

The role of university technology transfer centers in the development of the "green" potential of cities

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Abstract. A special role in creating a green economy of modern cities is assigned to service industries, which determine the conditions and quality of life of people. The aim of the study is to identify the contribution of Perm universities in the development of a city's green economy through the creation and dissemination of green technologies. Using the comparative case study methodology, the methods of content qualitative analysis and bibliographic analysis, we study the contribution of Perm universities and university technology transfer centers to the creation of a green economy in the city of Perm and other cities in the region. It has been established that scientific research carried out in Perm universities is capable of providing the industry and service industries with modern scientific developments in the field of green technologies and green products. The study confirmed the research hypothesis that Russian Universities can influence upon the green development of urban and regional economies in the places of their location (presence). It is concluded that Perm universities are in line with the modern innovation ecosystem and there is an opportunity to expand the participation of universities in the Perm Territory in creating the city's green economy.

Key words: Green economy; Green cities; Green service industries; Green technologies; University technology transfer center.

1 Introduction

The development of a green economy is one of the global challenges of modern development, in the solution of which all sectors and industries of the economy, business and individual citizens should take part. Service industries (utilities, healthcare, education, science, transport, recreation, tourism, waste disposal, improvement of public areas, etc.) are conductors of green innovation, provide more comfortable living and working conditions for people. In turn, green innovations are becoming a strong factor influencing the economic development of cities [1, 2], while modern universities are actively involved in the sustainable development of cities and regions through interaction with several community players [3-6]. As a result of such interaction, universities get the opportunity to “jointly create and transfer knowledge and innovation, develop the local economy and promote cultural diversity” [7].

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Modern foreign researchers note that “The contribution of universities are wide-ranging, encompassing scientific and technological advances and innovation in a wide range of fields, from digitalization to energy provision, mobility and infrastructure, food security and landscaping, active lifestyle, and human well-being, with all these aspects encompassing sustainable development” [4, 7, 8].

The main areas of interaction between universities, business and city authorities on the issues of sustainable development of cities, which are most often described in the scientific literature [9-11], are “promoting the improvement of society through teaching, learning and civic engagement” [4]. This makes it possible to increase the overall innovative receptivity of the region and the local community to new technologies and innovations in urban management [12, 13].

A special part of scientific research on the interaction between universities and urban communities in the field of sustainable urban development is the study of the experience of implementing university technology transfer (UTT) [14] “as a way to create both economic and social value” [15, p. 951]. In turn, a better integration of social and environmental values in the activities of universities becomes the basis of their own sustainability [16].

The green economy is such a key socio-economic value. Accordingly, the role of universities and research centers in the dissemination of the principles and ideas of the green economy in society and business is increasing. An objective requirement of modern development is increasing the participation of universities in the process of introducing environmentally friendly technologies into the industry and service industries, green approaches to assessing the interaction of business, society and the environment.

International experience shows that in large universities, the transfer of new knowledge and technologies to industry and other sectors of the economy takes place within the framework of the work of the so-called Technology Transfer Offices (TTOs). These divisions are responsible for the formation of the university "business model" of technology transfer using various mechanisms for the transfer of knowledge and technology to the economy, industry and society. A special place among such mechanisms is occupied by the mechanism for the transfer of environmentally friendly and resource-saving technologies, green technologies that ensure the green development of society. This requires a reorientation of the existing University Technology Transfer Business Model (UTTBM) towards goals of green development.

Russian universities and cities are no exception. The development of a green economy, including the development of green service industries, is today an important condition for the development of cities. In this regard, the general research goal of the article is to study the experience of Perm universities in the development of a green economy in the city through the creation and dissemination of green technologies in service industries.

It should be noted that the city of Perm occupies a special place in the national rating of green large cities (with a population of over 1 million inhabitants) in Russia. For many years, the city of Perm has been holding 1st place among all Russian large cities in the "green city" category in accordance with the annual rating of green cities in Russia [17, 18]. The leading positions of a large industrialized city in the category of green cities are of interest and require explanation. The study is devoted to the study and analysis of links between universities, sustainable (green) development and cities. It will also fill a gap in the scientific literature in this part of international studies that examines the contribution of universities to sustainable development at the city level. This will make it possible to apply existing experience in other universities and countries, especially in developing countries where, due to historical conditions and the current level of socio-economic development, there is no such national experience.

2 Research methodology

2.1 Literature review

The issues of developing green cities have become increasingly relevant in recent years [19-21], although the problems of forming green spaces in large cities and urban areas have been discussed for a long time [22]. At the same time, most of the literature is devoted to the analysis of ways to adapt cities to climate change [23, 24] and the role of green infrastructure in the urban economy [25, 26]. Urban greening to cool the air in residential areas is also being actively explored [27] for the implementation of tasks within the framework of green innovative development of cities and regions [28-31].

At the same time, a special role in creating a green economy in cities is assigned to service industries, which determine the conditions and quality of people's life [32]. Utilities, water supply, heat supply, electric power industry provide both people and business with the necessary resources (heat, gas, electricity, sewerage and water supply). At the same time the quality of water, the timeliness of supply and the cost of heat, gas and electricity, the size of the "carbon footprint" in the production of basic utilities [33], the possibility of saving them and reducing losses during the operation of buildings and during transmission in networks are determined by new technologies for the production and supply of utilities to consumers. In particular, the possibilities of creating an alternative electric power industry, primarily solar energy, in cities are being actively studied to increase the autonomy of individual residential complexes and obtain a sustainable energy supply [34]. Also, the use of green materials and green technologies in housing and communal services is becoming increasingly important and is actively spreading both in foreign countries and in Russia [35].

The public transport system, as well as air, road, and rail transport face ever more stringent tasks to reduce CO₂ emissions into the atmosphere, reduce vehicle operating noise, and improve their reliability and availability [36]. This, in turn, is also a direct manifestation of the use of green technologies in these industries and an important component of the green economy as a whole.

The potential of green technologies is huge in the field of waste management. Waste disposal system should become more and more safe for people, environment, nature.

As for the development opportunities for all these areas based on green technologies and green innovations, universities and the technology transfer centers established in them are playing an increasingly important role. At present, a special request of society, the state, industry and other organizations to universities lies precisely in the broad and multidirectional stimulation of the development of a green economy and green industries through educational activities, as well as through green R&D and green innovations.

A study of the scientific literature on this issue showed that the transition to the Quadruple Helix (QH) model (significantly expands the range of users and increases the demand for new technologies. This fully applies to the tasks of universities' participation in the creation and development of a green economy based on the transfer of technologies and approaches to external users for the implementation of tasks within the framework of green innovative development of cities and regions [37, 38].

In modern conditions and in the future an increasingly significant group of green technologies users are enterprises, organizations, various structures, individual citizens implementing the basic principles of a green economy. In these conditions universities should ensure a wider and more active introduction of green technologies into the economy and society.

However, a number of researchers note that despite the active development of concepts and approaches in the field of UTTBM, the ongoing research is still fragmentary [39]. As for the study of the participation of universities in the green development of cities, industries and countries, they are still poorly represented in the economic literature. The largest part of the research is devoted to the analysis of technology transfer to industry, to the extractive industries (oil production, oil and gas transportation), to the transport sector. At the same

time research conducted at universities on the development of green technologies in water purification, the creation of energy-saving and resource-saving technologies are reflected, first in industry scientific journals and do not fall into comprehensive studies on economics, management, and business modeling.

A special place among the sectors of the tertiary sector of the economy is occupied by the sphere of education and science. These organizations do not produce specific goods and products but provide all other industries with new knowledge and technologies, participate in the reproduction of human capital, and also shape public opinion on key development issues. Special studies are also devoted to the study of the contribution of universities to the formation of public opinion in the field of sustainable development and green economy [40, 41].

2.2 Data

Data on UTTBM and the areas of activity of technology transfer centers of 5 key universities in the city of Perm were taken as a base for the study (Table 1).

Table 1. The General information about universities - objects of analysis.

Full name of the university	Short name	Year	Web site
Perm State National Research University	PSU	1916	http://en.psu.ru
Perm State Agro-Technological University named after Academician D.N. Pryanishnikov	Perm SATU	1930	https://www.pgsha.ru/en
Perm State Medical University named after academician E.A. Wagner	PSMA	1931	https://www.pdma.ru
Perm State Pharmaceutical Academy of the Ministry of Health of the Russian Federation	PSPA	1936	https://www.pfa.ru
Perm National Research Polytechnic University	PNRPU	1953	https://pstu.ru/basic/information/

Source: compiled by the authors.

Quantitative performance results are not analyzed in this study. A comparative analysis was carried out according to the qualitative characteristics of technology transfer centers, highlighting the main directions of academic and entrepreneurial activities of universities and their participation in the creation and transfer of green technologies.

All 5 universities accepted for analysis are “anchor” for the city and the region. Branches of other Russian universities that are also present in the region (for example, the Perm branch of the HSE, the Perm branch of the Plekhanov University) are not included in this analysis, since their research activities only partially reflect the general policy of the universities. At the same time the analyzed universities differ in terms of research and academic activities.

The set of UTTBM characteristics, on the basis of which the strategic directions and prospects for the development of TTC's work was assessed includes a wider range of indicators and structural elements of activities than such traditional indicators for assessing the level of commercialization of knowledge and technologies such as the volume and number of licenses obtained and patents sold.

Based on the theory of network interactions, institutional theory, conceptual substantiation of the essence of modern UTTBM for content and context analysis, the following UTTBM elements of a specific university were identified, which formed the basis for the analysis:

- the description and structure of the network (external and internal);
- the structure and value needs of stakeholders, including an orientation towards green technologies;

- the scientific profile of researchers (including individual scientists, research centers and laboratories);
 - the role of the university departments responsible for technology transfer, including the role and functions of the TTO;
 - existing research initiatives (current and accumulated);
 - institutional system.
- The collected data were subjected to factor and context analysis.

3 Research results

The study has showed that the formation of the UTTBM, aimed at the development of green research and the transfer of green technologies, at the basic universities of the Perm Territory started at the beginning of the last decade as part of the intensification of innovative activities of both industrial enterprises and the urban sector [42, 43].

At the same time all UTTBMs have a pronounced sectoral nature, which is due to the sectoral affiliation of a number of universities (medicine, pharmaceuticals, agriculture), the sectoral nature of scientific research (specific industries - aerospace, road, chemical and petrochemical, etc.) and types of academic activities (fundamental branches of science - physics, chemistry, biology, etc.). Thus, the PSMA and PSPA research centers provide the healthcare sector of the city, region and country with innovative medical technologies, devices, new treatment methods, new drugs and means of monitoring the safety of drugs and medical products.

Studies and UTTBM Perm SATU are focused on the agricultural sector, including innovative developments in the field of agricultural production based on environmentally and chemically safe technologies, which ensures "green" production in the agro-industrial complex. Perm SATU is actively working in the field of modern technologies for land reclamation, adaptation vegetation to urban conditions. This direction contributes to the development and improvement of the city's beautification sphere with the help of green spaces, as well as the improvement of the environmental situation in the industrialized zones of the city and territories. Also Perm SATU is actively developing technologies for environmentally safe disposal of organic and inorganic waste, methods for environmentally effective cleaning of water sources, etc.

Fundamental and applied research of a natural science prevails in the structure of PSU research, carried out in the areas of geosystems; physical and chemical problems of rational nature management; information technologies in forecasting within the framework of the relevant world-class laboratories. As for the contribution of individual scientific departments of PSU to the development of the green economy of the region and the city, the results of research and breeding work carried out by scientists of the Faculty of Biology and the Botanical Garden of PSU are actively used in the work on greening urban areas and provide innovative support for the improvement and recreational sphere of the city and the region.

An analysis of the areas of scientific research, practical developments and green technologies transferred to industry, services and the economy, created in PNRPU, showed that their range is very extensive and extends to almost all areas of activity and urban economy, including many green areas.

In particular, the areas of implementation of innovative technologies relate to such service industries as housing and communal services; waste management; transportation system, including smart transport, smart traffic control, etc.

We told about the important role of Perm universities in the formation of the "green" city structure and their participation in innovative and technological support of several service industries (improvement, waste management and transport management) in the framework of the UN dialogue [44], as well as in a number of scientific articles [34].

Table 2 presents the main areas of green service industries' activity, as well as the contribution of the analyzed universities to green technologies in specific service industries

and the development of a green economy in general. The color fill characterizes the level of intensity of the contribution of each university to the development of a particular service industry: the darker the color, the greater the contribution. Lack of participation is indicated in white (no fill).

Table 2. The contribution of the leading universities of the Perm Territory to the green development of service industries.

Service industries	PSU	Perm SATU	PSMA	PSPA	PNRPU
Landscaping					
Improvement (lighting of public areas)					
Improvement (street cleaning, snow removal in winter)					
Heat supply					
Power supply					
Water supply and sewerage					
Gasification					
Waste management					
Road traffic					
Public transport					
Medicine and spa treatment					
Recreation and rest					
Tourism					

Source: compiled by the authors.

As can be seen from Table 2, many green scientific research is carried out simultaneously in several universities and is often in cooperation with each other in almost all areas.

Also, leading Perm universities participate in multilateral collaborations with local and regional authorities and business structures, including for the implementation of national projects and federal programs.

In 2019, a world-class scientific and educational center "Rational Environmental Management" was created. This scientific and educational center operates on the basis of three scientific and educational organizations: PNRPU, PSU and the Perm Federal Research Center of the Ural Branch of the Russian Academy of Sciences and with the participation of the leading industrial enterprises of the region and the country – PJSC LUKOIL, JSC UCC Uralchem, PJSC Uralkali and others. The work within this center is carried out on the principles of a consortium, and the main areas of scientific activity cover such areas as efficient energy and mechanical engineering; new materials and substances; chemical technology; automation and robotization of production and services; ecology and safety of territories. Also, the area of stakeholders' interest includes a wider range of issues related to the development of innovative technologies for subsoil use and related industries, including solid minerals and hydrocarbons. Many of these developments are green in nature.

In 2021, PNRPU and PSU became participants in the Priority 2030 federal program. PNRPU also participates in the Open University project.

In March 2023, the administration of the Perm Territory entered into a concession agreement for the construction and operation of an interuniversity multifunctional student campus in Perm. The project to create campuses is part of the national project "Science and Universities" implemented by the Russian Ministry of Education and Science. The cluster will include modern hotels, sports and recreation facilities, as well as modern world-class scientific laboratories. The anchor participants of the project are PNRPU and PSU.

There is also extensive experience of cooperation between Perm universities and city and municipal authorities in the field of sustainable development and urban improvement. For example, as can be seen from Table 2, PNRPU is actively developing new technologies and materials for the urban economy. Thus, by order of the Ministry of Construction and the

Ministry of Transport of the Perm Territory, a number of projects are currently being implemented within the framework of the NTI market "New materials". These are a project to develop regional standards for the use of local inert materials in the construction and road construction industry, a project to create a paving mix from recycled materials and a project to modify asphalt concrete. The use of new technologies will reduce the environmental burden on the environment and provide an economic effect of up to 35% compared to standard asphalt mixes for sidewalks and public areas. Also, the customers of these new technologies and materials are contractors that carry out works on the improvement of house adjoining and public territories.

The results of the study confirm the conclusions made earlier by other authors that the agglomeration of production services based on the "local neighborhood" effect contributes to a more active introduction of urban green innovations [45-47].

4 Conclusion

Service industries are an important part of the green economy ensuring the quality of life and activities of society, comfortable and safe living for people in large cities. The study of the current state, as well as the identification of the prospects for the participation of Russian universities in the creation and dissemination of green technologies in the service industries of a particular city was the purpose of this study. Based on the analysis of normative and reporting documents of five basic universities of the Perm Territory was made an assessment of their academic and scientific specialization in the field of creating innovative products and technologies, as well as an assessment of their participation in the development and maintenance of a green economy in Perm city and Perm region.

This study is based on a qualitative analysis of the process of consolidation of "green" studies of Russian universities in relation to the economy of a particular large city, namely Perm. The study used a comparative case study methodology.

The results of the study have showed the high potential of the education and science sector in the development of a green economy and green cities. As a result of the study, it was found that all the basic universities of the Perm Territory are actively involved in the creation and maintenance of a "green" economy in the region, including by creating "green" technologies for service industries. However, the speed and volume of transfer of such technologies and products are insufficient to maintain the high rates of development of the green economy within the urban economy. This requires a revision of the UTTBM of universities towards the transition to the Quadruple Helix model.

The results of the study make it possible to contribute to the literature on the green cities, university green technology transfer business model, as well as to the study of the experience of organizing technology transfer to stimulate a green economy within the framework of a specific national model of knowledge and innovation management. In general, the research results make a significant contribution to the theory of green innovation.

The contribution of this research to the development of science and practice can be defined as follows.

Firstly, the results of the study complement a small number of studies on a comprehensive analysis of the factors for the development of green cities in Russia, as well as on the development of university business models for the active transfer of green technologies to the city's economy.

Secondly, it allows expanding the scientific and empirical base on domestic TTO business systems, which is currently a relevant and sought-after area of research. In addition, an analysis of how green technology and green innovation policies affect urban and regional development "opens up several avenues for future work" [48, p. 61].

The prospect for the development of this study is to conduct a quantitative analysis of the dependence of the level of development of the green economy of cities on the functioning of the CTT in the direction of stimulating the transfer of green technologies in a freer form and for a larger number of stakeholders.

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