University of Moldova. Moreover, multiprocessor clusters were deployed in the Institute of Mathematics and Computer Science of ASM and in the RENAM Association [6].

The development of national scientific computing infrastructure in Moldova is coordinated by MD-Grid NGI (National Grid Initiative). MD-GRID NGI was created by uniting research teams from various scientific fields having special needs for high performance computing resources. Also, NGI was joined by representatives from main universities and research institutions of the Academy of Sciences of Moldova. The RENAM Association (National Research and Educational Network of Moldova), already a partner in a series of regional e-Infrastructure development projects, was selected as the NGI coordinating body, taking into account the existing capacities of the NGI members in terms of computing and human resources. The MD-GRID NGI goal is to unite all existing in Moldova computing resources into a common national, regional and Pan-European infrastructure. NGI is participating in the development of national policies related to grid and HPC. Together with its members, NGI organizes dissemination and training events and provides support for users' community in developing and deploying grid and HPC applications [6].

In 2013 a series of activities dealing with deployment of the scientific cloud infrastructure began. Development of scientific clouds is rather new, but it represents a perspective direction for computational technologies development [6].

Another important initiative for Moldova that combines analysis of optimal solutions and practical deployment of regional scientific cloud infrastructure is the regional project "Experimental Deployment of an Integrated Grid and Cloud Enabled Environment in BSEC Countries on the Base of g-Eclipse (BSEC gEclipseGrid)" supported through the Black Sea Economic Cooperation Programme (http://www.blacksea-cloud.net). The aim of this project was to select middleware for implementation of computing architecture that provide a collaborative, network-based model that enables the sharing of computing resources: data, applications, storage and computing cycles. A special outcome of the project was the introduction of a federated Cloud infrastructure, which can provide different solutions for universities, scientific and research communities and more [6].

4. Recommendations

The main recommendation of active actors from both groups of interest in HPC have been designed taking into consideration the Industry Guidelines developed through the InnoHPC project. The recommendations are presented in relation to the guidelines, in the following figure and table.

Figure 3: Recommendations for accelerating the digital transformation of industry in Moldova

Table 1: Analysis of the digital transformation of industry in Moldova

Efficient management of research processes
• Support education able to generate ideas, absorb new knowledge • Improve higher education programmes, so that graduates latter can recover investments in education after relatively quickly through employment
Favorable society for the innovative and firm inclusion
• Facilitate the social, economic and political inclusion in order to combat poverty, to consolidate human rights, to provide for the digital inclusion, equality, solidarity and intercultural dynamics by supporting interdisciplinary researches, indicator of the technological progress, organizational solutions and new forms of cooperation and co-creation • At national level, in order to synchronize the national research documents with the international ones, the scientific community must identify in a transparent manner, by consulting the opinion of the relevant central bodies of the public administration, the new strategic directions until 2020, which will be included in the future partnership agreements, submitted for approval to the Government and Parliament.
Strategic vision on research and innovation
• Develop a system capable of creating efficient scientific knowledge in view of increasing the competitiveness of the national economy and the welfare of the population • Orientation of research priorities to academic community to keep up the effort, since programs cover a wide range and provide additional resources valuable. • Enhance commercialization of research results: o in the absence of adequate public funding countries turn increasingly to alternative sources of finance o research institutes, universities and other entities ties are becoming increasingly aware of the value of intellectual property they generate • Evaluation of the research and innovation activities, growing importance of research management and, in particular, efforts to evaluate its effectiveness and quality
Implementation of innovative technologies
• Public research infrastructure to be open to businesses (large companies as well as small businesses) • Improve and access to research through research programs for the benefit of SMEs • Better management of intellectual property that will ensure recovery of patents, and adequate protection of intellectual property • Good integration among businesses and the national and international research environment • Knowledge transformed into technologies and products

Enhancing access and connectivity - wide optimized ICT infrastructure
• Improvement of connectivity and network access • Management and shared use of electronic communication networks including associated infrastructure through the development/adjustment of the legal and regulatory framework. • The electronic communications legal framework is harmonized with the EU legal framework
Digital content and affordable electronic public services
• Setting favorable conditions for the development and use of national digital content and digitization of the existing national one, as well as for implementation and use of electronic services • Undertake strong action in order to exploit the opportunities for creating and promoting the digital content and services generated in the Republic of Moldova, including the positioning services based on GIS.
Enforcing ITC usage
• Create appropriate conditions for social inclusion based on electronic services • Develop digital literacy educational standards compatible with the European practices
Secured and defended digital environment
• Establish conditions for increasing security and trust of/in the digital space • Improve cyber security of the national critical infrastructure (public authorities/institutions, electronic communications networks, water pipes, energy grids, transportation networks etc.) • Raise awareness of the risks in the digital space and implement measures that are necessary to ensure its cyber security • Promote and develop international cooperation in cyber security
Research, Technologies and Innovations
• Applying science by implementing scientific achievements and developing knowledge on advanced technologies • Focus on digital transactions between citizens and government • Promote access to information on the internet and ensure adequate security and privacy measures in place • Secure document workflow between EU and national institutions • Implement E-Government to cut bureaucracy, administrative costs, inefficiency and low level of productivity
The infrastructure of quality

• Harmonize the regulatory system and afferent infrastructure, so as to promote production and trade at the global level. • Support innovative activities of SMEs by implementing special programs to attract long-term credit lines from international financial institutions
Information society
• Implementation of European legislation and gradual liberalization of the mail sector
Human Resources
• Equipping the labor force with knowledge and skills to assimilated new technologies and to produce new goods and services to be competitive on international markets • Improve quality of education, support the development of science education and enhance access to research services and professional training

5. **Conclusions**

Moldova is a modest innovator and its innovation potential has been significantly affected by political instability and very slow economic growth. However, the situation has been improving in the past few years as public policies to support innovation have been put in place. A number of support programmes are currently being implemented by the Agency for Innovation and Technology Transfer (AITT) and the Organisation for Small and Medium Enterprises Development (ODIMM), with positive effects on R&D and technology transfer activities. Moreover, support from international projects allowed for the development of national high-performance computing resources. However, HPC is poorly developed in the private sector and no sound collaboration between academia and enterprises in the field of HPC was identified. Overall, the analysis outlines a series of recommendations, including measures to enhance the efficiency of R&D, develop the policy framework and enhance science-industry cooperation.

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National Case Study in the Danube Region: Montenegro

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Abstract: In this paper, we introduce the national case study in the Danube region for Montenegro. The current status of technological innovation in Montenegro does not yet allow for HPC application in academic and economic environment, however progress has been made in terms of research institution capabilities, and links between academia and industry. The general economic situation, lack of funding, the leak of a skilled workforce, low level of cooperation among stakeholders are some of the most important obstacles for the development of these areas. The alignment of National strategies to the visions of European Union is an important step to promote and improve the situations regarding high ICT usage and innovation, however, concrete actions are problematic due to the limited resources available. Montenegrin society is open and supportive towards high ICT practices, and their cultural frames can become the leading pylon for the development of national HPC infrastructure. However, there is much to work upon and obstacles to overcome.

Keywords: innovation, HPC, actors, Montenegro, academia, industry

1. Overview of Country Innovation Performance

Montenegro lies on the coast of the Adriatic Sea in the Balkans, SE Europe. Its economy is predominantly based on tourism, services and metal processing (World Bank 2013). The economic crisis in 2009 and consequent recession have shown that Montenegro economy is too unvaried and depends too heavily on external finance, however this could be reversed with innovation (ibid.). As a result of a lacking research infrastructure and financing, research institute laboratories are obsolete and no research institutions are able to provide added-value results (ibid.). In 2006 Montenegro became an independent country and instantly began formulating reforms to allow more investment in research and innovation (ibid.). The new quality assurance systems were founded on European standards and resulted in establishing connections between different research institutes and the institutes and private sector as well as provided a legal framework (ibid.). After establishing collaboration with the EU and European Research Area, the government developed Strategy for Scientific Research Activities (2008–2016), increased investment into research and development and began with improvements to the education system (ibid.).

The paper focuses on appraisal of High Performance Computing (HPC) technology and innovations actors active in HPC as crucial actors for further development in HPC in Montenegro.

2. Appraisal of HPC Situation

Montenegro was formerly the smallest republic of Yugoslavia. Although Yugoslavia was economically developed, Montenegro with its predominantly mountainous layout and coastal position was not as industrially advanced nor had expanded transportation for large industrial sites on par to other Yugoslav republics (Innovation and Entrepreneurship Centre Tehnopolis, Montenegro 2017). Due to its smallness, its higher education system consisted of one university, established in 1974. This number has only recently expanded to three universities.

Today, Montenegrin economy is based primarily on tourism and associated services. The most expanded industry is metal processing. Because the two industries depend heavily on external resources, Montenegro is very susceptible to fluctuating production and GDP in case of crisis (World Bank 2013). Since transportation system has not been fully modernized and expanded in the past decades, there is still no active connection to education institutions and industrial sites in nearby Croatia and Serbia. The research infrastructure is outdated and lacks resources to be comparable to European labs and institutes (ibid.). No substantial investments are made to make the research infrastructure more commercially appealing by the government (ibid.). Although the private sector spends one quarter of its expenditures on research and development, it has not established ties with local research institutions, while national education institutions limit collaboration to private education institutions (Regional HPC Capacity Report 2018). After Montenegro associated with the EU, they began modernizing the education system and gradually increasing expenditure for research and development (World Bank 2013).

The result of Higher Education and Research for Innovation and Competitiveness Project (HERIC), funded by a loan from the World Bank, was improved collaboration and knowledge transfer between education institutions and industry (Regional HPC Capacity Report 2018). The project provided a critical mass of research infrastructure, which indirectly postulated the support for high performance computing hard infrastructure and its use in connection with existing infrastructure (ibid.). To induce the use and development of innovative technologies, such as HPC, in research institutions, and other priority long-term goals in research and development, Montenegrin government has adopted The Strategy for Scientific and Research Activity (2012–2016) and Strategy of Innovation activity (2016–2020) (ibid.). The latter contains several focus areas, one of them being Information – Communication technology and the use of modern technologies, including HPC (ibid.).

In line with this strategic goal, several private institutions were recognized as potential drivers for exploring and using HPC. Institutions, such as BIO-ICT Centre of Excellence and Innovation and Entrepreneurship Centre Technopolis, were equipped with new laboratories and equipment for this purpose (ibid.). On the national level, governmental institutions and agencies provide support for HPC initiatives in cooperation with different size companies in energy, agriculture, banking and ICT sectors, research institutions and associations (ibid.). Not much has been done yet in terms of use and development of HPC applications, although Montenegrin institutions are encouraged to cooperate with different European and global institutions, such as Centres for Excellence (ibid.). The first phase of such cooperation should consist of building awareness and capacities for HPC application, including knowledge and competences. In the second phase, appropriate fields of actions should be nominated (ibid.). The Government of Montenegro has supplied sufficient funds for establishing new research institutions, knowledge transfer between academia and industry, and technological advancements in the industry (ibid.). This provides a good foundation for implementation of innovative technologies and HPC as one of them in academia and industry applications (ibid.).

3. Innovation Actors Active in HPC

During the period of InnoHPC project we have made through group interviews and surveys two HPC databases – with information on relevant enterprises in the electronic and the automotive sectors and with HPC providers and competence centres' infrastructure and competencies in Montenegro. The HPC situation of respondent enterprises is represented in the Table 1.

Table 1: The HPC Database of enterprises

No.	Type of organization	Type of company	Number of people with IT or other relevant engineering competencies working in the organization	Existence of a R&D department in the company	Usage of HPC solutions to meet business requirements
1.	Higher Education and Research	Medium-sized company (50–249 employees)	N/A	Yes	Yes
2.	Enterprise (Public Body) in ICT sector	Medium-sized company (50–249 employees)	N/A	No	Yes
3.	Enterprise in public sector	Medium-sized company (50–249 employees)	<10	No	No
4.	Enterprise in ICT sector	Small company (10–49 employees)	31-50	Yes	No
5.	Enterprise in business sector	Medium-sized company (50–249 employees)	<10	No	No
6.	Enterprise in business sector	Micro-company (<10 employees)	<10	No	No
7.	Enterprise in electronic sector	Large enterprise (250 or more employees)	51-100	No	No
8.	Public sector	Large enterprise (250 or more employees)	31-50	No	No
9.	Enterprise in ICT sector	Small company (10–49 employees)	N/A	Yes	No

Source: Database of enterprises and HPC providers, 2018

According to the results collected during the period of InnoHPC project, HPC and Innovative frameworks are not developed in Montenegro. Only two organizations, out of nine, implement HPC solutions in practice – to meet business requirements. One of these organizations, which is a higher education and research institution, implement usage of HPC for R&D in manufacturing or production. The second one, an enterprise in ICT sector, implements HPC in the form of engineering (design) and large scale data management. Moreover, only one third of organizations have an R&D department, showing potential for usage a HPC infrastructure. With the existing R&D departments and usage of HPC being underdeveloped, neither the number of IT skilled and engineers are showing an encouraging perspective. The database of HPC providers and competence centres' infrastructure and abilities are presented in the Table 2.

Table 2: The Database of HPC providers and competence centres' infrastructure and competencies

No.	Type of organization	Usage of HPC in organization	Can enterprises use your HPC infrastructure?
1.	Public Center	Only a department/part of the organization deals with HPC	No, we use it only for internal research
2.	Public Center	I don't know/No opinion	I don't know/No opinion
3.	Private Center (inside a company)	Only a department/part of the organization deals with HPC	No, we use it only for internal research
4.	Public Center	I don't know/No opinion	I don't know/No opinion
5.	Private Center (inside a company)	I don't know/No opinion	I don't know/No opinion
6.	Public Center	Only a department/part of the organization deals with HPC	Yes, but only if we are partners in a project/network
7.	Private Center (inside a company)	I don't know/No opinion	Yes, but only if we are partners in a project/network
8.	Private Center (inside a company)	I don't know/No opinion	Yes, but only if we are partners in a project/network

Source: Database of enterprises and HPC providers, 2018

These data suggest the same conclusions as previous analysis. Out of eight HPC providers and competence centres' only three use HPC – within a department or at least a part of organization deals with HPC. The same rate is for the openness, only three organizations are enabling enterprises to access their HPC infrastructure.

The current status of technological innovation in Montenegro does not yet allow for HPC application in academic and economic environment, however progress has been made in terms of research institution capabilities, and links between academia and industry (Regional HPC Capacity Report 2018). Accepted nation-al strategies and initiatives also demonstrate the government's detailed action plan and long-term focus on supporting innovative technologies (ibid.). All the measures mentioned above will gradually improve technological infrastructure, competences and capacities in Montenegro (ibid.). To help speed things in the right direction, Montenegrin institutions are encouraged to connect with European Centres of Excellence for additional knowledge and support (ibid.).

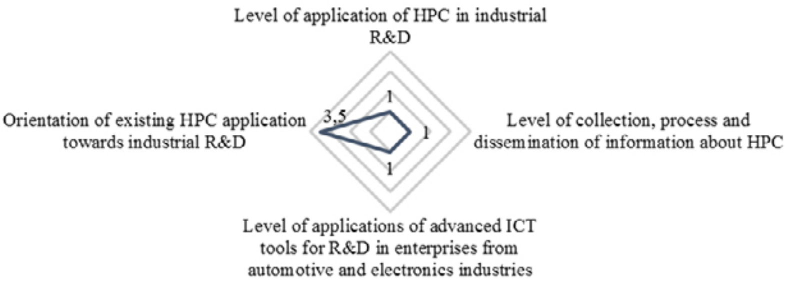
4. National Assessment of HPC Performance

As stipulated earlier, Montenegrin Innovative and HPC infrastructures are suffering from underdevelopment. According to WIPO Statistics[40] the number of innovations in automotive and electronics sectors counts less than a dozen active patens between 2006–2017. Electrical Machinery apparatus and energy sector gained 9 patents, and stands one of the most innovative in the country. However, other industrial sectors show a lesser performance. Area of Engines, Pumps and Turbines registered 6 active patents, while Machine Tools only 3. Such results are definitively lower than the existing average among Europeans and Balkans countries.

Following the results of the Workshop and Interviews (Regional HPC Capacity Report 2018), one can drown the same conclusions about Montenegrin Innovative and HPC application performance. Participating stakeholders, representatives of triple helix (administrative-education-business sectors), considered the heavily underdeveloped status of automotive and electronics industries, the lack of domestic funding and available funds for innovative projects, lack of information about ICT and especially HPC capabilities for the SME's development and innovation, and lack of general information about the HPC infrastructure, as crucially important in understanding the current situation. The case of both HPC and Innovation ventures can be represented in the figure 1, with scores that respondents agreed upon (1 being the lowest score and 4 highest).

40 https://www3.wipo.int/ipstats/IpsStatsResultvalu

Figure 1: HPC and Innovation Profile



Source: Interview results and workshops within InnoHPC

The graph highlights the low application of HPC in industrial R&D. A potential explanation for this can be the general economic situation of Montenegro and its Industrial R&D, that are underdeveloped, especially regarding automotive and electronic areas. The lack of information about HPC infrastructure and its innovative opportunities, including the low profile of HPC in education institutions, especially universities and research centres, leaves its marks upon the exploitation of high-level ICT. Respondents also mentioned that there is no actual institution that is leading the development or represents the interest of HPC providers or users. The existing strategy resources and documents regarding the inclusion of ICT and modern technology in the development processes do not necessarily concern themselves with the HPC framework.

Although it is clear that the actual status of events is not very positive, in terms of HPC application, and that a clear-defined regulation is missing, the potential for the HPC usage is nonetheless present. Montenegrin strategy for development documentation, defined until 2020, considers overall modernization of development and innovative technologies. That leaves the HPC sector as a potential alternative. Interviewed respondents commented that despite the fact that Montenegro is a small country and the vast majority of its databases can be processed on a standard computer, there are areas where the application of HPC is plausible. Agricultural sectors' research and development activities (e.g. BIO-ICT centre of Excellence); defence sector[41]; billing, finances, and ad-

41 In 2018 Montenegro Armour Group presented a concept of MAŠAN, first domestic armoured vehicle, that is still receiving feedback from relevant stakeholders regarding its design. This can be a particular example of the potential of HPC usage in automotive R&D. Due to the fact that data was collected prior to MAŠAN's presentation, respondents did not consider this case.

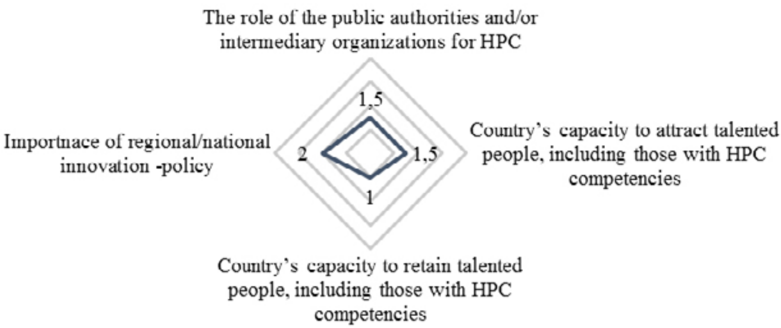
vanced business intelligence; telecommunications and internet providers; gas exploitation and research on alternative energy sources; or even the enterprises that engage into big-data collation can benefit from an HPC or high ICT infrastructure. They also shared their optimism regarding Montenegrin human capital and its capacity to learn and accommodate with using high ICT skills for R&D.

As a result, the current status of HPC application in automotive and electronic industries is low, due to the limited importance of these sectors for the overall economy and the absence of legal framework, alongside with scarce interest in HPC and ICT technologies for innovation among the general public. However, there is potential for the HPC application in Montenegro, that still remains unsupported by the strategic vision of decision-makers. The next step to perform is to unveil a more concrete attitude and analysis of HPC relevance, including the status of active actors and contextual variables, following the explanatory model of Social Field Theory (Beckert 2010; Fligstein 2001). Also, the methodology of data collection was focused on interviewing regional stakeholders that were selected following the theory of triple-helix approach (Leydesdorff and Etzkowitz 1998; Etzkowitz 2003) Thus, the chapter will capture the importance of Institutional, Networking and Cultural frameworks for the applicability of the HPC in R&D and innovation processes.

4.1. The Relevance of Institutions for Montenegrin HPC Performance

Montenegrin authorities approve and are open for general ICT modernization and improvements, however, they have their limits especially when considering real support. General situation of authorities' efforts to promote HPC and high ICT development is presented in the figure 2.

Figure 2: Institutions



Source: Interview results and workshops within InnoHPC

One of the most prominent obstacles that impede public authorities and other institutions to be more supportive in the promotion of HPC and other ICT policies is the issue with funding capacity. Respondents mentioned that the existing support programmes at the national level embody a limited fund-resources pool, commenting: "*They recognize, they support, but they don't give funds…*". Considering Montenegrin economic profile, with an 11,5% of GDP foreign direct investment and an external debt of 65% of its Gross National Income (data from The World Bank for 2017), it creates complications for the aforementioned support. Even if there are sectors with identified potential for usages of advanced ICT technology, like research on oil, energy and energy sources, those seem to be only strategic visions, with no concrete actions yet performed.

In the respondents' opinion, the government is expecting the private sector to take the initiative, beginning clustering and involving in R&D propjets. These conclusions came after the comments that for the most innovative processes actors from enterprises and academia are creating their own networks with local and foreign partners, receiving little help from public authorities. In this regard, they also mentioned that the High Education Institutions (HEI) are lacking support from the government and that they have no curricula to include HPC frameworks. They "*are not doing very well*", as presented by respondents. Thus, the missing teaching subjects on HPC services and the general atmosphere in HEIs contributes to the lack of HPC training for many other groups.

Alongside the funding problem, Montenegro is not competitive with other countries. As Figure 2 shows, Montenegro has issues with the ability to attract and sustain talented people, skilled with high ICT competencies. As respondents mentioned, it cannot offer the same conditions as other countries, especially for the target demographics who would like a job in a big, transitional company.

Nonetheless, there are some promoted projects by the government that can benefit from the HPC. One of those is the "Technopolis" centre[42], in Nikšić, that was established by the government in 2013. Also, as the respondents commented, Montenegrin authorities are engaged in a partnership with the EU, and are tangential to the general European HPC strategy. Those relationships seemed optimistic for the usage of foreign HPC infrastructure and network development of national actors. Also, these were perceived as hopes for the development of Montenegrin own HPC infrastructure and extension of ICT capabilities.

42 http://www.tehnopolis.me/online/en/what-is-tehnopolis/

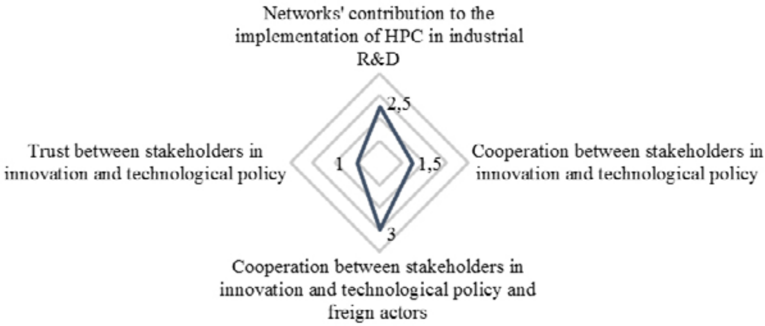
As for the skilled staff, respondents considered that the learning capabilities of young generations are on a decent level and up to the task to re-profile and use high ICT skills if the necessity arises. Even if there is the drain of talented specialists, they recognized the fact that Montenegrin citizens have an easier task to develop a business in the country due to governmental regulations. That, in their opinion, is the leverage to sustain a relatively innovative society, in non-competitive conditions. Moreover, the Ministries of Science and Education, including HEIs, try to attract skilled staff to increase the visibility of their successes and spread their network reach. In that regard, respondents commented that those practices shall include attraction of Montenegrins established or working abroad, to enhance the results through knowledge sharing.

Concluding remark on the importance of institutions is suggesting that the potential for the applicability and usage of HPC exists. Moreover, there is the possibility to work with European specialists, bringing more visibility for these projects. However, lack of funding and drain of the skilled workforce is affecting the situation, at the moment. Even the alignment of national policies and strategies with EU practices are not necessarily improving the existing status-quo. As mentioned in the previously, not only the automotive and electronics industries are underdeveloped in Montenegro, with a low innovative profile, there is limited applicability of HPC for such purposes.

4.2. Network Impact on Innovation and HPC Framework

As a major concept in any explanatory innovation theory, networks usually assume the role of the carriers of information, spreading it among interconnected actors (Granovetter 1985). By colliding existing and new information, networks succeed to influence the innovative performance of involved actors. The general overview of Networks' impact upon the Montenegrin HPC and Innovative frameworks is presented in figure 3.

Figure 3: Networks



Source: Interview results and workshops within InnoHPC

Interviewed respondents considered that the best practice, regarding the collaboration of using HPC infrastructure, or other high ICT skills, for the purpose of innovative performance, is mainly done by the good level of collaboration with foreign actors. They mentioned that the Ministry of Science has a collaboration with the European Organization for Nuclear Research (CERN), allowing Montenegrins to use their existing HPC infrastructure for co-creative practices. Other institution, who do not have access to these resources, are mainly seeking their own transnational networks and foreign funding for the development issues. Many practices are already established, mostly with EU partners, enforcing know-how and technological transfer, improving capacity building of national actors, etc. There are certain push-backs, linked to the complications of international collaboration, like communication or information transfer, but those seem to have little effect since the best score was granted to the international collaboration procedures.

National networking is less reliable as the international one, concerning the use of HPC infrastructure. It is due to the low level of dedication and trust among national institutions and organizations. Respondents' suggestion was to foster cooperation between national actors, since practice shows that agents, sharing mutual activities, tend to have better confidence in each other. The public-private partnership was defined as a potential area where HPC infrastructure can foster. "Technopolis" centre at the Science and Technology Park, or European Information and Innovation Centre Montenegro (EIICM)[43] are examples of existing efforts, of Montenegrin government, to encourage inter-institutional

43 https://wbc-rti.info/object/organisation/10915

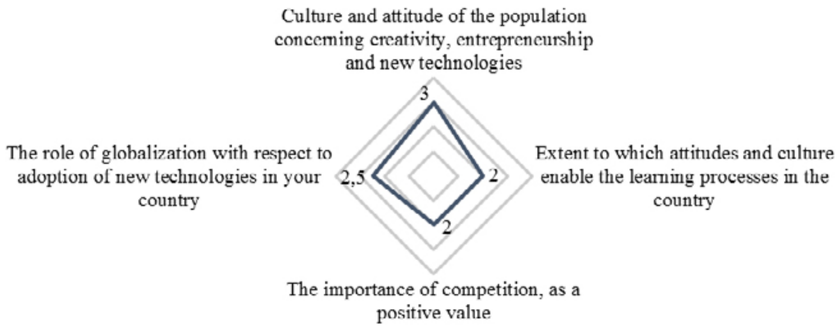
networking, identified by the desktop research. Despite that, lack of communication and absence of Technology Transfer offices were listed as weaknesses, following respondents' opinions. The contradiction can probably suggest that those practices can be improved to promote trust and fruitful collaboration between engaged parties. Also strengthening of Intellectual Property Rights protection could be a potential area for the governmental structures to focus, in order to strengthen trust and collaboration.

National networks are significantly less important and offer limited opportunities for HPC usage in industrial R&D. Better practices can be identified by looking at the collaboration of national stakeholders with international partners. Collaboration with the EU and CERN are optimistic applications and real opportunities for the Montenegrin enterprises or HEIs to access HPC foreign infrastructure.

4.3. The Role of Cognitive Frames for HPC Implementation

Montenegrin cultural and value framework, as a pylon for encouraging HPC infrastructure, shows the best overall scores, compared to institutional and network concepts. The openness of the general public towards modernization and advanced technologies is a supportive background for the HPC infrastructure in the future. The general appraisal of Cognitive Frames' impact can be addressed through picture 4.

Figure 4: Cognitive Frames



Source: Interview results and workshops within InnoHPC

Montenegrin interviewed respondents were suggesting that the citizen's attitudinal framework is supportive and open for the new technologies and ICT methods. General entrepreneurial spirit, increased awareness about technological state-of-the-art methods and creativity levels of Montenegrin public were commonly addressed throughout the interview. Thus, it is reasonable to say that the Montenegrin mind-set could be the first milestone of HPC implementation in the country. Learning capabilities of young demographic are also to consider in this chapter. As previously mentioned, respondents were optimistically evaluating the capacity of students to learn and adapt to high ICT necessities. A potential setback is the lack of motivation for young generations to be more actively involved and study harder.

As an important cultural and economic engine, respondents noted that competition is a specific feature of the population. However, they also considered that it can become an obstacle since lack of trust and high competitive attitude between companies affect the rate of their co-creative and collaborative actions. Competition is emphasized in Montenegrin culture, but it deteriorates the teamwork. Prior to this section, respondents commented that the Montenegrins are driven by the idea of being self-employed, indirectly suggesting that they are accommodated with a competitive environment.

As established previously, internationalization plays a great role in Montenegrin innovative and development process. As most of the networks spread to foreign partners, globalization is an influential component for Montenegrins HPC usage. Abroad collaboration and fund-searching were established as "winning practice" by the respondents. They also acknowledged that there are several issues with globalization since most of the foreign companies and partners impose certain standards that are not cost-efficient at the national level. Moreover, the interest of international companies to reduce costs of production or cost of services, creates the risks of moving parts of the national databases or other production elements abroad. One way to oppose that is through national regulations, trying to maintain the relevant resources in the country. Respondents gave a real example of telecommunications, where the risk of movement can leave companies at 10–20 % of the actual volume of work. Such a setback will influence the general economic environment and the innovative practices as well.

The Cognitive Framework of the Montenegrin population is characterized by openness and supportive attitudes towards modernization of technology. Education capacities were considered sufficient and up-to-the-task by the respondents. Also, the general alignment to international practices, networks, strategies and visions are creating the opportunities to use HPC infrastructure abroad. International practices and precedents of HPC usage can have a decisive influence and encourage groups to advocate for implementing it at domestic level.

5. HPC Development Recommendations

As established in the aforementioned chapters, Montenegrin situation regarding innovation, development and HPC infrastructure feels the necessity for improvements. As interviewed experts suggested numerous unsettled issues remains in the sector of financing, dissemination of information and engagement of the general public. Regional HPC Capacity Report (2018) provides a set of documentation and aggregated collected data, regarding strategic and suggested objectives for the improvement of the general circumstances.

One of the most important documents, worth considering, is the Montenegrin Strategy of Information Society Development 2020. This is a framework of goals to be achieved until the second decade of the XXIst century and ensure an overall usage and importance of ICT technologies, including the development of basic and above-average ICT skills. Main focus areas, of the mentioned document, are cyber security, e-economy, e-health, e-education and e-inclusion, also the general research and innovation performance for ICT area.

Some concrete examples of established goals include the development of cybersecurity infrastructure. The objective concerns prevention and ability to combat the internet frauds, insecurity and incidents. Thus, Montenegrin government plans to establish local cybersecurity centres, meanwhile increasing the awareness of the general public towards the importance of secure navigation. Education about cybersecurity measures shall start from early stages of learning processes, in 6th to 9th grades of primary school. In the fields of e-education and e-health main objectives is to raise the number of available services and provide continuous on-line assistance, and gain the attention of the general public of their availability. The strategy is channelled to increase the overall ICT usage in all important sectors of national development and perform an information-based society.

The development propositions, concerning HPC infrastructure, can be found in the performed workshop, that included Serbia – Bosnia and Herzegovina – Montenegro region. Experts agreed that several general steps shall be performed. Firstly, if it is to consider the implementation of HPC infrastructure at national levels, the strategic documentation must be developed, including legislation to regulate and represent the interest of HPC. Also, dissemination of information among management of SMEs and other relevant stakeholders shall be one of the basic actions. That will make raise advocacy voices and will create a necessity for the development of courses for HPC skills in universities and other training programmes. Bringing this topic to the attention of authorities was seen as concluding step, so that more fruitful action can be performed, like the creation of international conferences, etc. to stimulate the efficiency of HPC for innovative purposes.

6. Conclusion

Montenegro, as a small economy, aspiring to join the European Union, faces multiple obstacles considering innovative and development status. Its economy is vulnerable because of is homogenous characteristics, with an underdeveloped automotive and electronics industry. Most important issues are the financial problems, embodying the public debt and dependency on foreign investments. That leaves its marks upon general education system, economic opportunities of enterprises and overall innovative performance.

Regarding HPC infrastructure, and most of the innovative actions, Montenegro leans upon international networking since domestic cooperation of actors suffers from lack of trust and financing. As established by the interviews, national institutions, networks and general context are insufficient to provide necessary conditions for fruitful development. Even if national strategic vision is open and supportive towards the development of general ICT capabilities and an increase of high-tech skills, the aforementioned problems directly affect the implementation of proposed objectives. It is due to the collaboration with the EU partners and CERN Institute, Montenegrin researchers are able to use foreign HPC infrastructure, in cases of joint projects.

A milestone for the national HPC implementation can be the general cultural characteristics. As respondents commented, the population is very supportive and acknowledges the importance of ICT skills. Education and learning capabilities of the young generations were considered up to the task when suggesting the potential development of HPC in the country.

Considering these general assessments, authors mainly agree with the proposed solutions. Increasing the awareness of the public about the potential usefulness of HPC, implementing university and school curricula to capture HPC-related competences, attracting SME management and increasing their awareness about rewarding experiences (of actors using HPC for innovation) and performing national strategy/vision and legislation for HPC, shows potential for improving the existing status-quo. Montenegrin efforts to become an Information Society would definitively have a positive impact on the matter. However, there are multiple obstacles of delicate matters like financing, inter-institutional trust, and domestic networking that would be wise to consider first. The future will show if there is a place for the Montenegrin domestic HPC project.

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National Case Study in the Danube Region: Romania

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Abstract

Romania remains a modest innovator, as revealed by the latest edition of the European Innovation Scoreboard. While national funding mechanisms have proved largely inefficient, EU policies and funds remain the main source for driving and financing innovation in Romania. Several R&D projects (e.g. ELI-NP – Romania's star public research project) have been developed so far, but otherwise Romania's innovation potential remains largely unexploited. The present paper analyses the actions taken by Romania at national and EU level in order to enhance innovation and use the potential of Industry 4.0 - especially High Performance Computing – including the national programmes implemented so far. A SWOT analysis of Romania is also performed, revealing Romania's strengths and weaknesses in what regards Industry 4.0 and HPC. The results of the analysis, combined with management and leadership techniques, should be a useful resource for improving Romania's weaknesses in the field of innovation, by contributing to the adoption of adequate digital policies and strategies.

Keywords: Romania, HPC case study Romania, InnoHPC project

1. Overview of country innovation performance

At EU level, Romania is still a junior in innovation. Insufficient funding aside, more damaging factors include the self-created domestic obstacles, by which legitimate research is over-shadowed and/or squeezed out by weak projects draining a significant part of the national funds. Given the inefficiencies of national funding mechanisms, the main drivers of innovation (in all sectors) are the European policies and funds. There are a few high-prestige R&D projects (such as the ELI-NP – Romania's star public research project) in what otherwise could be described as a sea of yet-to-be-fulfilled potential.

Romania is listed in the Modest Innovators category of the EU 2018 Innovation Scoreboard [1], similar to the 2017 edition of the report. The country shares the category with Bulgaria and ranks last in the EU on its innovation performance. The annual European Innovation Scoreboard (EIS) offers a comparative assessment of the research and innovation performance of EU member states and selected third countries. It analyses the relative strengths and weaknesses of national research and innovation systems. The EIS assesses countries on four main types of indicators and ten innovation dimensions, capturing in total 27 different indicators, such as human resources, attractive research systems, innovation-friendly environment or investments. The Modest Innovators category includes countries with a performance level below 50 % of the EU average. Romania's performance has been decreasing since 2010 by 14 %. Alongside Cyprus, with performance declining by 9 %, Romania is among the two member's states with a performance that declined by more than 5 %. As revealed by the report, 'innovation-friendly environment' and 'sales impacts' are the strongest innovation dimensions in the case of Romania, while 'innovators' and 'firm investments' are the weakest. The 'innovation-friendly environment' dimension covers broadband penetration and opportunity-driven entrepreneurship. The 'sales impacts' dimension covers medium and high tech product exports, knowledge-intensive services exports, and sales of new-to-market and new-to-firm product innovation.

The 'innovators' dimension refers to SMEs with product or process innovations, SMEs with marketing or organizational innovations, and SMEs innovating in-house. 'Firm investments' covers R&D expenditure in the business sector, non-R&D innovation expenditures, and enterprises providing training to develop or upgrade ICT skills of their personnel. On average, innovation performance in the EU has increased by 5.8 % since 2010. Performance registered the highest growth rates in Lithuania, Malta, the Netherlands and the United Kingdom.

The present research illustrates the actions taken by Romania at national and EU level in order to enhance and better use the potential of Industry 4.0 – especially High Performance Computing. The research is therefore focused on national programmes supporting Industry 4.0. Although Romania is a country in which industry has a relatively low share in the overall economy, a SWOT analysis of the country does reveal a number of strengths in this field. The results of the analysis may be further used in the formulation of appropriate digital policies and strategies.

2. Appraisal of HPC situation

Romania is still underdeveloped in the field of high performance computing, but the importance of HPC was recognised in the National Strategy for RDI 2014–2020. Thus, the strategy mentions that "developing software, technologies for the internet of the future and high performance computing play a central role in solving the big societal problems" [2]. The existing HPC infrastructure was developed inside the national research institutes through projects funded through national or European programmes. According to the "Engage in the Romanian Research Infrastructure System" – ERRIS national platform, there are 348 pieces of equipment matching high performance computing [3]. Hardware main contribution for HPC comes from parallel computing systems hosted by national research institutes and universities. Except the supercomputer BlueGene/P from the West University of Timisoara, the other systems are in general heterogeneous clusters witch multicolour processors. The national HPSC infrastructure is generally used to roll parallel applications developed in-house, from external sources (ownership or open sources) or codes obtained through contribution to external codes.

The need to have well skilled human resources in HPC is seen in the increasing trend of developing educational programs in HPC, one example being the MA in Artificial Intelligence and Distributed Computing at the West University of Timisoara. Regarding the private sector, even if the number of enterprises that benefit from HPC is small, there are several large companies like IBM which offer HPC facilities. Some SMEs are also active in this field, as for example Spearhead Systems SRL, SC Wing Computer Group SRL or ETA2U.

3. Innovation actors active in HPC

Preliminary literature review shows that the Romania supercomputing has grown continuously and changed constantly. Based on the literature review we conducted semi-structured interviews, desktop research and we organised workshop to find key-elements of active actors involved in HPC in Romania. Firstly, we divided actors into two groups: HPC providers and SMEs (including also large enterprises) providers from the industrial area. In what regards HPC hard infrastructure and soft competencies in the country, including experience, thematic focus, available infrastructure we identified thematic research projects in which Romania has been involved and has demonstrated the necessary experience for developing HPC, i.e.:

- 2001: National Center for Information Technology (NCIT) of the University Politehnica of Bucharest started with the creation of CoLaborator, a Research Base with Multiple Users (R.B.M.U) for High Performance Computing (HPC) that benefited from funding through a World Bank project [4]
- 2006: NCIT's infrastructure was enlarged with the creation of a second, more powerful, computing site, more commonly referred to as the NCIT Cluster [4]
- 2007: the creation of the High Performance Computing Laboratory of the Faculty of Electrical Engineering and Computer Science at University "Ştefan cel Mare" in Suceava is motivated by the need of developing and improving new methods for computing high volumes of data using parallel and grid systems [5]
- 2009: A National Centre for Supercomputing was established in close relation with IBM, but in 2013 this was embodied in the Romanian Digital Agenda Agency [6]
- 2010–2013: FP7-eInfra HP-SEE (High-Performance Computing Infrastructure for South East Europe's Research Communities) project was implemented, linking existing and upcoming HPC facilities in South East Europe in a common infrastructure and provided operational solutions for it [7]
- 2012–2014: HOST (High Performance Computing Service Centre) project was implemented. The main objective of HOST project was to improve the research capacity and reinforce the scientific and technological potential of the Research Centre in Computer Science of the West University of Timisoara in order to unlock its capacity and make it accessible for the European Research Area [8]
- 2013: Cluster HPC was developed by ETA2U enterprises at West University in Timisoara [9]
- 2015–2017: FP7-EINFRA SESAME-NET (Supercomputing Expertise for SmAll and Medium Enterprise Network) project was implemented. The aim was to create a same named open and inclusive European network of Competence Centres and Organizations joining forces in order to raise SMEs' awareness on HPC and to demonstrate its features and benefits [10]
- 2015–2018: VI-SEEM (Virtual Research Environment in Southeast Europe and the Eastern Mediterranean) project built on the success of previous e-Infrastructure projects that have been crucial for enabling high-quality

research & ICT developments by providing networking and computational resources, application support and training, in both South East Europe and Eastern Mediterranean, and have supported the European vision of inclusive and smart growth, based on knowledge and innovation, enriching the European Research Area. [11]

Based on the desktop research conducted in April 2017 we identified that Romania has all the actors needed for an innovative HPC development in the country: research centres, universities, enterprises, professional Associations & NGOs. Moreover, a variety of applications of HPC in the industry and R&D have been developed to increase technology transfer at country level.

During the implementation of the InnoHPC project, semi-structured interviews and workshops were conducted to identify the HPC development gap in this part of Danube Region. For a clear interpretation we designed a SWOT analysis as presented in the following table:

Table 1: SWOT analysis of HPC development in Romania

Strengths	Weaknesses
• The emergence of professional associations in the field – e.g. ARCAS; the existence of IT clusters; availability of HPC infrastructure in universities; good level of IT knowledge • Openness to new technologies • Highly skilled professionals and intellectual capacities • Dissemination efforts from academia to find and inform industrial partners. • Implementation of projects in the field • HPC is studied in universities • Competitive workforce in the field of new tech • Access to opportunities and knowhow. There are several ways to receive information (i.e. thematic events) • Relevant stakeholders are involved in the processes of promoting and using HPC	• Low level of application in automotive – big projects are split into smaller ones which do not require HPC • Delay of 3-5 years comparing with developed countries regarding usage and implementation of the latest technologies • General problems related to industrial research • Lack of appropriate research infrastructure in companies or in public and academia • In academia, a lot of research infrastructure is out of date • Most skilled people work in outsourcing even if they have potential to innovate • Funding – HPC applications are quite expensive • Professionals are very good in executing, but fail to express their creativity or innovativeness

Strengths	Weaknesses
• Advanced ICT tools support the increasing speed of tasks • Advanced ICT tools help improve PM and QC • HPC is mostly used in automotive in testing and development • Access to funding and cooperation • Advanced ICT tools support the emergence of common research objectives for industry partners and academia • Advanced ICT tools make automotive and electronic industries stronger • HPC is mentioned in the national strategies and plans (i.e. National Strategy for RDI 2014-2020) • HPC is dispersed: somewhere in companies, somewhere in research • Synergy-based opportunities • European funding programmes facilitate access to cooperation • Informal trainings • There are plenty of talented and very well trained people already in Romania • There are opportunities for locals to work in any field • Migration Policy can potentially attract talented people • Low costs for life • Technology available from the previous programming period • Incentives for researchers (salary income derived as a result of carrying out research and development is exempt from income tax) • Existence of ICT hubs • Good results are recognized and valued	• Advanced ICT tools are not much used in daily practice • Few individual enterprises with a high dependency on RTD • Problems with institutional capacity • Tech enterprises produce rather low added value products • The companies in automotive fail to focus on interconnectivity • Few companies use ICT advanced tools • Strategies are orientated towards science and not towards industrial R&D (only a few companies have the financial power to implement such applications; there are few companies that actually need so much computation power and they are generally active in different areas of the industry • Big investments are not performed at the right time, and technology can become easy obsolete • No clear strategic orientation towards industrial R&D • Lack of technology transfer • Not so many companies use HPC tools • HPC is considered too expensive and is not in the area of interest • No connection with tech transfer offices; actually, there are no operational tech transfer centers in any field • Few formal trainings • No vision, no concrete goals, only a general approach • No role for regions and cities • Public authorities do not manage to intermediate between actors using HPC • The quality of life is rather low

Strengths	**Weaknesses**
• Great potential of private initiatives for RDI • High quality of some research institutions • Technological development existent in some parts of Romania, as for example in Cluj, Iasi, Bucharest and Timisoara. • Existing networks are open toward new actors • Cross border: networks built through Interreg programmes, Enterprise Europe Network • RO: 2nd place regarding the number of clusters awarded with Silver Label • Few existing clusters (i.e. in Cluj, Brasov, Sfantu Gheorghe, Timisoara, Bucharest) are doing good work in cooperation within industries. They are part of National Cluster Association • There is strong cooperation between the private companies that are active in this field, with a positive impact on sharing information and knowhow related to the same domain • Partners are chosen / involved because they have a clear added value for innovation development • Companies in networks are active in asking for policy changes for regional development, R&D, industry etc. • The cooperation between active stakeholders brings added value • The cooperation is orientated more towards international partnership • Knowledge transfers are more consistent with the outside partners • Public sector is engaged in doing innovation outside, while in Romania cooperation is driven mainly by private sector in voluntary initiatives	• Few opportunities for future professional development • Romania is rather a talent provider than a talent retainer • Mobility problems • Technological resources are not properly exploited • Negative balance between talented people leaving / coming to Romania • No concrete vision for innovation • No long-term objectives • No real regional innovation policies: S3 are national • National innovation policy is not designed based on a territorial approach • The networks are focused on one sector • Few well defined networks • Problems with the effectiveness of the clusters (the evaluation process is descriptive) • Most stakeholders do not continue the collaboration after the completion of their projects. • Networks in automotive are little focused on research • HPC/ICT are related only to one enterprise or to similar companies in the same sector • No a viable public-private partnership • Little work/project continuity due to the lack of national programmes to ensure the sustaibability of projects funded under EU programmes • Top down approach for policy makers • Lack of trust between industries in the same sector (competition) • Enterprises' lack of trust in existing networks

Strengths	Weaknesses
• The fact that students know that what they learn is applicable after graduation motivates them to focus on gaining/ improving skills during their studies • The presence of big associations who built networks and thus foster trust between their members • Openness toward new technologies. • Existence of successful innovation centers and test centers for new tech in our country • A high rate of early adopters • Good steps in the entrepreneurial direction • Creative entrepreneurs	• Enterprises' lack of trust in existing networks • Lack of territorial approach in designing policies for networks • Academia does not allow access to private companies to use their infrastructure • Entrepreneurs do not trust academia • Key actors have a rather conservative attitude • Low competitiveness • Majority of companies are low and medium-tech • People do not trust in their capacities
Opportunities	**Threats**
• Entering European networks to develop new projects and to increase knowledge • Accessing structural funds for infrastructures	• brain drain • existing infrastructure becomes obsolete • lack of interest from companies in cooperating with research environment; reluctance for cooperation

4. HPC Benchmarking

To share and validate the results of the needs and opportunities for HPC within the Danube region, in relation to the electronic and automotive sectors, we selected a series of recommendations for HPC development at EU and national levels:

1. To solve the legislative issues related to the interdiction of generating revenues from the exploitation of public infrastructure: companies which want to benefit from the expertise of HPC specialists working in universities or public research centres should host their clusters in the HPC centres – this would allow HPC specialists to better work with companies.
2. To bring business and research closer:
    - Developing a "bridging" framework in which companies ask for solutions and there are teams of researchers proposing them. Thus, companies will be able to choose the solution most adequate for their needs.

- o Joint internships
- o Academic thesis in joint coordination university-industry

3. To attract companies: research institutions should present the acquisition of their services as an investment which will generate profit over time.

Based on the recommendations and surveys applied during the project's implementation we found that more than 60% of active actors are involved in innovative R&D activities using HPC. This allows us to design a series of guidelines for the digital transformation of industry in Romania, as described in the next section.

5. Recommendations

The main recommendation of active actors from both groups of interest in HPC have been designed taking into consideration the Industry Guidelines developed through the InnoHPC project [12]. The recommendations are presented in relation to the guidelines, in the following figure and table.

Figure 1: Recommendations for accelerating the digital transformation of industry in Romania

Table 2: Recommendations for accelerating the digital transformation of industry in Romania

Co-financing research and innovation (R&I)
• Supporting projects initiated by economic operators by funding thematic projects through a set of instruments focused on priority areas (ICT including HPC is one of Romanian national smart specialization) – on short/ long term, on phases from idea to market • Supporting projects initiated by economic operators by funding RDI projects conducted by enterprises, individually or in partnership with research institutes and universities for process and product innovation (goods and services) in economic sectors with high growth potential (ICT including HPC is a national smart specialization)
Infrastructure
• Co-financing research and development infrastructures for enterprises • Financing projects for research and development infrastructures in the public sector – developing the existing ones and creating new infrastructures • Creating a unique point (National Register of Research and Development Infrastructures) to provide increased access to infrastructure for both public and private entities, to create a market for scientific and technical services, to increase the international visibility of research results in Romania and their economic sustainability
Support factors and services
• Human resources and education: Improving the quality of the educational system to be correlated with the labour market (e.g. educational offer based on ICT to be at least 30% of compulsory educational programmes) • RDI: Supporting SMEs to launch new innovative products or services through venture capital, grants, collaborative projects • Digital infrastructure: Improving digital broadband infrastructure (e.g. basic broadband for 100% of citizens until 2020)
Enhancing the digitization of Romanian industry
• To offers an environment for strategic dialogue and decision for the digitization of industry • To bring startups at the forefront of the conversation on digitalization
Addressing industry verticals where digitization projects can have significant impact
• Stimulating projects in industry verticals where digitization projects can have significant impact (e.g. smart/autonomous cars, smart cities, agritech, energy 4.0, e-health, fintech)
Establishment of Digital Innovation Hubs (DIH)
• To establish Digital Innovation Hubs (DIH) to offer companies a chance to identify and attract talent, technology, and solutions; to improve their competitiveness; and to position themselves at the forefront of the fourth industrial revolution

Promoting innovative groups and competitive poles
• Promoting competitive groups (clusters) and the specialization of employees in the field, with a focus on those within the clusters of excellence in Bucharest, Cluj, Iasi and Timisoara
Supporting research for regional infrastructure development
• Developing research and ICT infrastructure at global level based on the existing regional scientific research • Promoting knowledge transfer between partners and supporting a comprehensive legislative framework for intellectual property rights
Financing ICT innovative initiatives in Romania
• To support investments in three categories: o Type 1: Small investments in new ICT instruments with market potential, but small contribution o Type 2: Medium investment in ICT initiatives with proved market potential and the possibility of returning investment o Type 3: Big investments in ICT, in confirmed models which received finance from multiple sources
Technological development in a global context
• Supporting innovative projects aligned with the most performant European and international standards • Supporting early adoption of disruptive technological solutions • Supporting applied research and industry digitalization • Supporting entrepreneurship and the development of national technological solution competitive at global level
Technological development orientated towards future
• Supporting last-hour technology and permanent innovation in high-tech by offering a constant framework for digital education and training for all citizens
Awareness about existing HPC facilities
• Increasing the visibility of existing HPC infrastructure and competencies • Supporting the access of all interested actors to HPC infrastructure financed by public funds
Realization of a common integrated HPC infrastructure in Romania
Prioritizing the development of the existing HPC infrastructure instead of financing new ones • Allocating funds to support exploitation of the existing HPC infrastructure (e.g. for human resource) • Developing top-down policies to capitalize on the spillover around the existing HPC infrastructure

6. Conclusions

Despite its modest position in the European Innovation Scoreboard, Romania does have a significant potential for developing HPC-based industries. The SWOT analysis conducted as part of the current research revealed multiple strengths in what concerns Industry 4.0 and HPC, which could be further exploited through the development of coherent policies. Although the analysis is exploratory, the results provide an excellent basis for more in-depth research into the potential of HPC. Overall, the analysis shows a stringent need for a better policy framework – including dedicated programmes and funding schemes – that would not only enhance innovation and digitization at national level, but also support the development and use of HPC in both public and private sectors.

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High Performance Computing in Slovakia

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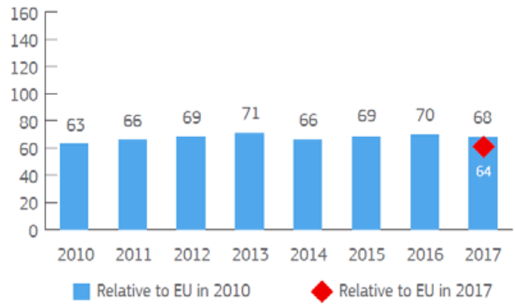
Abstract: Thanks to the strong support of Slovakia government, during years 2007-2013, working network of HPC infrastructure, hardware and software, was developed. Currently, 7 regional centres, working under universities and Slovak Academy of Sciences (SAS), maintain the infrastructure providing these capacities to R&D activities. As the infrastructure still do not reflect needs and requirements of the demand, in 2017 has started implementation of projects financially supporting development of new infrastructure. Despite the development of infrastructure during last years, the cooperation with the industry and skilled staff are still not based on the higher level and we can observe the lack of communication between quadruple helix model members. On the base of situation analysis, we identified the strong need of fast and simple tools for communication and cooperation on the local, regional, national and naturally international level.

Keywords: high-performance computing, Slovakia, research

1. Overview of country innovation performance

Slovakia is moderate innovator. Over time, performance has increased relative to that of the EU in 2010. Employment and sales impacts are the strongest innovation dimensions. Finance and support and Innovators are the weakest innovations dimensions.

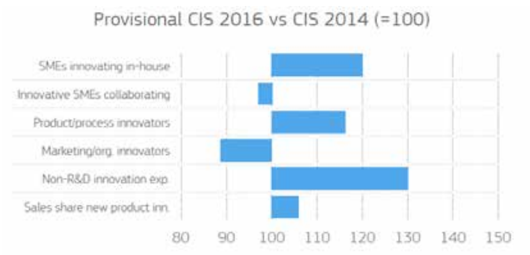
Figure 1: Slovakia in European Innovation Scoreboard 2018



Source: European Innovation Scoreboard 2018

Provisional CIS 2016 data show improved performance for four indicators and reduced performance for two indicators.

Figure 2: Provisional CIS 2016 vs CIS 2014 of Slovakia



Source: European Innovation Scoreboard 2018

2. Appraisal of HPC situation

2.1. General appraisal of situation

Thanks to the strong support of Slovakia government, during years 2007–2013, working network of HPC infrastructure, hardware and software, was developed. Currently, 7 regional centers, working under universities and Slovak Academy of Sciences (SAS), maintain the infrastructure providing these capacities to R&D activities.

As the infrastructure still do not reflect needs and requirements of the demand, in 2017 has started implementation of projects financially supporting development of new infrastructure. Despite the development of infrastructure during last years, the cooperation with the industry and skilled staff are still not based on the higher level and we can observe the lack of communication between quadruple helix model members. On the base of situation analysis, we identified the strong need of fast and simple tools for communication and cooperation on the local, regional, national and naturally international level. Availability of HPC hard infrastructure and soft competencies in the country, including experience, thematic focus, available infrastructure etc.

Before 2007 did not exist in Slovakia no major research centers and even no real funding system for this type of research capacities development and it created the big obstacle in comparison with the other EU countries. The significant change occurred only in the programming period 2007–2013, when research and development capacities were built in Slovakia, mainly by investments from EU Structural Funds.

Thanks to the financial support, national network of HPC infrastructure was developed. Today, the network is composed by 7 HPC centers providing free approach to HPC for students and employers of universities as well as other R&D experts. Approach for private companies is also available, while its price and content depends on bilateral agreement. Complete information can be found on the official website: http://www.sivvp.sk/home/

2.2. Hardware

Within the HPC infrastructure network in Slovakia, we can find technical infrastructure for cluster computing, massively parallel processing and shared memory processing. For cluster computing are available 2 976 cores, memory of 12 144 GB and total hard disk capacity 483,2 TB. Technical infrastructure for massively parallel computing is situated in Computing Center of SAS composed of IBM Power 775, with 4 096 cores and memory of 32 TB, with the operating system AIX.

Shared memory processing capacities are located in Žilina. In is composed of:

- Cluster of SMP nodes linked by Infiniband computing network (IBM Power 755/750)
- High-performance SMP nodes (IBM Power 755)
- Separate SMP server (IBM Power 780)

2.3. Software

With the described technical infrastructure is possible to compute thanks to the wide range of software tools, which are permanently updated and their offer is extended on the base of users' needs and requirements. Just to mention a few, we can currently use tools like e.g.: HMMER (v3.1), GAMESS (2010, 2012, 2014), Maxent (v3.3.3k), NWChem (v6.5), OpenFOAM (v1.5.0), openModeller (v1606+), Structure (v2.3.4), trinity (v2.0.6), Gromacs (v4.6.5, 5.0.5) and many others.

Their complete list is available on the website: http://www.sivvp.sk/softver/

2.4. Applications of HPC in the industry R&D

Today, the institutions of R&D cooperate with the industry, within the all phases of innovation development, but rarely using HPC.

There is only one such a case, the partnership of private company and Slovak Academy of Science. Other HPC centers within Slovakia did not report cooperation of that form, but we hope that the situation will get better in the near future.

2.5. Other country-specific relevant aspects

When we are speaking about research activities, there is need to mention several basic facts from history and actual institutional and funding structure, so the reader could fully understand the context of provided information.

As in other European countries, also in Slovakia, the research activities are aimed at basic or applied research. From this point of view, Slovakia has a very high share of basic research, up to 77 % of public sector spending on research and development is heading for this area, which is the highest value of the European OECD countries evaluated. An exception is research and development at departmental research institutes and centers, where applied research and follow-up development and transfer of knowledge into practice are dominated.

Asymmetry can be observed also in the factor of territorial distribution. From the point of view of the research and development potential, more than 50% of the Slovakian capacities are located in the Bratislava Region. R&D organizations located in the Bratislava region are performing more than 60 % of the international research and development activities under international projects and their employees are authors of more than 70% of all Slovak scientific outputs published in renowned international magazines.

The share of R&D personnel in total employment in 2015 was less than 1 % in Slovakia, which was below the EU average. From the point of the structure, the distribution of R&D staff within sectors was as follows: R&D staff, their distribution to the different sectors is as follows:

- business sector 6 119,
- university sector (college teachers and researchers) 17 005,
- government sector (SAS and departmental institutions) 5 529,
- non-profit sector 99.

The R&D sector cooperates on the national and international level, mainly thanks to wide variety of funding schemes. In the range of projects funded by EC, Slovakia is actually on the 19th place, with the success rate of 17,39 %, when we are assessing the number of project proposals. But when we look at the situation through the financial contribution, our country is at the level of 10,63 %.

The university sector is the most active in the number of applications (717) as well as in the projects received (114). However, in the amount of the financial contribution, the more successful were companies, not academic sector.

Research organizations (SAS and departmental institutes) participated in 87 projects with a total EC contribution of 12,73 mil. EUR. The number of participants throughout the FP7 is much more prevalent than in our universities, at the expense of the business sector. However, the relatively high participation of SMEs (participated in 71 projects) is a positive factor in our country.

But when we compare our data with the outputs of other countries in Europe, we can conclude that we are poorly involved in European initiatives aimed at jointly coordinating research activities between individual countries. Out of the total of 31 European Research Area Nets (ERA-NET) we have only been involved in 9 (11 in total). While in 6 cases the Slovak participant is a research organization, not a grant agency or a ministry. APVV did not join either of ERA-NET.

The low level of cooperation is also observed within the country, between R&D academic and government institutions and industry. The Slovak government has been trying to change the situation through the offer of provided funds. In 2015, 13 projects of applied R&D have been supported thanks to this scheme.

When we look at R&D expenditures in 2015, according to the source of funding, we find that

the main sources of growth of investments were mainly foreign sources that increased by 67.52 % in 2014, while government expenditure increased by 11.82 % and business sector investment by 7.69 %.

But according to the goals presented in strategic documents, we can expect the change of sources in the future, as one of the main objectives of Research and Innovation Strategy for Smart Specialization of the Slovak Republic is to support the financing of R&D from private resources so that the private sector would contribute 2/3 of the total R&D funding by 2020 In Slovak republic.

We hope, that this aim will be achieved thanks to the effort of companies. As the presented in R&D Survey 2016, performer by Deloitte, in the short-term (up to two years), 42 % of addressed businesses plan to invest in research and development at least as much as 2014. Over a period of up to three to five years, 69 % of respondents intend to increase their spending in this area.

Approximately one third of respondents surveyed spent more than 10% of their revenue last year on research and development.

3. Innovation actors active in HPC

Academic institutions, universities and Slovak Academic of Science, cooperate with the industry, especially within two main areas – research and education.

Cooperative research activities are organized especially under the special 7 science parks and 5 research centers.

Science Parks:

- University Science Park for Biochemistry Bratislava.
- University Science Park of Comenius University in Bratislava.
- Medical University Science Park in Košice (MediPark, Košice).
- University Science Park of University of Žilina.
- University Science Park Technicom(Košice).
- University Science Park STU Bratislava.
- University Science Park CAMBO (Trnava).

Research Centers:

- Martin's Center for Biomedicine.
- AgroBioTech Research Center (Nitra).
- Research Center of University of Žilina.
- Center for Applied Research on New Materials and Technology Transfer (Bratislava).
- Research center of progressive materials and technologies for current applications "PROMATECH" (Košice).

Their aim is to stimulate and manage the flow of knowledge and technology between universities and businesses, and so facilitate communication between businesses, entrepreneurs and technicians. Their staff is also working on development of environment that improves the culture of innovation, creativity and quality.

Transfer of technologies and new innovation development is supporting also via establishment of new businesses through incubation and spin-off mechanisms and accelerate the growth of small and medium-sized enterprises.

Cooperative research activities are also supported through special national funds, like Operational Program Research and Development, transferring financial support by European Structural funds. In the period of 2007 – 2013, Slovak Academy of Science, implemented 32 project in cooperation with the companies operated on the area of Slovakia.

Concrete form of research activities depends on the topic, while we can observe theoretical, applied and combined research. Technologies are widely used performing the research, but actually, not including HPC infrastructure.

Cooperative activities can be observed in various fields. Applied science is e.g. realized thanks to cooperation of Huawei Technologies and University of Žilina, focused on transport technologies and Smart City solutions. University of Žilina is by this step widering portfolio of cooperative companies, among which is also another important technology company – Siemens, while the company is working on research topics also with Slovak Technical University in Bratislava. Knowledge and capacities are searched also by energetic companies, RWE IT Slovakia, s. r. o. and traditionally, by engineering companies with wide range of focus, e.g. Železiarne Podbrezová, a. s., Continental Matador Rubber, MATADOR HOLDING, a. s. and others. Observed can be also joint research activities in food production field, e.g. between Slovak University of Agriculture in Nitra and brewery Heineken Slovakia, a.s.

Education activities, and general recommendations for academic activities and other R&D representatives, are discussed on the regional and national level and their output is presented in the form of national (Through knowledge towards prosperity Research and Innovation Strategy for Smart Specialisation of the Slovak Republic) and regional research and innovation strategies, for implementation of European and national strategies.

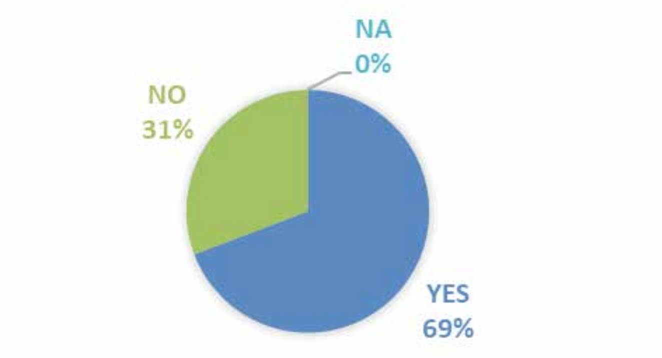
Future aims, current needs and requirements and other relevant topics are discussed also thanks to several specialized organisations, like e.g. Union of Industrial Research and Development Organizations, Slovak Organization for Research and Development Activities etc.

4. HPC Benchmark

4.1. Main findings of Survey on HPC needs and competences for enterprises

Is your company having a research and development (R&D) department?

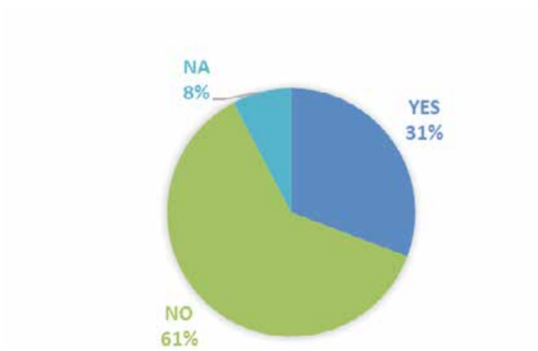
Figure 3: R&D Department in Companies



Source: own processing

Is your company using HPC solutions to meet your business requirements?

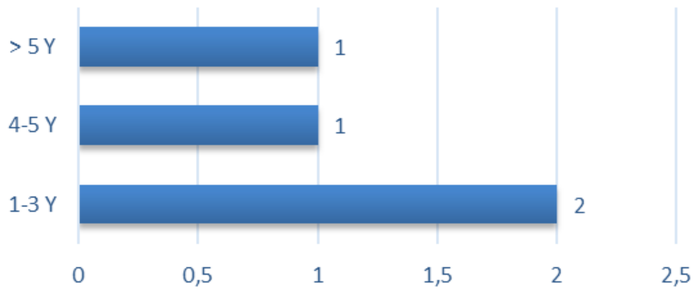
Figure 4: HPC use rate



Source: own processing

For how long does your company use HPC solutions to meet your business requirements?

Figure 5: Use HPC Solutions to meet your business requirements



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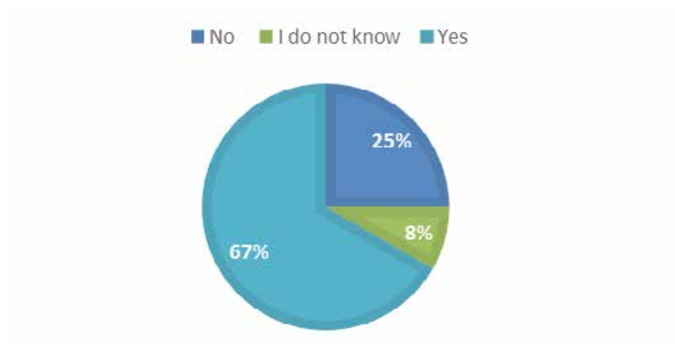
Do you think cooperation with science/industry could foster the HPC usage and your organisation development?

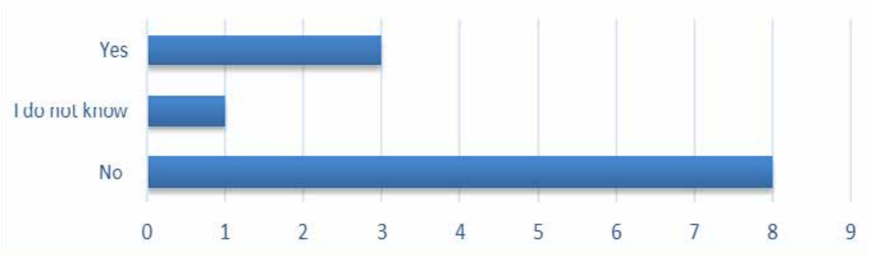
Figure 6: Cooperation with Science/Industry could foster the HPC Usage and Organization development



Source: Own processing

Has your company been involved in international projects related to HPC?

Figure 7: International projects related to HPC



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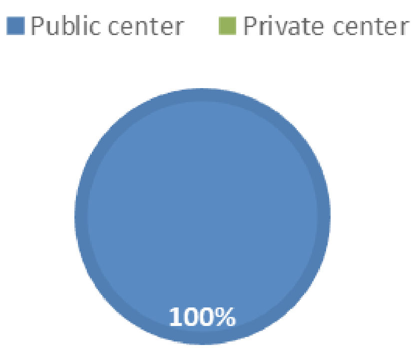
4.2. Main findings of Survey on HPC providers

Ownership of HPC provider

Figure 8: Ownership of HPC Provider



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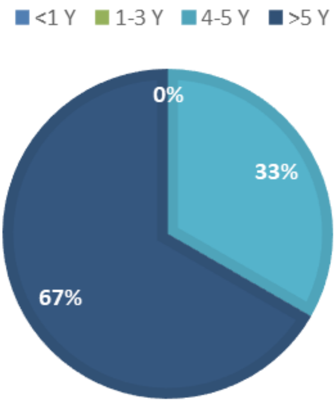
For how long does your organisation deal with HPC?

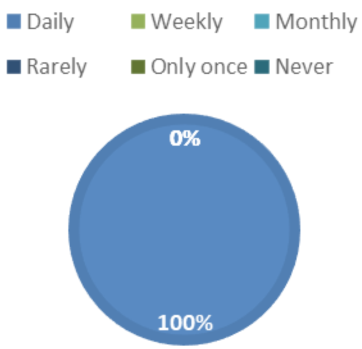
Figure 9: Period of using HPC



Source: Own processing

How often do you use the organisation HPC facilities?

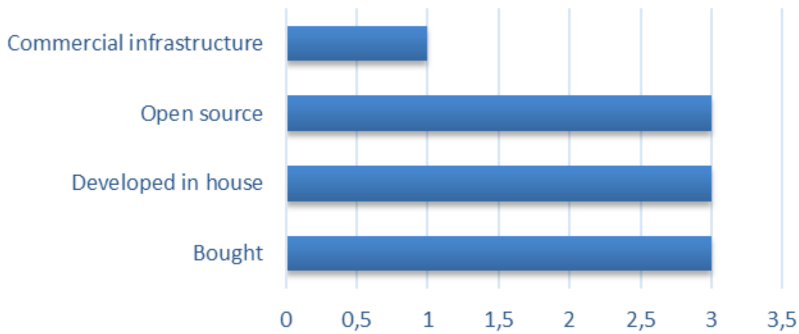
Figure 10: How often do you see the organisation HPC Facilities



Source: Own processing

Related to HPC, the software applications and infrastructure you use are:

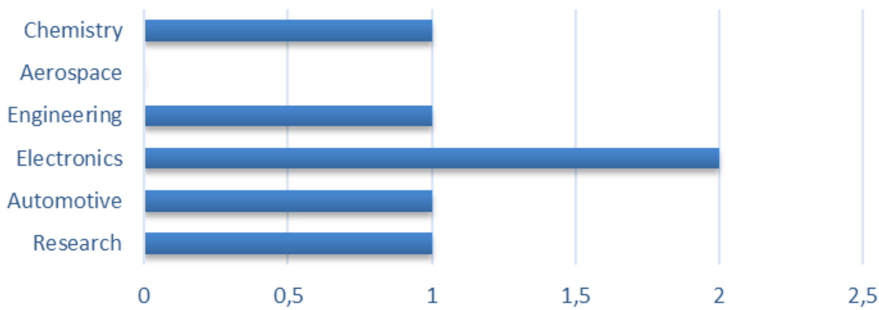
Figure 11: Related to HPC, the software applications and infrastructure



Source: Own processing

Which industries you serve with your infrastructure?

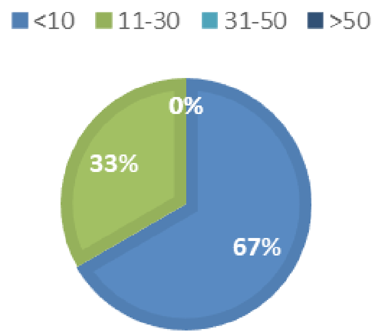
Figure 12: Industries served by HPC Providers



Source: Own processing

What is the number of academic and technical staff working on HPC in your organisation?

Figure 13: Number of academic and technical staff working on HPC



Source: Own processing

5. **Recommendations**

"The priority is to ensure the cross-border portability of on-line content-providing services on the Single Market. We want to give citizens and entrepreneurs the freedom to move in the digital space and to ensure the freedom for data movement as a fifth freedom throughout the EU internal market". Peter Pellegrini, Deputy Prime Minister for Investment and Informatisation, SR.

Table 1: Digital Transformation of industry guidelines at national level: Slovakia

Digital transformation of Industry Guidelines at national level: Slovakia	
Smart Industry for Slovakia (Industry 4.0)	Intelligent manufacture
	• setting up a network of interconnected factories able to cooperate (production plants and enterprises) within the supply chain. • ensuring a high-speed, secure and reliable Internet connection that will be governed by defined standards in communication. • Promoting more flexible manufacturing and delivery processes that will benefit from Big Data • Implementation of an integrated security and security architecture and unique identifiers, along with relevant enhancements in the field of training and other content of career development.
	Intelligent research
	• Reorganizing the research and innovation system - wider application of R & D results in business practice that will lead to a change in the ratio of applied and fundamental research to: 70% for applied research and 30% for basic research. • support of key technologies in industrial manufacturing, especially through cloud solutions, high-speed networks (5G), add-on processing (3D printing), robotics, mobile sensory systems, automation, nanotechnology and artificial intelligence • Creating international cooperation with R & D institutions such as VTT (FI) and Fraunhofer (DE) to help Slovakia make progress in its national research, support Slovakia's research and development capacities and potential, and develop similar models of cooperation with universities in Slovakia. Collaboration should also involve startups and innovative small and medium-sized businesses to find creative and non-standard solutions in research and development projects
	Digital society
	• Systematic development of the necessary skills in the public sector (boot camp), building the trust in a new IoT economy (including computer security) • To create innovative state education programs for study and learning departments at all levels of education. All of the study and teaching departments should be involved in computer science as applied computer science. • The use of open IT technologies in education and the use of public licenses for educational resources should become a standard. • Intelligent industry should create exchange programs that bring together Slovak professionals in industry and trade with relevant study classes and study programs, and should also invite representatives of international industry and trade to share expertise, professional skills and creativity.

<table>
<tr><td rowspan="2">Smart Industry for Slovakia (Industry 4.0)</td><td>For the future prepared Regulations and Government</td></tr>
<tr><td>
The Intelligent Industry Concept for Slovakia has the ambition to create favorable framework conditions for the development of the Slovak ecosystem IoT. Therefore, specific areas of public sector support and incentives for the adoption of the Intelligent Industry need to be specified for which regulatory barriers (Future-prepared regulation) should be removed, administrative burdens reduced and international cooperation should be promoted.
A future-based regulation to remove regulatory barriers, ensure the introduction of common standards and foster growth and international cooperation (RIA, DIA, IIA)
More emphasis should be put on public dialogue (with businesses, relevant actors and regulators) in the preparatory phase of new regulatory proposals. Preparing the proposed regulation for the future should be an essential part of regulatory processes that will result in the determination of standards and standards.
Build trust by creating a single service infrastructure and intelligent state administration (data-use, personal data management)
Propose a transparent and effective public sector digitization plan (new types of digital services, public sector interfaces for innovative use of public data and mobile eGovernment)
Ensure active participation by state authorities in the promotion and implementation of the Intelligent Industry
Continue to develop the necessary skills in the public sector (boot camp), build trust in a new IoT economy (including computer security)
Ensure the acquisition, flow and commercial use of data (Open Data and Big Data), IP rights and data protection and adopt open standards for interoperability and security
</td></tr>
<tr><td rowspan="2">OP Integrated Infrastructure</td><td>Informatization of society</td></tr>
<tr><td>
Increase of broadband Internet / NGN coverage
Increasing the innovation capacity of, in particular, small and medium-sized entrepreneurs in the digital economy
Improving the quality, standard and availability of eGovernment services for entrepreneurs
Improving the quality, standard and availability of eGovernment services for citizens
Improving the overall availability of public administration data in the form of open data
Improving digital skills and inclusion of disadvantaged individuals in the digital market
Facilitate the modernization and rationalization of ICT governance by ICT tools
Rationalization of the operation of information systems through cloud eGovernment
Increasing cyber security in society
</td></tr>
</table>

Strategy for R&D for smart specialization of SR	Big data	
	• New approaches to processing large data (Big Data), in particular processing of fast-growing data and data streams (Fast Data); • Data storage, storage and accessibility, Open Data and Linked Open Data; • Methods and tools for intelligent data processing, including usage of semantics, which is a prerequisite for efficient work with large data in large distributed digital environments (such as the web environment); • Machine learning and Optimization; • Effective data processing algorithms; • Methods and tools for a social collaborative digital space taking into account the individual's individuality in the digital space; • Methods and tools for privacy protection (identification, authentication) and data security.	
	Information security	
	• Security systems models, identification methods and security requirements for systems, methods of developing reliable and secure systems, assessing compliance with the specification, assessing the strength of security mechanisms, detecting vulnerabilities and hidden channels in software systems. • Study of IB management methods in the context of new ICT and threats; • Development of IB level assessment, economic aspects of IB; • Recognizing the symptoms of attacks / emerging security incidents; • Effective methods of addressing and recovering security incidents; • Computer crime (taxonomy, development, legislation, methods of detection, provision of evidence); • Identification and authentication, combination of technical and non-technical means (biometrics, etc.) • Research on the security aspects of e-Government, e-Health, e-commerce, social networks; • Research focused on the impact of ICT on youth development, social relationships, way of life; • The possibilities and methods of collecting, processing personal data, their use, abuse to influence the behavior of individuals and groups of people; • Effective methods for creating user security awareness	

	Cyber space
	• Devices capable of recording information and then sharing it, as well as receiving information remotely and effectively using it (for example sensors, robotics, intelligent systems and services - autonomous systems and artificial intelligence, additive technologies - 3D printing, and intelligent devices for household and day-to-day use); • Services and solutions in the field of large data processing, fast data processing (Big Data); • Preservation and disclosure of information (Open Data); • Interoperability of inputs and outputs, anticipation of production, distribution, consumption and market behavior of subjects (for example, interactive interfaces to work with data via enhanced reality and virtual reality, application of web and mobile technologies, expert systems, cloud systems and services); • Support for new business models (eg data processing and storage, generation of outputs) and streamlining of public institutions • Intelligent transport systems (creation of navigation systems, collaborative economy systems and improvement of intermodal transport; • Robotic workstations and automated systems for industrial manufacturing applications; • Control systems for the accumulation and redistribution of energy in energy, industrial and transport applications
	Interdisciplinary application of ICT
	• development and use of methods for computer modeling, simulation and testing of materials • management of technological processes of preparation of new materials using ICT • ICT applications in medicine, biotechnology, agriculture and the environment • ICT in industry and services • ICT in public administration, health, education, culture and defense

Source: own processing of available data

6. Conclusion

Before 2007 did not exist in Slovakia no major research centers and even no real funding system for this type of research capacities development and it created the big obstacle in comparison with the other EU countries. The significant change occurred only in the programming period 2007–2013, when research and development capacities were built in Slovakia, mainly by investments from EU Structural Funds.

Thanks to the financial support, national network of HPC infrastructure was developed. Today, the network is composed by 7 HPC centers providing free approach to HPC for students and employers of universities as well as other R&D experts. Approach for private companies is also available, while its price and content depends on bilateral agreement.

Today, the institutions of R&D cooperate with the industry, within the all phases of innovation development, but rarely using HPC.

There is only one such a case, the partnership of private company and Slovak Academy of Science. Other HPC centers within Slovakia did not report cooperation of that form, but we hope that the situation will get better in the near future.

But according to the goals presented in strategic documents, we can expect the change of sources in the future, as one of the main objectives of Research and Innovation Strategy for Smart Specialization of the Slovak Republic is to support the financing of R&D from private resources so that the private sector would contribute 2/3 of the total R&D funding by 2020 In Slovak republic.

We hope, that this aim will be achieved thanks to the effort of companies. As the presented in R&D Survey 2016, performer by Deloitte, in the short-term (up to two years), 42% of addressed businesses plan to invest in research and development at least as much as 2014. Over a period of up to three to five years, 69% of respondents intend to increase their spending in this area.

Approximately one third of respondents surveyed spent more than 10% of their revenue last year on research and development.

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- Computing Center of SAS
    - http://www.vs.sav.sk/
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    - http://kame.uniza.sk
- Slovak Technical University in Bratislava – Department of HPC
    - https://www.hpc.stuba.sk
- Technical University of Košice – Department of HPC

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- Center of Scientific and Technical Information
  - http://www.cvtisr.sk/

National Case Study of Slovenia

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Abstract: Slovenia is often positioned around the average of EU member states. This also holds for several aspects of innovation performance and for its position in high performance computing (HPC). In this paper we explain the main outcomes of the project InnoHPC related to Slovenia. We first present the main indicators which explain how Slovenia is performing in innovation activities within EU. Then we explain the current situation in Slovenia in the domain of high-performance-computing. We list current limitations and expose the main actors and actions in this area in Slovenia that are expected to be accelerators of future development. The last part of the paper contains list of recommendations that Slovenia needs to follow to catch with the most developed countries in the domain of high-performance computing.

Keywords: Slovenia, HPC case study Slovenia, InnoHPC project

1. Overview of Slovenian innovation performance

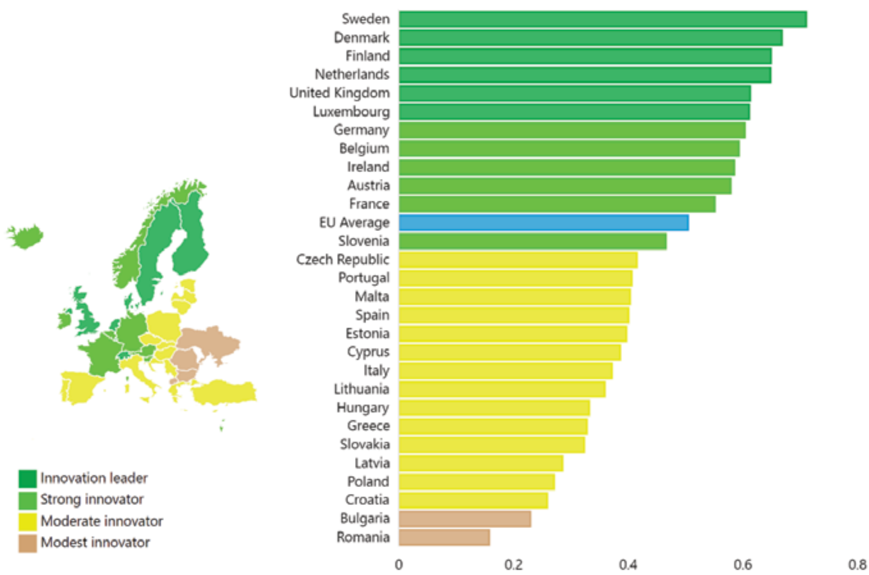
Every year the European Commission publishes a comparative assessment of the innovation performance of Member States. In the 2018 European Innovation Scoreboard (EIS) results show that the EU's innovation performance continues to improve, but there is room for further betterment and even brighter examples.

Slovenia, one of the bloc's "newcomers" scored **12th among its European partners in the field of innovation,** justifying the choices of the state to support innovative projects and the wish of the Slovenes to lead the way through such a trend. Slovenia is now a Strong Innovator, see Figure 1.

The country was given a 2017 innovation index of 92.2 and, although it is 7.8 points below the EU average, "it has however advanced in the index measuring the performance progress made in the period since 2010. Here, **Slovenia has advanced from 95.9 points in 2010 to 97.3.** Slovenia fares the best in human resources (index of 143) and company investment in innovation (121)", the report said.

Among the 27 indicators included in the EII, Slovenia achieved above-average results in particular in human resources and corporate R&D investments, while a widening of the gap to the EU average was recorded in particular in financing, public sector support for innovation and the impact of innovations on sales. Weaknesses of the innovation system are also apparent in insufficient cooperation between stakeholders and lack of policy coordination. All this hampers the achievement of the relevant goal in SDS 2030, i.e. ranking in the group of leading innovators as measured by the EII.

Figure 1: Summary innovation index for EU member states shows that Slovenia is a strong innovator



Source: https://interactivetool.eu/f/extensions/DGGROW4/EIS_2.html#a

Investment in R&D remains fairly high, though in recent years it has been scaled back significantly. R&D investment of the business sector has increased the most since the beginning of the crisis, as companies strived to enhance growth and competitiveness. To a certain extent, these developments were also a result of higher R&D financing from structural funds, which required co-financing by companies, and a positive impact of tax relief. Since 2015, R&D investment of the business sector has been declining. In the public sector it had started to contract already after 2011 and declined by about EUR 115 million by 2016. In 2015 Slovenia had the lowest share of public funds in overall R&D spending (about 20%) among the EU Member States. In the best performing countries in terms of innovations, the share of public R&D funding is roughly 10 pps higher than in Slovenia. Public financing of R&D facilitates basic research and the development of human resources, which is a precondition for breakthrough innovations in cooperation with companies. At the same time, providing a stable environment for R&D at public research institutions is key to generating new knowledge, which in essential for the international cooperation of these institutions, allowing them to keep up with the rapid progress of scientific and technological development.

The innovation activity of Slovenian companies stagnated in 2010–2014. During that period large and medium-sized companies, in both manufacturing and services, achieved rates of innovation activities that were above the EU average. Small companies, on the other hand, are problematic, as fewer than 40 % are innovation-active, a share that is even declining (see Indicator 1.17). In Slovenia the gap in innovation activity between large and small companies is significantly wider than that in countries that are more successful at innovation, which may also be a consequence of the better instruments such countries have for the promotion of innovation activities in small companies. In such countries, small companies are also more likely to participate in the innovation processes of large companies, which can strengthen the innovation activity of both (e.g. partnerships in certain fields, clusters, competence centres, etc.). Moreover, investments in intangible capital in Slovenia, which accelerate the introduction of innovations, are significantly below the EU average.

Slovenia has been slow in coping with the challenges of digital transformation and the digital maturity of Slovenian companies is weak. In 2014–2017 Slovenia failed to improve on its rank of 17th on the Digital Economy and Society Index (DESI). Unbalanced development across the five main DESI areas (see Indicator 1.11) has been hampering synergies. Notable progress has been achieved in the use of cutting-edge technologies for the digitalisation of enterprise processes and moderate progress has been recorded in digital public services. Slovenia has stagnated in terms of human capital, connectivity and internet use. In some indicators of digitalisation that are not included in DESI, Slovenia ranks around 5th place in the OECD, for example in the industrial stock of robots over manufacturing value added and the share of large enterprises that use big data analysis.35 On the other hand, there are shortcomings in particular in the share of ICT companies investing in R&D (with 13 % in 2015, Slovenia is at the tail end of the EU rankings), low level or absence of digital skills in 40 % of the workforce, and low share of investments in ICT (2015: 2 % of GDP), which increases the risk of being left further behind. Fewer than 20 % of companies are digitally mature and only around 40 % develop digital potentials. Key factors for improving the situation include appropriate understanding of digital transformation, human resources, pace of experimentation with new solutions and an organisational structure that better accommodates digitalisation in corporate development strategies.

2. Appraisal of HPC situation in Slovenia

2.1. General overview

It is widely accepted that high-performance computing is one **of the main accelerators of modern science.** This comes through:

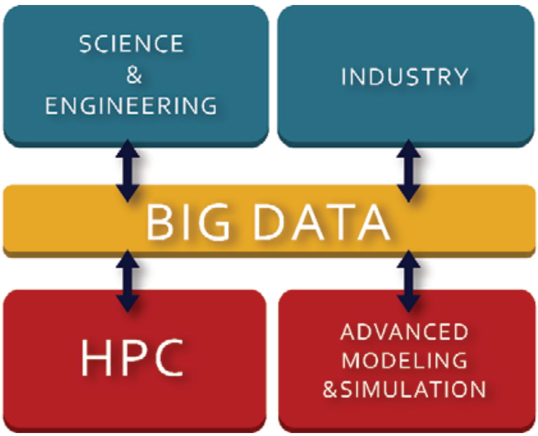
1. Fostering the R&D of **new, high-performance hardware and software** to produce better and faster supercomputers. The EU wants to catch up with computer-producing giants like the USA, China, South Korea and Japan, and is competing with them in the race to develop the first exascale supercomputer (a computer capable of performing 10^{18} floating point operations per second - flops),
2. Developing **new computational methods** and related software applications to tackle long-standing and evolving challenges in engineering, life science, physics, environment, social science, etc. The EU already dominates in this area, but wants to maintain its position.

It is less known that HPC also drives business: The European Commission (EC) sees HPC as a way in which the European electronics industry can catch up with the world's leading computer manufacturers by developing and producing European microprocessors and new structures for processors, memory and communication units, which will result in the arrival of EU-based exascale supercomputers.

HPC also has a major impact on the automotive industry. Testing prototypes of new cars under different physical conditions in virtual environments using HPC makes the car-development process both quicker and cheaper. Additionally, autonomous vehicles and smart factories with digital twins and the related Big-Data and Internet-of-Things environments will only be possible with HPC, although probably on a smaller scale.

All these issues probable made the European Commission to put HPC at the top of the EU's priorities as part of the Digital Single Market strategy [7], which supports the EU's ambition to become the world leader of the digital economy. The EU has made major strides to implement this strategy by (i) establishing the EuroHPC Joint Undertaking in September 2018 [11], (ii) financing 16 centres of excellence in the area of HPC applications, (iii) supporting the European Processor Initiative – a consortium to develop Europe's microprocessors for future supercomputers – and by funding several FETHPC projects within the H2020 programme, see e.g. for more details [8].

Figure 2: high performance computing together with advanced modelling and simulation enables large scale computations and big data analysis and this way accelerates science and industry



2.2. Recent progress in Slovenian in the area of HPC

Slovenian government has recently recognised the importance of HPC and has decided to catch up with the most developed countries in this field. It has listed HPC as a key-enabling technology in the Slovenian Smart Specialization Strategy. As a consequence, Slovenia joined the EuroHPC initiative in 2017 and became a founding member of the EuroHPC Joint Undertaking in September 2018. Additionally, all the research groups in Slovenia that demonstrate any kind of HPC activity decided to establish a national consortium for supercomputing called SLING, in 2018, which became the Slovenian member of PRACE in October 2018 and this way continues Slovenian membership in PRACE which was initiated by University of Ljubljana, Faculty of mechanical engineering.

In 2018 the Slovenian government also decided to invest approximately 20 million by 2021 in a national HPC infrastructure that will be available to all Slovenian researchers and under special conditions also to industry. This operation will mostly consist of investments in hardware and software and establishing the necessary team of system engineers. Some funding will be available for training in scientific computing and experimenting with this infrastructure.

This will certainly have a positive impact on Slovenian science and industry, and will bring HPC closer to academic and industrial users, but further long-term actions will be needed (new research programs and projects related to HPC) to exploit this infrastructure and to establish a cutting-edge scientific community around it.

2.3. Current HPC hardware infrastructure

Computer clusters in Slovenia can be divided to those owned by public entities and to those owned by private companies, see Table 1. The HPC clusters owned by research organizations, are mainly used by the research groups within the hosting institution who provided funds for this equipment. Two HPC systems available at private companies Arctur and Kolektor Turboinsitute are used for business needs:

- Arctur has two HPC clusters Arctur1 and Arctur2 and is offering HPC services to SME's in Slovenia and across the border in Italy.
- Kolektor Turboinsitute manages HPC with name BladeCenter HS21, which is very old (purchased in 2008) and is mostly shut down.

Table 1: List of HPC infrastructure in Slovenia

Owner of HPC infrastructure	Number of cores (2017)	Other info (2017)	Content/	Access
Arnes	4500 (736 of that from FIŠ) 4 x NVidia	2 x 10 GB net IB	Research and development work of all Arnes beneficiaries, including development centres in industry;	Central node SLING, all types of uses; Preference is given to groups without their own cluster.
ARSO	740	128 TB HD, 2,57 TB RAM, 2 x FDR IB	Dedicated (internal) use	Member of SLING; older cluster (240 cores) is fully available to SLING.
National institute of chemistry	HPC centre: 1824 cores, predominantly Intel Xeon servers. Varna System: Approx. 3000 cores, predominantly Intel Xeon servers	HPC centre: 3.6 TB RAM, 182 TB HDD, InfiniBand QSFP 40Gb/s. Vrana System: 1Gb/s Ethernet	Molecular simulations at various levels - classical, quantum-chemical and multi-scale;	Mostly for own use - research work in the framework of programs and projects financed by the ARRS European projects. They are discussing to join SLING.
University of Ljubljana, Faculty of Mechanical Engineering (UL FME)	System 1 (2010): Intel Xeon X5670 (1536 hyper cores) with IB connectivity System 2 (2016): E5-2680 V3 (1008 hyper cores)	IB QDR 4,6 TB RAM 164 TB HD (Lustre) 24 TFlop	Simulation in mechanical engineering (fluid dynamics, finite element method); Methods of mathematical optimization	Leading member of the Consortium Supercomputer Centre Slovenia. The equipment is, in principle, accessible to anyone who can pay for the cost of using it. Researchers within the UL FME have a special status.
University of Maribor, Faculty of Mechanical Engineering (UM FME)	240	IB	Use for faculty research needs.	They are entering SLING.

Jožef Stefan Institute (JSI)-Experimental particle physics	4400	4.6 + 6 PB HD, 12 TB TAM, 1/10 Gbit Ethernet, 2 x 10 GB net	Physical simulations (CERN – ATLAS)	Member of SLING
JSI - reactor physics	1812 16 x Tesla M2075 (each 448 CUDA cores, 6GB RAM)	117 TB HD, 10.686 RAM, FDR IB	Computer support for nuclear simulations	Member of SLING
JSI - theoretical physics	2941		Computer support for research in physics	Member of SLING
JSI - biochemistry, knowledge technology	984	40 TB HD, 8 TB RAM, GB Ethernet	Member of SLING, user od SLING.	Member of SLING
JSI K3	500		Computational chemistry; long tradition and a great deal of knowledge.	Dedicated: there is no free access
JSI common cluster (NSC)	1984 16 x Nvidia Kepler 40 (each 2888 CUDA cores, 12 GB RAM)		Member of SLING. All areas of the IJS, among others: machine learning, deep learning, biochemical modelling, experimental particles physics, computational chemistry, genetics.	Open access through SLING, an advantage for JSI users and project collaboration
University of Ljubljana, Faculty of Mathematics and Physics (UL FMP)	1200		Support to the scientific and research work of the faculty	Dedicated: there is no free access

Faculty of Information Studies Novo mesto (FIŠ)	736 + 2 X NVidia + Xeon PHI	13,5 TFlop Linpack	/	Member of SLING
University of Nova Gorica (UNG)	240		Support to the scientific-research part of the University, Pierre Auger project	Member of SLING
Kolektor Turboinsitute	2000		Simulation in mechanical engineering	Once the possibility of industrial cooperation, now unknown
Arctur d.o.o.	Arctur 1: (2010) 1024 cores Arctur-2 (2016): - 1008 CPU (Xeon E5 v4) - 64 GPU (NVIDIA Tesla)	1TB/server, 25/100 Gb Ether, 1.5 PB distributed storage, flexible configuration	- Providing HPC-based services. - Cloud computing - Big data calculation - Model SaaS (SW as a Service) - Model IaaS (Infrastructure as a Service)	Industrial cooperation, project cooperation, by arrangement via SLING, Fortissimo partner, Special attention to SME users. Collaboration with the Academic Sphere
University of Maribor, Faculty of Electrical Engineering and Computer Science (UM FEECS)	14336 cores = 4 x Nvidia Titan X (Pascal)	10 TB HDD, 24 GPU RAM, 128 GB RAM	Parallel Station of the Institute of Computing	UM FEECS and external collaborators by appointment

Source: AKCIJSKI NAČRT SRIP PAMETNA MESTA IN SKUPNOSTI [5, p. 70]

2.4. Current HPC competencies in Slovenia

Beside the HPC infrastructure, it is also very important to have competencies for working with this infrastructure. Each organization that owns HPC has also created a team of experts who can maintain the infrastructure and adapt it for different research or industrial needs. Some organizations (e.g., Xlab), do not have their own HPC infrastructure, but they are nevertheless active in the HPC field and have qualified people for this job.

Academic institutions, mostly University of Ljubljana, Faculty of mechanical engineering (UL FME), offer training programs to wide range of audience. They organize training for the academic staff and students via Summer of HPC Summer Workshops, autumn and campus HPC schools, they also organize training events for people from industry. They use PRACE implementation projects (e.g., PRACE-4IP, PRCE-5IP and PRACE-6IP) and InnoHPC project to fund these activities. In addition, UL FRI, UM FERI and FIŠ offer optional and regular courses in the field of HPC.

In the area of wholesale, we find that there are a lot of companies that have large amounts of data. These are typical companies that have a large number of customers and / or who carry out a large number of operations (telecommunication companies, financial transaction companies, real-time companies – e.g. electric companies, companies that store (archive) data; trade companies ...). These companies are often unaware of the business value of their data and do not invest any effort into how to link these data and to build new business models on them.

In particular, it is worth emphasizing the shift in the field of public information, which is available at various public institutions. Open public sector data will enable companies and research and development organizations to develop new services for the economy, the public sector and the population. Infrastructure (development innovation cloud, hybrid cloud, state computer cloud, OPSI portal), developed by MPA in the field of cloud computing will be a good platform for accumulating this data and an excellent starting point for their integration and upgrading into new services for citizens.

2.5. Innovation actors active in HPC

Based on the Deliverable D3.2.3. from the InnoHPC report[44], there are two weakly connected innovation systems in Slovenia: the first consists of the research and higher education institutions and the other from business organisations, see Table 1 above for the complete lists of actors related to HPC.

44 http://www.interreg-danube.eu/approved-projects/innohpc (last visited on 6. 3. 2019)

The research system mainly produces competent people in the domain of HPC and pilot solutions (studies, results of simulations, prototypes ...) for the industrial innovation system, see the following section for a sample of successful stories.

The Slovenian industry is mostly component oriented industry, but with a clear strategic ambition to progress towards the level of complex subsystem providers. Therefore, companies are usually aware of existence of HPC technology because they monitor the competitors on the market and follow the trends of Industry 4.0. On the other hand, they don't have enough "internal advocates" of HPC technology that could present economically valid arguments to shift to using the HPC in the R&D phase.

There are two business organisations (Arctur, Kolektor Turboinsitute) that are specifically designated to HPC based innovations, the first has HPC as a part of their business model, while the second uses (rather old) HPC in developing new products, mostly parts of power stations.

2.6. Some applications of HPC for industrial needs

Slovenian industry has expressed strong interest in using HPC. In the process of preparing the operational plans for the Smart Specialisation Strategy of Slovenia (S4), 16 Slovenian companies from different domains, including 12 SMEs, expressed strong interest, and emphasizes their need in boosting their business activities by using HPC and other Big Data technologies, if they can attract enough qualified personnel and if the scientific environment was at a higher level in HPC.

We list two outstanding cases from Slovenia, where HPC has proven to improve R&D activities in SMEs. The source for this list is the report of the Fortissimo project[45] and the web page of the Synergy project[46].

HPC-Cloud-based simulation of light-aircraft aerodynamics

Slovenia hosts few companies that develop hi-tech products using HPC. Pipistrel, an SME that produces lightweight aircrafts, simulates the flow of air around the aircraft using HPC and Computational fluid dynamics. It estimates that it is 10 times cheaper to use Cloud-based HPC simulations than have a suitably powerful in-house system which is only used for part of the time. The indicative annual costs of using Cloud-based HPC simulations are approximately €30k compared with an in-house cost of €300,000, which shows that this saving is considerable.

45 https://www.fortissimo-project.eu/ (last visited 6. 3. 2019)

46 http://synergy-twinning.eu/ (last visited 6. 3. 2019)

They involve two SMEs in this part of R&D activities: XLAB operates as an HPC expert and Arctur as an HPC provider.

Lamination and casing optimization for electric motor

Domel is the leading supplier of electric vacuum motors, DC motors, EC motors and components. In the design of modern electric motors high quality, low cost, long lifespan, and maintenance free operation need to be achieved. The problem is how to set geometric parameters of electric motor to achieve the desired goals. As a solution simulation tools for simulating electric motor power losses and casing rigidity were developed and validated on real product with close collaboration of mechanical experts. As a result, lighter, cheaper, and more powerful electric motor was developed. Electric motor power losses decreased up to 40%. Casing thickness of the electric motor was reduced from 1 mm to 0.8 mm, while maintaining all the characteristics. Due to smaller consumption of material a possibility of substantial reduction of production costs was achieved.

- End User: Domel
- HPC Expert: Jožef Stefan Institute
- HPC Provider: Jožef Stefan Institute

3. HPC Benchmark

3.1. Current HPC related limitations in Slovenia

Despite very positive decisions from the Slovenian government in the past two years, the country is seeing its HPC infrastructure, knowledge and research falling behind the most developed European countries, like Germany, Italy, Spain, France and Switzerland. We can group Slovenia's limitations into three categories:

1. **No national HPC infrastructure:** Slovenian universities and research institutes possess about 10 small HPC clusters, see Table 1, but all of them are rather old (more than 2 years) and were purchased by a specific research group, typically from limited research-project funds, and are usually only available to the members of these groups, not even to all the researchers from the same institution. This limitation will be mainly removed when the new HPC system comes into operations in 2020.
2. **No training or study programmes for HPC:** students, academics or development engineers from industry can gain HPC competencies only occasionally from training events that are usually sporadic, like the autumn schools organised by ULFME in 2014 and 2018. Computer-science students get some basic knowledge about what an HPC system is and

how they can benefit from using them during their studies. Students of engineering, mathematics and physics acquire knowledge about complex numerical methods, but usually test them only on regular desktop or laptop computers. Members of research groups that own small HPC clusters obtain the necessary HPC qualifications in their own narrow scientific area from their older colleagues or from workshops and training events outside Slovenia.

3. **Very limited HPC-related research:** only a few of those groups that can afford to buy their own HPC clusters are doing HPC-related research, like the development of new, computational methods adapted for HPC or solving computationally demanding scientific problems using HPC.

This is one of the reasons why Slovenian researchers are **completely excluded** from a very important part of excellent European science:

- No Slovenian research group is a project partner in any of the prestigious FET projects in the HPC domain ([8]);
- Only one Slovenian research group (Arctur) is a project partner in one of the prestigious Centres of Excellence in HPC, see [8];
- No Slovenian researcher has ever won a PRACE project to gain access to the largest EU supercomputers, for 2018 see [9];
- Only one (non-HPC) Slovenian research group is a partner in the Human Brain project.

It looks that Slovenian researchers are currently not at the level where they can apply for such projects. We see the following reasons: (i) they do not use the methods and tools that can scale up to the largest supercomputers, (ii) they do not have the necessary competencies to adapt the methods and codes to run on such machines or (iii) they are not integrated in the well-connected networks which usually apply for such projects and are cantered around the largest EU supercomputing centres.

Consequently, HPC technology penetrates to Slovenian industry at a very slow pace. The automotive and electronics industries, which are very important in Slovenia and could have proven benefits from using HPC, are mainly at the level of tier-2 suppliers in Slovenia. They can develop, test and produce small components where most of the testing is done on physical prototypes. Virtual prototyping and testing are used rarely and only for small-scale products. State-of-the-art simulations that need HPC are out of reach for them, since they do not have access to the necessary hardware and software and are often without the necessary knowledge from these domains. If they used advanced simulations coupled with state-of-the-art HPC systems, they would carry out the development and testing processes faster and more accurately, and could move upwards in the hierarchy of suppliers.

3.2. Outcomes of The InnoHPC Workshop.

This workshop was organized by InnoHPC partner Chamber of Commerce and industry of Slovenia on 13.9.2017. It has confirmed all shortcomings mentioned above. Additionally, it has exposed the following important shortcomings:

1. **Lack of experts on fields of simulation and/or HPC** Students rarely work on field of simulation and almost never come in contact with HPC during undergraduate studies. In postgraduate studies situation is slightly better, but at the end of the day, the number of experts in the field of simulation and/or HPC coming from Slovenian faculties is not covering the needs of Slovenian industry.
2. **High cost of using HPC** It should be distinguished between hardware (HW) and software (SW) costs. Most of the attending companies have already been using simulation SW as their daily tool on non-HPC working stations. The exposed that the biggest cost leap to move to HPC is not the price of the HW but the price of SW licenses when moving to HPC. SW licencing models that would stimulate transitions to HPC would be an important benefit for the industry.
3. **Lack of trust in simulations** Lack of trust is a result of lack of knowledge and fear from not well-known technologies. It results in is parallel working in the old and in the new way. As a consequence, the costs of R&D process are higher. With an increase of knowledge and experience in fields of simulations and HPC, the trust in results will also increase.

Surprisingly, at the workshop the participants also claim that they do not see a shortage of HPC hardware resources in Slovenia – in their opinion the demand and the supply are in balance. This clearly suggests that the demand needs to be stimulated by a wide range of actions, see the Section Recommendations.

4. Recommendations

To achieve a level of development in the domain of HPC that the most developed countries have, Slovenia needs to do the following measures

1. **Infrastructure:**

a. Slovenia must accomplish the establishment of national supercomputing centre as has been stare by project HPC RIVR.

b. As a founding member of EuroHPC [10], Slovenia should establish strong links with future pre-exascale and exascale systems that are planned to be available in the period from 2021 on. This will give the opportunity to Slovenian researchers and students to work on these systems and therefore keep contact with the best.

c. Beside the national HPC system, Slovenia must also support "institutional" HPC systems (small systems owned by scientific or university departments), since this will increase the knowledge related to HPC and will also generate new users and new applications.

2. Competences

a. Slovenia shall establish a national HPC competence centre. This action can be aligned with the forthcoming action of EuroHPC which is aimed at establishing a networks of national PC competence centres.

b. Slovenian universities should develop a list of mandatory and elective courses which will be part of the curricula of study programs in several domains, ranging prof mathematics and physics via engineering do social science and medicine.

c. We also recommend a designated study program on postgraduate level devoted to high performance computing. We suggest an inter-university program, also with foreign universities.

d. The core of HPC competences comes from its usage in science, therefore we strongly support to establish new scientific research programs strongly related to HPC.

e. Slovenian Government should incorporate measures to follow the strategic scientific directions, published in The Scientific Case for Computing in Europe 2018-2026 [6].

3. Measures to increase uptake of HPC technology in business. We suggest to stimulate HPC demand within companies, especially within SMEs, by:

a. Supporting and promoting new value chains with high-tech products requiring simulations in R&D phase based on HPC technology.

b. Stimulating the usage of simulations in innovations of current products and processes in industry, e.g. by introducing dedicated vouchers for HPC training and for pilot development project based on HPC.

c. Attracting foreign experts to Slovenia

d. Demanding flexible licencing models for HPC SW from SW vendors.

e. Raising awareness and informing the industry about the potential of Real-time Industrial Data analytics.

f. Support for adaptation of open source based for selected domains
g. Promote and stimulate the usage of simulation chains in companies

8. Conclusions

In this paper we presented current situation in Slovenia in the domain of High-performance computing. We first an overview of Slovenian innovation performance, which demonstrates that Based on the 2018 European Innovation Scoreboard (EIS), Slovenia is a strong innovator and is scored around the average (12th among European countries).

In the second part of the paper we provided an appraisal of HPC situation in Slovenia. We listed the main HPC infrastructures and the most competent actors in the domain of HPC. We also explain the main current limitations in this area and the forthcoming actions that are designed to remove these limitations.

In the last part of the paper we wrote a list of recommendations which is based on the outcomes of the InnoHPC project and on the expertise of both co-authors. We claim that significant public investments into (i) new HPC infrastructure and (ii) new HPC competences is needed. However, to achieve impact of these investments, several measures to increase uptake of HPC technology in business are needed, including (i) support for new value chains where the R&D phase is based on HPC technology, (ii) stimulating the usage of simulations in innovations of current products and processes in industry, (ii) attracting foreign HPC experts to Slovenia and (iv) demanding flexible licencing models for software that is designed to be run on HPC from SW vendors.

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HPC in Serbia: The State and Progress of the Field

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Abstract. High-performance computing (HPC) is becoming a mainstay of modern society, not just as an influencer but as an enabler. In this chapter we will discuss the current state, the recognized needs, and the progress made in the process of wider adoption, recognition and use of HPC concepts and infrastructure in Serbia. Starting from a somewhat pessimistic overview of the situation with a plethora of "to-dos," both in terms of digitalization in general and HPC-deployment in particular, we reach a more optimistic outlook through a discussion of activities realized within the project High-performance Computing for Effective Innovation in the Danube Region (InnoHPC).

Keywords: high-performance computing, history, state, Serbia

1. Introduction

In the "information age" we live in today, where practically all kinds of human endeavour are driven by computers and highly influenced by data processing, the field of high-performance computing (HPC) is steadily gaining in importance. Once "confined" to specialist labs for solving specialist problems, supercomputers have emerged as a major factor influencing (and even enabling) modern society. However, HPC is not evenly developed, deployed and used in all parts of the world, with the Danube region, and Serbia in particular, lagging behind in many respects compared to the developed world.

In this chapter we will discuss the current state, the recognized needs, and the progress made in the process of wider adoption, recognition and use of HPC concepts and infrastructure in Serbia. Starting from a somewhat pessimistic overview of the situation with a plethora of "to-dos," both in terms of digitalization in general and HPC-deployment in particular, we reach a more optimistic outlook through a discussion of activities realized within the project High-performance Computing for Effective Innovation in the Danube Region (InnoHPC).

The rest of the chapter is organized as follows. Section 2 describes the current (i.e. pre-project) state of the field of high-performance computing in Serbia, from the viewpoint of infrastructure availability, research and development, and cooperation between academia and industry. Then, Section 3 discusses general strategies for the digital transformation of Serbia, and HPC-related recommendations and conclusions. Section 4 continues the discussion with an overview of progress that was made, and avenues that are most promising for short-term improvement of the situation. Finally, Section 5 concludes the chapter.

2. The Current State of HPC in Serbia

The idea to use supercomputers existed in Serbia at least from 2004 (InnoHPC 2017a). Since that time, the need for computer processing of increasing volumes of data from various scientific institutions continued to grow, highlighting the need for Serbia to join the European network of institutions that use and/or facilitate high-performance computing.

One of the key events for HPC in Serbia took place in 2014, when the supercomputer "Paradox" at the Institute of Physics in Belgrade was upgraded. Serbia received the most powerful supercomputer in the Balkans at the time, worth about one million Euro. The existence of this Supercomputing Centre benefits Serbia in different aspects. With it Serbia became a centre of knowledge and innovation, which is one of the key necessities of our society.

However, the basic studies at universities in Serbia often have insufficient content related to parallel programming and distributed computing. However, such concepts are actively taught at most of the universities in the world. Considering that there are several cluster computers in Serbia (at universities), the larger problem is the education of programmers. Unfortunately, cooperation between enterprises and most of the existing clusters of computers in Serbia is underused and underdeveloped due to the lack of awareness of enterprises and industry. There is no clear information on such infrastructure existence in Serbia and how it can be useful for SMEs business development purposes.

In the rest of this section, we will first describe the currently available HPC infrastructure in Section 2.1. Then, in Section 2.2 we will discuss the state of HPC-related research and development. Finally, in Section 2.3 we will outline the perceived level of cooperation between Serbian academia and industry in the HPC domain.

2.1. Availability of HPC Infrastructure

Based on the initial capacity survey and assessment, HPC infrastructure in Serbia is primarily concentrated in academic institutions. The institutions are networked within AEGIS – the Academic and Educational Grid Initiative of Serbia. The members of AEGIS are researchers and academic institutions in Serbia that use, provide and/or develop Grid resources. It exists since 2005 and now includes 13 institutions, working together to spread the knowledge and the integration of local scientific institutions into European structures.

Serbian institutions are also more widely interconnected within the SEE-GRID (South Eastern European Grid-enabled e-Infrastructure Development) programme, which has set up a powerful regional Grid infrastructure. It attracts a number of user communities and applications from diverse fields from countries throughout the South-Eastern Europe. From the infrastructure point view, the first project phase has established a pilot Grid infrastructure with more than 20 resource centres in 11 countries. During the subsequent two phases of the project, the infrastructure has grown to currently 55 resource centres with more than 6600 CPUs and 750 TB of disk storage, distributed in 16 participating countries (Balaž et al. 2011).

The most recognized institutions with HPC resources are the University of Belgrade Institute of Physics, University of Kragujevac, University of Novi Sad Faculty of Sciences and University of Niš Faculty of Electronic Engineering.

The Institute of Physics Belgrade is highly recognized research institute at the EU level, being host to four EU Centres of Excellence and the first National Institute of the Republic of Serbia. Available HPC resources include Paradox IV and Paradox III nodes with significant CPU and GPU power (globally relevant at the time they were acquired). The HPC infrastructure at the University of Kragujevac exists since 2003, when the Centre for Advanced Computing as a university unit was established. Resources include 17 multiprocessor nodes and two storage servers. The computer cluster at the Faculty of Sciences in Novi Sad consists of 16 nodes and one access node, with 6-core processors and Nvidia GPUs attached, interconnected by 10 Gigabit Ethernet and supported by two storage units with the total capacity of about 40 TB. The HPC cluster located at the Laboratory for the Design of Electronic Circuits, Faculty of Electronic Engineering in Niš boasts 4 dual-board Supermicros totalling 8 nodes, each with four quad-core Xeon CPUs.

In all, it can be said that supercomputing capabilities of Serbia, in global terms, are modest at best. The Paradox cluster at the Institute of Physics was state-of-the-art in its time and is still highly usable, but unfortunately 5 years is a long time in the

HPC world, requiring updates much more frequent than the Serbian economy can withstand. Therefore, with respect to progress in the HPC field Serbia as a whole can only benefit from networking with outside institutions relevant in HPC.

2.2. HPC in Research and Development

Applications of HPC in research and development are again mostly concentrated in the Serbian academic realm.

AEGIS organizes dissemination and training activities, helps the Serbian research community to develop and deploy Grid applications, and coordinates related fund raising activities.

The Institute of Physics Belgrade is designated by the Serbian government as the referent institution for Grid computing and HPC in the country, and appointed to represent Serbia in European HPC-related projects and infrastructures. IPB coordinates AEGIS and provides various HPC-related services. At the University of Kragujevac Faculty of Sciences, cluster utilization led to the publication of more than 50 scientific papers in international journals. The computer cluster at the Faculty of Sciences in Novi Sad is a modest 100 CPU core cluster used only at the university for research purposes. The HPC cluster in the Faculty of Electronic Engineering in Niš was prominent in the realization of four educational and research projects supported by the EU.

The Scientific Computing Laboratory of the Institute of Physics in Belgrade conducts research in various areas of physics that require substantial computational power and HPC resources. One of those directions is devoted to the Gross-Pitaevskii equation. Multiple variants of HPC programs have been developed for various platforms including MPI, CUDA, OpenMP, as well as hybrid versions of those programs that include combinations of those technologies. Those programs contain implementations of numerical solutions of the dipolar Gross-Pitaevskii (GP) equation including the contact interaction in two and three spatial dimensions in imaginary and in real time, yielding both stationary and non-stationary solutions. The algorithm used is the split-step semi-implicit Crank-Nicolson method. This research direction has been pursued in cooperation with researchers from Faculty of Sciences and Faculty of Technical Sciences, University of Novi Sad (Lončar et al. 2016a; Lončar et al. 2016b; Satarić et al. 2016).

Another research direction within the Scientific Computing Laboratory of the Institute of Physics has been undertaken in cooperation with researchers from the Faculty of Sciences, University of Novi Sad. Researchers developed an implementation of the density functional theory based charge patching method using the basis of Gaussian functions. The method is based on the assumption that the electronic charge density of a large system is the sum of contributions of individual atoms, so called charge density motifs, that are obtained from calculations of small prototype systems. Implemented programs enable calculations of electronic structure of systems with around 1000 atoms on a single CPU core and with tens of thousands of atoms using HPC equipment (Bodroški et al. 2018; Bodroški et al. 2015).

The research group from the University of Kragujevac conducted an investigation of possibilities to use HPC in hydrology and electricity production with partners from Serbian industry (Lecca et al. 2011). The group developed six different surface and subsurface hydrology applications that have been deployed on the Grid. All the applications aimed to answer to strong requirements from the Civil Society at large, relatively to natural and anthropogenic risks. Grid technology facilitated e-cooperation among partners by means of services for authentication and authorization, seamless access to distributed data sources, data protection and access right, and standardization.

Moreover, the group developed an adaptive system for dam behaviour modelling that is based on a multiple linear regression (MLR) model and is optimized for given conditions using genetic algorithms (GA). Throughout an evolutionary process, the system performs real-time adjustment of repressor's in the MLR model according to currently active sensors (Stojanovic et al. 2013).

There is still a lack of joint research and development projects between Serbian academia and industry, as discussed next.

2.3. Cooperation Between Academia and Industry

There are large differences between the HPC competence centres in terms of size and experience, and there is no clear information of such infrastructure in Serbia and how it can be useful for SMEs business development purposes and benefits.

Cooperation between academia and industry is based on cooperation with large systems and companies, such as companies in the oil industry, telecommunications, electric power, etc.

HPC resources in Serbia are mostly used for the purpose of scientific research within the universities and institute projects.

The conclusion is that the HPC centres in Serbia do not have concrete, planned, systematic and organized cooperation with SMEs regarding the application of these clusters or services that they can provide.

There were some consultation meetings with SMEs, and their participation in several training sessions that HPC centres organized earlier. These were mainly part of the project activities on certain programs and did not result in creation of appropriate supporting systems.

3. Needs for Successful HPC Deployment

In order to describe the conditions that need to be met and actions that need to be taken for HPC to become fully successfully deployed in Serbia, we will first outline the officially recognized need for a general digital transformation of Serbia, discussing the role of HPC in this ongoing process (Section 3.1), and then summarize concrete conclusions relevant to the field of HPC, made in a regional workshop (Section 3.2).

3.1. Digital Transformation of Serbia

The need for a digital transformation of Serbia was recognized both at national and international levels. According to national-level strategic documents (InnoHPC 2017b), the following three aspects were identified as important: (1) University-level transformation; (2) Research, innovation and entrepreneurship, and; (3) Industry development strategy and policy (see Figure 1).

Figure 1: Digital transformation of industry in Serbia – officially recognized strategic directions.

The following needs were identified for university-level transformation:

- Innovation of study programs and their alignment with trends in scientific, technological, economic, social and cultural development so that the final outcome of education is fully synchronized with market demands.
- Support for higher-education institutions (HEIs) in modernization, procurement and implementation of software and hardware.
- Increase of the capacity of faculties that educate ICT experts and respective budget quotas.

HPC is obviously a highly relevant field with respect to the above. In Serbia, HPC does require innovation of curricula, updates of hardware and software, as well as more HPC specialists being output from universities.

Research, innovation and entrepreneurship were determined to have needs in the following areas:

- Direct research within the HEIs towards priority areas for Serbia's development.
- Support for the concept of "entrepreneurial university" – the creation of a new knowledge-based industry nucleus.
- Joint applied and developmental research of the academy and industry in the framework of the projects implemented at the HEI level.
- Establishing a strong scientific and research base at universities and research institutes.
- Development of technological and business infrastructure, in support of the creation of innovative enterprises.
- Improving conditions for easier foreign technology transfer; Digitalization of telecommunication infrastructure, Internet access, encouraging the development of the web economy, ensuring efficient access to information and knowledge.
- Building an information society – applying ICT in different areas.
- New legal solutions in the field of electronic document, electronic identification (signature, timestamp, electronic seal, reliable delivery and storage), electronic accounting.

Again, HPC is directly applicable to the above needs: as a key experimental facility for research in many priority areas, a promising avenue for university-connected entrepreneurship, an enabler of joint academic and industry research, an important asset for innovative enterprises, driver of the Web economy, and so on.

Lastly, industry development strategy and policy was deemed to need:

- Measures and activities of the development of a knowledge-based society and lifelong learning, application of innovations, development and use of ICT.
- Expansion in existing frameworks through technological modernization of the Medium-Low-Tech sector and the introduction of high-tech content.
- Changing the technological profile of the industry, through the migration of the focus of industrial production from the dominantly low-tech sector to high technology.
- Development of new business models of the Serbian industry based on the wide use of ICT technologies at all levels.
- Incentives for investing in start-up projects, exploiting the capacity of technological parks and local technology centres development.

As an instance of "high technology," HPC is one of the key fields to be encompassed in the industrial development strategy and policy, as well: ITC development and use, technological modernization with high-tech content, new business models influenced by HPC, and local tech centres and parks devoted to HPC.

At the international level, EU and Danube region strategic documents (InnoHPC 2017b) highlight the following areas: (1) Improvement of framework conditions for SMEs; (2) Cooperation between universities and industry, and; (3) Organizational aspects of digital transformation.

Improvement of framework conditions for SMEs involve:

- Improving the use of EU funds for ICT.
- Promotion of the internationalisation of SMEs and facilitation of interdisciplinary cooperation.
- Support for investments in competitive infrastructure for SMEs, especially in rural and border regions.
- Support for openness to new research and market developments in a public and people oriented approach.
- Support for initiatives to stimulate the creation of new markets and diffusion of new technologies.

HPC promises to play an active role in the above developments as well, by facilitating interdisciplinary cooperation (HPC users and providers), investments, research and market developments, and creation of new markets (e.g. HPC services directly, or indirectly through "game-changing" practices exemplified by computerized stock trading).

Cooperation between universities and industry:

- Fostering the environment for technology transfer and dissemination of accumulated knowledge at the university level.
- Establishment of labs through which industry and academia jointly develop new products by involving customers from very early stages.
- Establishment of a national high performance computing centre.

The above points scarcely need additional comment, as they end by highlighting the need for establishing national NPC centres.

Organizational aspects of digital transformation:

- Establishment of new centres of digital transformation and their integration with pan-European network of such centres.
- Better support for digital transformation through funds and programmes.
- Education of experts with highly specialized skills.
- Digital training for all decision-makers involved in designing, consulting and supporting policies and regulations.
- Promotion of entrepreneurship as an opportunity for acquiring digital skills.

Finally, HPC is directly or indirectly relevant in all above points.

In all, it can be concluded that HPC is highly relevant, in all important aspects of the impending digital transformation of Serbia. On the one hand it is encouraging to see so many promising avenues for HPC-related activities and deployment. On the other hand, this supports the assessment for the previous section about Serbia's current low level of development in the area of HPC. In the next section we will discuss the progress that has been made so far.

3.2. HPC-Related Recommendations and Conclusions

At the workshop held in September 2017 at Zlatibor, Serbia, representatives from Serbia, Bosnia and Herzegovina, and Montenegro agreed that the whole region is late compared to other parts of Europe in terms of using HPC (InnoHPC 2017b). Therefore, the region should be treated as an initiative and start from the basic activities that represent recommendations and conclusions:

- More intensive promotion and education.
- Deeper focus on research and development.

- Organization of more meetings with the SMEs management for the purpose of HPC for their companies.
- Choosing the right companies.
- Organization of specialist trainings.
- Spreading of European practices and successful stories from the global market.
- The necessity of organizing training for students on the use of HPC.
- Raising the level of information in both sectors, the business and education.
- Strengthening cooperation between the academy and the economy.
- To point out the advantage of digitization in the industry to gain competitive advantage and for the optimization of their processes.
- The necessity for the request and the need to use HPC comes from companies.
- To involve the other industries and business sectors in the project (like energy and electric power industry).
- Make HPC more familiar to the authorities.

4. The Progress

On a personal note, one of the biggest, and probably most long-lasting effect of our activities within the InnoHPC project is networking, i.e. establishing connections with partners from academia which otherwise would hardly have happened. We were pleasantly surprised by the number and proximity, as well as the advanced HPC infrastructure and experience of our project partners. From the perspective of Serbia as a whole, it can be said that the scope of AEGIS has been extended to connect not only Serbian institutions, but institutions from the Danube region as well, which has already started to pay dividends (at least) in the following areas:

- Education: new and shared teaching materials, organized workshops, and related project activities promise to help enhance university curricula and boost the output of HPC-expert (or at least HPC-literate) IT professionals;
- Knowledge transfer: exchange of technical knowledge and practical know-how will certainly help Serbian institutions enhance their HPC hardware, software, and general practices – leading up to the last point,
- Opportunities for joint research: with identified joint needs and goals, project partners have enhanced opportunities to engage in joint research projects and ventures.

The role of the InnoHPC Lab platform developed within the project has been tantamount with respect to within-project networking, and is beginning to show its promise in connecting HPC service providers with potential users. With a fulfilled quota of SMEs that answered the open call for SMEs from the automotive and electronic sectors, we are already witnessing engagement between academia and industry that may lead to all sorts of successful outcomes.

The mentioned call for SMEs was answered by three enterprises from Serbia, making our country a significant contributor to the project in terms of industry engagement. This is not only beginning to improve the described situation of the lack of mutual awareness between industry and academia within Serbia, but also building new connections between Serbian industry and foreign partners.

In a comprehensive poll (InnoHPC 2018) that featured a significant portion of Serbian SMEs (relative to the number of poll participants), project activities identified the existence of awareness of SMEs about the importance and promise of HPC, with major reasons (adding up to more than 70%) for the decision on using HPC solutions in the daily work including:

- Solving problems that could not be addressed through other means;
- Addressing problems more efficiently, faster, at the lower cost; and
- Developing new products or services.

We envisage that at least a few Serbian SMEs will turn the above reasons into concrete long-term goals in the near future.

Therefore, in light of the HPC-related recommendations and conclusions discussed in Section 3.2, it can be said that progress has been made in most of the highlighted areas: promotion and education, focus on research and development, meetings with the SME management, choosing the right companies, etc. Of course, more long-term goals such as raising the level of information and strengthening cooperation will take more time to evaluate, but we are optimistic that such goals will be fulfilled as well.

5. Conclusion

This chapter described the somewhat pessimistic state, but optimistic outlook for the field of high-performance computing in Serbia. From better inclusion in university curricula, to improved networking between Serbian academia and industry both within and beyond our country's borders, we see great potential of HPC as a driver of innovation and general progress.

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National Case Study in the Danube Region: Ukraine

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Abstract: Political and economic turbulences in the last couple of years have not remained unnoticed for the Ukrainian development. The existing HPC infrastructure is a good starting point for further development and improvements of the regional innovation ecosystem. The latest comparative assessment of the research and innovation performance ranks Ukraine as being a modest innovator. As a result, there are many aspects that have to be addressed in order to achieve a better milieu for R&D. This paper deals with the appraisal of the HPC framework in Odessa and emphasizes concrete recommendations needed for improving the HPC and innovation profiles. Thus, HPC Benchmarking and Digital Industry Guidelines are at forefront. The analysis of the desktop research and focus groups result can be considered as a starting point for further policy recommendations due to their targeted approach.

Keywords: Ukraine, HPC case study Ukraine, InnoHPC project

1. Overview of country innovation performance

Recent political, social and economic challenges in Ukraine determined the stakeholders to undergo a number of reforms in order to redress the damages. Thus, Ukraine will need to advance reforms in multiple sectors to achieve sustainable recovery and shared prosperity (World Bank 2019). A particular focus is on innovation. The latest European Innovation Scoreboard (2018), which provides a comparative assessment of the research and innovation performance of the EU Member States and selected third countries, has ranked Ukraine as being a modest innovator. The report highlights that even though the human resources and employment impacts are the strongest dimensions for Ukraine, the innovation-friendly environment and linkages are on the opposite pole. Even more, in the moment we consider the benchmarking against its European neighbour, Romania, the innovation performance is lower. Thus, having the lowest score among all present countries (EIS 2018, 26). Additionally, this highlights the big discrepancy that still exist between Wester, Central and Eastern part of Europe. As result, Ukraine asked for assistance from the Word Bank in a better utilization of its innovation and industrial potential, embodied in a strong scientific and machine building tradition. Also, the aim is to grow the potential in the outsourcing of digital services (World Bank 2017).

2. Appraisal of the HPC situation in Ukraine

High Performance Computing remained more as a legacy from the Soviet Union. Nevertheless, In Ukraine, there are 2 main institutions that possess HPC: High Performance Computing Center and NSA V.M. Glushkov Institute of Cybernetics of National Academy of Sciences of Ukraine. The NSA's supercomputer center incorporates two cluster systems with users from 12 of 14 departments of the NSA, and more than 20 academic institutions. Thus, the focus on HPC in Ukraine, does not only rely only on building the super computers themselves, but also developing the necessary infrastructure for networking, especially the academic one ().

The shift to a market economy determined the country to embrace HPC usage in other areas, rather than the nuclear or military sectors. Thus, the application of HPC is not as diverse as it is in different countries that poses HPC, especially in the West. However, it does not mean that it does not exist or is not important. Therefore, in present the application of HPC in R&D can be seen in: economy, nuclear, military, automotive, shipbuilding, education, energy/ research or even air-crafting.

2.1. Academia – Industry collaboration

HPC plays an important role for the collaboration between academia and industry, thus contributing to the application of HPC of Ukrainian scientists to a considerable contribution to world fundamental and applied sciences. The presence of HPC clusters offer the possibility for various actors to interact and use the capabilities of the HPC in different fields. For example, in 2009, the National Resource Center of the UNG was established at the Institute of Cybernetics (Sergienko 2014). It provides resources for computations and data storage to a number of virtual organizations engaged in astronomic research (Virgo), molecular biology (MolDynGrid), computational chemistry (CompuChem), medical research (MedgGrid), geosciences (Geopard), etc.

SCIT supercomputer powers were completely used by scientists of institutes of NAS of Ukraine and higher educational institutions. As the author points (Sereinko 2014, 20), when it is used skillfully, the SCIT supercomputer powers allow more efficiently solve problems of prevention of ecological catastrophes connected with the influence of human economic activity on the environment, problems of processing and interpretation of geophysical data to prospect for oil and gas, weather modeling and forecast, and consequences of harmful emissions to the atmosphere. Another area that the Supercomputer Computation Center solves problems is the space. It processes space photos obtained by the satellite "Meteostat" to forecast cloudiness and origination of extreme meteorological situations whose tracing is important for planning air traffic and aerospace photography. Calculations performed by the Institute of Space Research of NAS of Ukraine on SCIT-3 make it possible to efficiently use the obtained data by the satellite "SICH-IM" and to assist in providing the efficient use of the satellite "SICH-2". Additionally, it optimally chooses orbits and plans the functioning of Earth remote sensing satellites for the purpose of land use, protection of large forests, and monitoring of the development of elemental and techno-genic processes (Sergienko 2014, 20).

Another result of the cooperation between academia and industry is the creation (by specialists of the V. M. Glushkov Institute of Cybernetics) of a computer technology that supports making crucial decisions in various situations. It was applied to strategic planning and management, design and development of systems of production and commercial activity, and also in analyzing, modeling, and predicting consequences of actions in solving some economic and sociopolitical problem or other.

On the other hand, for successful operation of atomic power plants under conditions of insufficient information, new algorithms of estimation of reliability parameters are proposed whose accuracy considerably exceeds that of previously used methods and algorithms. This issue highlights again the importance of cooperation between the important sectors of the industry and academia.

Another area of HPC usage refers to the Ukraine's economy transformation. Thus, a number of projects were proposed and carried out that support making crucial decisions and are directed toward the transformation of the economy of Ukraine into a market economy. Also, these project projects aimed to control the over complicated hi-tech systems, systems for computer-aided production management in small-scale manufacturing businesses, and modeling and medium-term forecasting of the dynamics of changing main macroeconomic indicators of the economy of Ukraine (Sergienko 2014, 24). Even more, decision-making supports several key aspects that are developed and implemented:

- export–import policy;
- formation of investment priorities;
- search for economic equilibria;
- estimation of the behavior of a foreign investor under risk and uncertainty;
- economic dynamics of the labor market and models of financial mathematics.

Some of these projects were carried out under contracts with the Ministry of Economy and European Integration of Ukraine, Ministry of Extreme Situations of Ukraine, and Ministry of Education and Science of Ukraine. These collaborations, resulted in the forecast of the real GDP of Ukraine. This approach showed that the developed model has a high confidence level in comparing the forecasted and actual results of the development of the economy of Ukraine. This level surpasses even the well-known short-term (annual) forecasts made by specialists of such well-known organizations as the International Monetary Fund (IMF), World Bank, European Bank for Reconstruction and Development, etc. Thereby, the possibility of adaptation of components and means of the created information technology to new classes of problems has been practically confirmed. Even more, the available data support the thesis that the developed mathematical models and created technology of system analysis make it possible to obtain a fundamentally higher confidence level of results (Sergienko 2014, 24). Therefore, the developed methodology can become the base for further investigations of the economy of Ukraine.

As stated within this chapter, the knowledge obtained from the collaboration between academia and industry does not remain only on pages of monographs and in texts of scientific articles. It is also used for the benefit of the people and for human development. Additionally, want can stress after the analysis of the status-quo, is that the aspect of collaboration is highlighting the importance of association of relevant stakeholders from different fields on various projects.

3. Innovation actors active in High-Performance Computing

As it was mentioned, the usage of HPC can be found in several key industry sectors. Among these the automotive, shipbuilding, air-crafting can be highlighted. Besides the heavy industry, the usage of HPC for R&D is also mostly coming from the academic sphere, meanwhile the SME segment is absent. The absence of HPC usage among SME is explained through several points as lack of resources (both financial and experts) or lack of HPC marketing. Nonetheless, it is important to stress that the SMEs must understand the benefits of HPC usage for boosting their own innovativeness.

Table 1. HPC application in R&D

Entity	Sector/ Area
Ministry of Economy of Ukraine	Economy
Research and Production Association “Impulse”	Nuclear
State Scientific-Technical Center of Nuclear and Radiation Safety	Nuclear
Higher Command-Engineering Military School of Rocket Forces (Kharkiv)	Military
Association “Motor-Sich” (Zaporizhia)	Automotive
”Zorya-Mashproekt” enterprise and VATT “Damen Shipyards Okean” shipbuilding enterprise (Mykolaiv)	Shipbuilding
Poltava University of Consumer Cooperation of Ukraine	Education
Research Institute of Economy of the Ministry of Finance of Ukraine	Economy
“Energoryzyk” Ltd, etc.	Energy/ research
State Enterprise “Antonov”	Air-crafting
Kryukov Rail Car Building Plant (Kremenchug)	Automotive
Zaporizhzhya Atomic Power Station	Nuclear
Public Corporation “Motor Sich”	Air-crafting
State Enterprise ‘Zaporizhzhya Machine-Building Design Bureau “Progress”’ named after Academician A. G. Ivchenko; ‘Melta’ Ltd	Automotive

Sources: Regional HPC capacity report with detailed and systematic assessment of competencies and opportunities of HPC applications for the electronic and automotive industry and assessment of awareness and entrepreneurial spirit of academic institutions 2018

4. HPC Benchmark: the case of Odessa region

In present, there is still present a big gap between countries and regions in terms of innovation development. In order to decrease this gap, it is at upmost importance to tackle this discrepancy. Thus, developing countries and regions have at their disposal various tools to reduce the handicap and to redress the division between center and periphery. In order to undergo with the development of the regional potential, for the HPC Benchmarking in Ukraine[47]. The tool was developed in accordance to the Social Field theory, which argues thatthat any particular field is embedded “in a broader environment consisting of countless

47 The focus group was conducted with stakeholders from academia, HPC centre and SMEs in the Odessa region.

proximate or distal fields, as well as states, which are themselves organized as an intricate system of strategic action fields" (Fligstein and McAdam 2012). Hereby, as Beckert (2010) refers to three social forces that are relevant for economic outcomes: institutions, social networks and cognitive frames. Placing this theoretical framework in the context of the InnoHPC project, the aim was to understand how do social forces help or hinder the development of the HPC and the innovative profiles of particular regions.

Therefore, there were invited several stakeholders (including from academia, SMEs and HPC centres) to take part in a thematic focus group. The discussion with the stakeholders focused on four main topics:

- HPC and Innovation regional profile;
- Institutions
- Networks
- Cognitive Frames

By conducting the focus group with these stakeholders, we obtained relevant information about the strengths and weaknesses of the regions on these four dimensions (see Table 2.). Each dimension was measured with the help of four questions.

Table 2. Overview of the HPC and social forces strengths and weaknesses in Ukraine

	Strengths	Weaknesses
Level of application of HPC in industrial R&D	advanced industry still uses them	seems to me minimal
Availability of High-Performance Computing information	all resources are available and free	for the industry opportunities are limited, because the resources either closed, or paid or information is a trade secret and real, very private information
Applications of advanced ICT tools for R&D in enterprises from automotive and electronics industries	where an industrial enterprise is developing, research is being conducted	all research is abroad automotive industry is developing poorly
HPC oriented towards industrial R&D	presence of good practices	R&D for own purpose
Role of the public authorities for HPC	N/A	the state slows down the processes

Capacity to attract talented people	N/A	there are no financial resources for specialists
Capacity to retain talented	certain companies are trying	absence of retaining capacity
Regional/national innovation-policy	N/A	low implementation
Networks' organization	presence of communication easy to find partners	too many specialists
Cooperation between stakeholders	stimulates the movement of others	people are trying to save money
Cooperation between stakeholders and actors outside the region	Usage of the information provided foreign partners	lack of abroad travel opportunities (lack of financial resources)
Stakeholders' trust	trust is present	no possibilities
Culture enabling creativity, entrepreneurship and new technologies	entrepreneurial population	presence of grey market
Culture enables the learning processes	culture enables learning processes	N/A
Competition a positive aspect	will reduce the cost of services in this market and they will become more accessible (HPC)	bad for manufacturer
Globalization	fully integrated into these world processes and everything is changing quite synchronously	best specialists and the best technologies are sailing away

Source: Regional HPC capacity report with detailed and systematic assessment of competencies and opportunities of HPC applications for the electronic and automotive industry and assessment of awareness and entrepreneurial spirit of academic institutions 2018

The focus group with the stakeholders, highlighted that the weakest dimension is the Institutional one, because there weren't identified any strengths, except the fact that some companies are trying to retain experts. Thus, the region does not have any possibilities to attract or retain people, which influences the innovation process. Even more, as the stakeholders pointed the public authorities are slowing down the process of HPC. Meanwhile, we can point that in the case of Networks and Cognitive Frames, these two dimensions have both strengths and weaknesses in the region.

Another aspect of the HPC Benchmarking was in assessing scores considering the strengths and weaknesses of each dimension. Thus, it offers additional information regarding how the stakeholders perceive the state of affairs in the Odessa region (see Table 3).

Table 3. Overview of the HPC and social forces scores in Ukraine and the Danube region

	Ukraine	Average in the Danube region
Level of application of HPC in industrial R&D	1	2
Availability of High-Performance Computing information	3	2.43
Applications of advanced ICT tools for R&D in enterprises from automotive and electronics industries	1	2.07
HPC oriented towards industrial R&D	4	2.25
Role of the public authorities for HPC	1	2.18
Capacity to attract talented people	1	1.96
Capacity to retain talented	1	1.71
Regional/national innovation-policy	1	2.07
Networks' organization	4	2.61
Cooperation between stakeholders	3	2.29
Cooperation between stakeholders and actors outside the region	2	2.57
Stakeholders' trust	4	2.54
Culture enabling creativity, entrepreneurship and new technologies	4	2.54
Culture enables the learning processes	4	2.5
Competition a positive aspect	3	2.61
Globalization	4	3.07

Source: Regional HPC capacity report with detailed and systematic assessment of competencies and opportunities of HPC applications for the electronic and automotive industry and assessment of awareness and entrepreneurial spirit of academic institutions 2018

Even more, by conducting the Benchmark also in other countries across the Danube region, it offered more details concerning the HPC and innovation situations. The main conclusion is that the stakeholders from Ukraine, consider the HPC/ innovation and Institutional profiles as being the weakest. Compared with the average scores at the Danube region level, these two profiles are less developed. This could be explained by the economic/ political instability that is present in the country, but also with the fact that HPC/ innovation or R&D is part of very specific industry. There is access to HPC that is used for industrial R&D, but it is not spread toward SMEs. Companies struggle to exist, thus the usage of HPC is not in their area of priority usage or even these companies do not see the added value of HPC. Even if the companies would see the benefit, it would be hard to train or obtain experts with HPC knowledge, especially the region does not have the capacity to attract and retain them. Nonetheless, it is important for authorities to perceive HPC infrastructure important not only for the areas where it is being used, but also as an opportunity for other.

At the same time, the scores for the other two dimensions, Networks and Cognitive Frames, are above the Danube average. One of the plausible explanations for a higher score than at the Danube region, would be that in moment there is a region with low level of institutional help and which is a modest innovator, networks and society's openness will come at forefront toward innovations. As the stakeholders pointed, the region lacks cooperation of the stakeholders with actors outside the region, because the travel possibilities are scares.

As mentioned earlier, the Benchmarking highlighted on one hand the strengths and weaknesses of the region and on the other hand translated these characteristics to scores. As we can observe, there is no discrepancy between the two aspects. Thus, we can state the goal of the of the Benchmarking has been achieved. It offers valuable assets for future development of the HPC/ innovation in the region, by triggering specific actions toward improving the situation.

5. Recommendations Digital Transformation of Industry Guidelines

Ukraine's aspirations of becoming an EU member determines national authorities to harmonize the legislation according to the European one (Spiliopoulos 2014). As a result, on the key areas to which authorities have to look-up to improve the legal framework in various sectors, including the Digital Transformation of Industry. In order to assess the needs and opportunities for HPC inside Ukraine with a specific focus on SMEs from the electronic and automotive sectors, the present chapter deals with a set of specific guidelines for improving the framework. Thus, considering the current state of affairs, there is a set of guidelines that can contribute to the improvement and change toward a Digital Industry:

- To create a Strategy of High-Technological Developments before 2025
- To steer entrepreneurship

- To provide of financial support for innovation, research and development of high technology
- To preserve and support of intellectual capital
- To create a modern information and communication infrastructure
- To introduce effective institutional mechanisms for the development of high-tech industries
- To increase the exports of high-tech products and services
- To stimulate the development of advanced technologies
- To reduce the import dependence of the domestic high-tech sector (Digital Transformation of Industry Guidelines 2017)

Figure 1: Accelerating the digital transformation in Ukraine

Sources: Digital Transformation of Industry Guidelines 2017

These steps have the aim to improve the conditions for research and innovation. Additionally, it is expected that following the good practices from the West, it will enhance the diffusion of HPC as a general-purpose technology by fostering access to HPC infrastructure and competencies. Nevertheless, by creating a favourable milieu for the SME R&D, it is expected to have an increase of HPC usage among enterprises from different sectors.

6. Conclusion

Political and economic turbulences in the last couple of years have not remained untraceable for the Ukrainian research development. The existing HPC infrastructure is a good sign for further development and improvements of the regional innovation ecosystem. Additionally, the existing good practices in Western countries can be considered as anchors for the Ukrainian stakeholders.

The analysis of existing state of affairs, but also the implementation of the InnoHPC project it was possible to highlight the particularities of the region. As a result, it is important to mention several key aspects that can contribute the HPC/ innovation potential. The collaboration of the academia and the industry has to be regarded as good premises for further development and spread of HPC in the region and in the country. Nevertheless, as it was showed there are many aspects that have to be addressed, in order to achieve a better milieu for R&D. Ukraine is considered a modest innovator. In the same time, the InnoHPC project, provided a reliable tool of benchmarking the HPC/ innovation profile of the region. Thus, it points the strengths and weaknesses of the regions from the perspective of the three social forces. The development of the HPC infrastructure and regulatory framework is seen as vital steps toward improving the regional innovation context. Local stakeholders have to work on the region's capacity to attract and retain experts in the field. Current political, social and economic situations contribute to the brain drain, even if the culture enables creativity, entrepreneurship and the learning processes.

Additionally, the need of transformation of the Industry toward Industry 4.0, which can be addressed through steering entrepreneurship, providing financial support for innovation, research and development of high technology or reducing the import dependence of the domestic high-tech sector. There is a need for promotion of the Open Innovation paradigm, which can boost the level of innovation performance in the region. Additionally, it is important to understand that the strategic orientation of key actors is crucial for path-creation (Rončević and Fric 2017). These actors contribute at launching effective policies that would result in a developmental break through. As the authors point, firstly specific socio-cultural conditions have to be met. Nevertheless, these results can be considered as a starting point for further policy recommendations due to their targeted approach.

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