Methods and technologies for assessing the impact of energy on the geoecology of a region (using the examples of the Baikal region (Russia) and Belarus)

Massel L.V., Massel A.G.
Energy Systems Institute of SB RAS
Irkutsk, Russia
massel@isem.irk.ru, amassel@isem.irk.ru

Zorina T.G.
Institute of Energy NAS Belarus
Minsk, Belarus
tanyazorina@tut.by

***Abstract*—The article examines the results of an international project carried out with the support of the EAPI Fund together with researchers from Belarus and Armenia. The project aims to develop methods and technologies for assessing the impact of energy on the geoecology of the region. The article is devoted to the development of tools for intelligent support of decision-making in this field.**

***Keywords*—intelligent support of decision-making, energy, ecology, quality of life**

I. Introduction

Studies of the impact assessment of energy on the geoecology of the region [1, 2] are conducted within the framework of an international project supported by the EASR[1]-RFFI funds, in cooperation with the teams of scientists of Belarus and Armenia. The article examines the main provisions and results of the project carried out by the Russian side[2].

The fundamental scientific problem addressed by the Project is the development of methods and geoinformation technologies for assessing the impact of energy on the geoecology of the region [3]. The object of research from the Russian side is the Baikal natural territory, comparable in size to Belarus and Armenia.

The article is devoted mainly to the development and integration of modern information technologies for intelligent decision-making support within the framework of the problem. To implement the project, a Web-based information system (WIS) is being developed that integrates mathematical and semantic methods [4, 5] and tools for assessing the impact of energy on the geoecology of the region, a database, a knowledge base and a geographic information system. Individual WIS components will be implemented as agents- services [6]. The ontology of the energy impact on the environment, ontology of pollutants and WIS architecture is presented in the article.

The aim of the project is to develop methods and technologies for assessing the impact of energy on the geoecology of the region. Geoecology is understood as an interdisciplinary scientific field that unites research into the composition, structure, properties, processes, physical and geochemical fields of Earth's geospheres as a habitat for humans and other organisms. The main task of geoecology is to study the changes in the life-supporting resources of the geosphere shells under the influence of natural and anthropogenic factors, their protection, rational use and control in order to preserve productive and natural environment for present and future generations [1, 2].

The purpose of this project fits into the main task of geoecology. The relevance of the project is determined, on the one hand, by the importance of the problem of assessing the impact of energy on the geoecology of the region, and on the other, its insufficient research and the need to attract modern geoinformation and intelligent technologies for its solution.

In the course of the project, the formulation of the main specific tasks to be solved in the project was clarified and expanded: 1) to conduct an analysis of existing methods for estimating of pollutant emissions from energy facilities and existing models for the spread of pollution caused by emissions from energy objects (taking into account the wind rose, transfer, etc.); 2) to make a choice and justify the methods recommended for use in the project, their modification and adaptation, the development, if necessary, of the original methods; 3) to identify critical objects that affect the life support and natural environment of the region (in the energy,

[1]EASR – The Eurasian Association for the Support of Scientific Research, established in July 2016 on the initiative of the Russian Foundation for Basic Research in cooperation with partner organizations of Belarus, Armenia, Kyrgyzstan and Mongolia.

[2]The international project "Methods and technologies for the impact assesment of energy on the geoecology of the region" is being carried out, on the Russian side, with the support of the RFBR grant No 18-57-81001, under the leadership of L.V. Massel.

water supply, etc. sectors), the connection of critical facilities with the quality of life of the population [7]; 4) to analyze the approaches to the construction of geoinformation systems, design a geoinformation system based on 3D geo-visualization, determine the types of interfaces for displaying and analyzing information; 5) to determine the composition of information necessary for the use of recommended methods, to identify sources of information, assess their availability and financial costs of acquiring information; collection and structuring of necessary information; design and implement a database; 6) to develop the architecture of a Web-based information system (WIS) that integrates mathematical and semantic methods and tools for assessing the impact of energy on the geoecology of the region; database, knowledge base and geoinformation system; to develop a knowledge base structure within WIS; 7) to develop a system of ontologies [8] for describing the domain, to adapt and develop tools for semantic modeling, to construct semantic models for assessing the impact of energy on the geoecology of the region; 8) carry out approbation of WIS and apply the developed methods and technologies to decision making support on the justification and development of recommendations for the development of energy taking into account the requirements of geoecology.

II. The impact of energy on the environment

In recent years, the problem of the impact of energy on the environment has become widespread in the scientific world. Various scientists are trying to investigate the negative consequences of the functioning of energy enterprises for geoecology and identify areas of harmful influence. Below the results of Russian and foreign scientists are considered.

According to Vorobyov V.I. (Russia), the analysis of existing principles for the design and development of large thermal power plants (TPPs), as well as optimization models described by different authors, shows that they do not take into account the actual effects of air pollution, since the specific placement in the the area of settlements (especially in built-up areas) that fall into the contaminated zone. On the base of a full-scale instrumental survey of the urban area, Vorobyov V.I. determined the concentrations of harmful impurities at various distances from the pollution source – the territory of the TPPs, the sanitary protection zone, the residential development, confirming the exceeding of the maximum permissible concentration at a distance of up to 18 km. Arslanbekova F.F. (Russia), who investigated the damaging effect on the environment of thermal power plants (TPPs) and motor vehicles, believes that the zone of the most intense air pollution by harmful impurities under torches of TPPs reaches a radius of 3-5 km. Nikiyenko Yu.V. (Russia) investigated the main points of the influence of thermal pollution on the microclimate of the adjacent territories. Based on the calculations, she concludes that the presence of a cooling pond in the area where NPPs and TPPs are located will inevitably lead to negative environmental consequences, including maximum temperature, precipitation and relative importance anomalies. Kozhanov A.A. (Russia) offers methods of geoecological assessment of the influence of the fuel and energy system, based on establishing the relationship between natural conditions and antropogen impact. Studies on the interconnection of Energy, Environment, Climate Change are also conducted abroad, for example, [9-12], the use of GIS-technologies and 3D-geovisualization are considered in [13, 14].

Nevertheless, in studies related to the assessment of the impact of energy on the environment, the quality of life has not been considered so far.

III. The quality of life

This concept was first introduced into the scientific revolution in the 60s of the last century in connection with attempts by foreign researchers to model the trajectories of industrial development. There are many different definitions of the quality of life, but this concept is most fully disclosed in the context of health care. Quality of life is understood as a set of objective and subjective parameters that characterize the maximum number of sides of a person's life, his position in society and his satisfaction with him. Among the factors determining the quality of life according to the definition of the World Health Organization [15], not only financial well-being, but the state of security, health, human position in society, ecology and, most importantly, its own assessment of all these factors is included (Fig. 1) The integral indicator of the quality of life summarizes the indicators of health, social-personal well-being and financial well-being. In the framework of our project, it is important that ecology is included in the quality of life indicators.

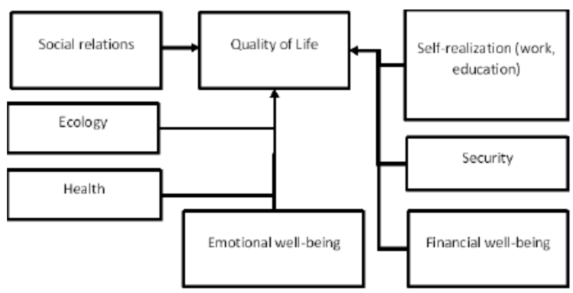

Figure 1. Quality of life as defined by World Health Organization

Under the guidance of the author, work has been done in which it is justified that it is difficult to obtain an integral index using rigorous mathematical methods. It is suggested to involve artificial intelligence methods for this purpose, namely, cognitive modeling is one of the directions of semantic modeling [5, 16]. In addition, quality of life research in the integrated quality of life indicator has not taken into account the impact of energy supply until recently, while a shortage of energy resources can have a significant impact on both the level and quality of life. It is suggested to include external factors in the quality of life indicators, in particular, the degree of provision with energy resources (Fig. 2) [17].

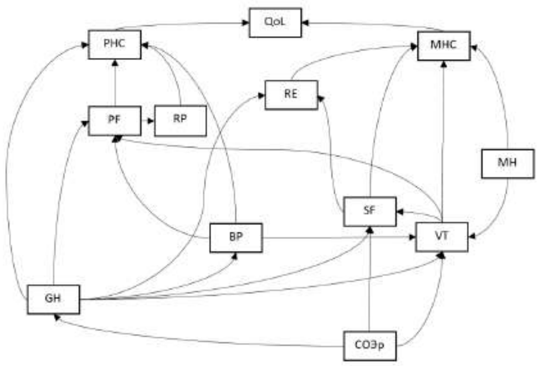

Figure 2. Cognitive map of indicators of life quality using procedure SF-36 (all links are positive)

Comments on Fig. 2:

- PF (Physical Functioning) – physical functioning;
- RP (Role-Physical Functioning) – role functioning conditioned by physical state;
- BP (Bodily pain) – pain intensity;
- GH (General Health) – general health;
- VT (Vitality) – life activity;
- SF (Social Functioning) – social functioning;
- RE (Role-Emotional) – role functioning preconditioned by emotional state;
- MH (Mental health) – Mental health;
- PHC (Physical health) – general component of physical health;
- MHC (Mental health) – general component of mental health;
- QoL (Quality of Life) – integral indicator of quality of life;
- COEr (DSEr) – degree of supply with energy resources.

IV. Proposed methods and approaches to solving the problem

In the development of tools for intelligent support of energy and environmental decision-making, the proposed project is based on the application of methods of geoinformation technologies based on 3D geo-visualization [18], critical infrastructure research methods [7], decision support methods, knowledge engineering methods, object approach methods (analysis, design, programming), system and application programming methods, design methods of database ,of information and expert systems, as well as author methods of situational management, semantic modeling (primarily ontological and cognitive) and intelligent technologies for desicion-making support [5]. It’s proposed to develope and adaptate to the project theme the author’s methods of constructing an ontological space of knowledge in the field of energy; methods of semantic (ontological and cognitive) modeling in power engineering, methods of 3D-geovisualization and methods of visual analytics with elements of cognitive graphics, as well as methods of intelligent systems development for supporting the adoption of strategic decisions in energy [19].

As an illustration of the approach to constructing a ontologies system of applied domain, Fig. 3-4 present the ontology of the impact of energy on the environment (Fig. 3) and the ontology of pollutants from energy facilities (Fig. 4)

From Fig. 4 it can be seen that energy companies (enterprises of electric power industry, heat power engineering and fuel and enterprises for energy resources extraction and transportation) can pollute water, air and soil (first of all, the chain associated with air pollution is considered in the project, see Fig. 3) Negative impact on the quality of life of a person can be either direct or indirect (through the plant and animal world, i.e. through the food chain).

In Fig.. 4 shows the first version of the ontology, of pollutants from energy facilities, built on the basis of [20], which rather illustrates the way of structuring knowledge about the subject area. In the following, the ontology can be extended or used as a hybrid: some of its concepts can be considered as meta-concepts, which will be described by detailed ontologies: for example, the concept of "Purification" can be represented by detailed ontology of the methods and levels of purification; the concept "Combustion method" can be represented by extended ontologies describing different combustion methods for small and large boiler plants and thermal power plants, etc.

As mentioned in the introduction, a Web-oriented information system (WIS) is being developed to implement the project, integrating mathematical and semantic methods, tools for impact assessment of energy on geoecology in the region, a database, a knowledge base and a geographic information system. It is supposed to use the authors’ results done earlier to study energy security problems: semantic modeling tools, Geocomponent, knowledge base tools and the Repository. Individual WIS components (Geocomponent, semantic modeling support tools, individual computational modules, database access components), can be implemented as agents-services [6].

The WIS architecture is shown in Fig.. 5. There are four levels in the architecture: 1) the level of mathematical methods, models and software, which includes developed on the basis of selected methods and models the software for calculating the volumes of pollutants

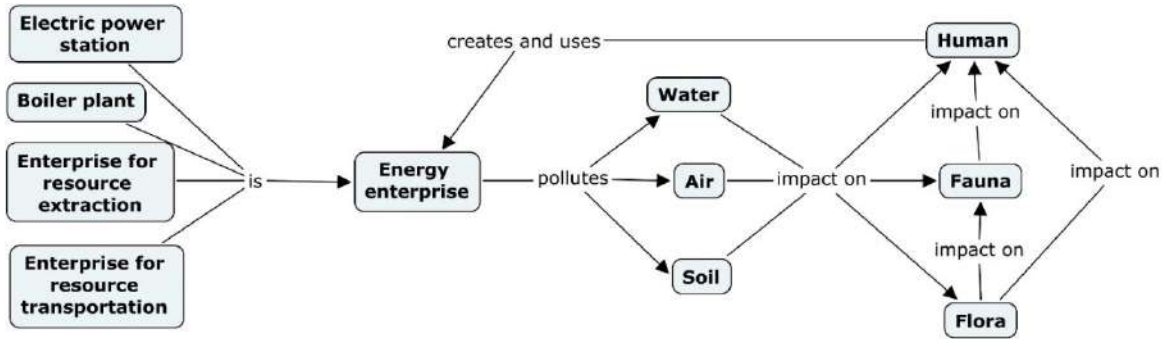

Figure 3. Ontology of the energy sector impact on the environment

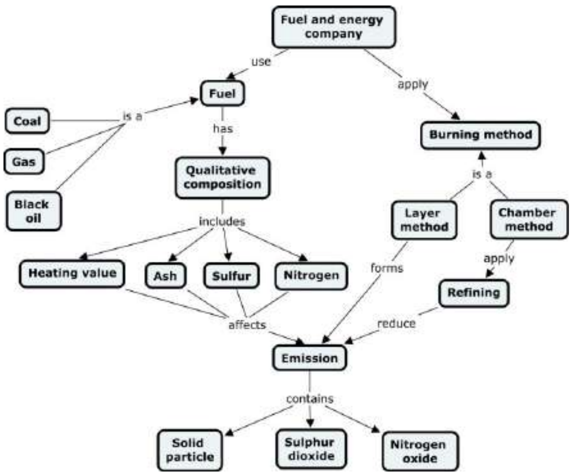

Figure 4. Ontology of pollutants from energy facilities

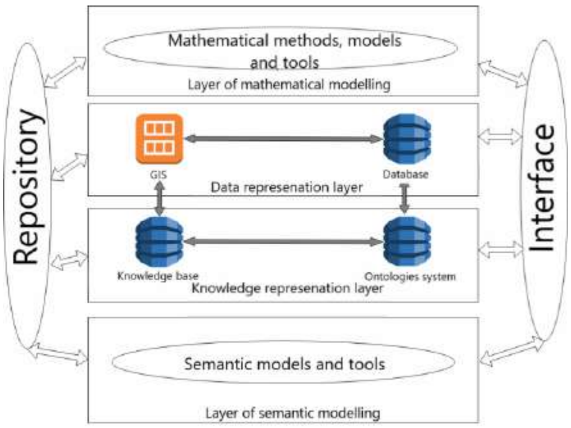

Figure 5. The architecture of the Web-based information system (WIS) to assess the impact of energy on the geoecology of the region

and their impact on the quality of life of the population, taking into account the capacity of energy facilities (energy supply) and population density in the territory under consideration; 2) the level of semantic modeling, including semantic (primarily cognitive) models for describing the interrelationship of factors that determine the quality of life, taking into account anthropic-technical factors: the provision by energy resources and the influence of pollutants from energy facilities on the environment; 3) the level of knowledge representation - unites the knowledge base storing descriptions of knowledge for constructing semantic models, and an ontology system for describing knowledge of the subject domain; the latter can be used both for building a knowledge base and for database designing; 4) level of data representation - integrates the geographic information system (GIS) and database, including geographic coordinates of energy facilities. GIS can be used both to illustrate the results of calculations, and for visual interpretation of semantic models.

The meta descriptions of information presented at all four levels are stored in the Repository (its scientific prototype and tools for working with it were developed by Kopaygorodsky A.N., the co-executor of the project). When implementing the user interface, it is intended to apply the components of the situational management language CML [21].

The methods listed above are used to assess the impact of energy on the regional geo-ecology (using examples from the Baikal region (Russia) and Belarus). In fig. 6 presents the two main territories of the Baikal region and the Republic of Belarus, which are currently being studied.

V. Results and discussion

The article is devoted to the actual problem of assessing the impact of energy on the geoecology of the region. As a rule, emissions from energy facilities are not considered separately in environmental studies, so it is difficult to separate them from general environmental pollution. This makes it difficult to plan and implement measures to reduce pollution by individual energy facilities. The article proposes an approach to solving the problem of monitoring the impact of energy sector on the geoecology of the region, based on the

a)

b)

Figure 6. Display of the energy infrastructure of the facilities of the RUE “Vitebskenergo" (a) and the central ecological zone of Lake Baikal (b)

integration of mathematical models, GIS technologies and modern intellectual technologies in the framework of Web-oriented information system. The novelty of the project is also determined by the fact that when assessing the impact of energy on geoecology for the first time it is proposed to take into account the quality of life of the population. Cognitive modeling is seen as a tool for implementing this idea. To organize information support, it is proposed to use the ontology system as a basis for designing databases and knowledge bases. The proposed Web-based system is considered as a prototype of the intelligent decision-making support system for improving the quality of life, taking into account the requirements of geoecology, including an improved analytical tool for estimating emissions of energy facilities and the spread of pollution.

Conclusion

The article considers the International Project, carried out under the guidance of the author with the support of the EASR-RFFI funds. The statement of the problem is formulated (the fundamental scientific task and the project goal), the urgency and expected results of the project are determined, and proposed methods and approaches to its implementation. The main attention in the article is given to the information and technological part of the project carried out by the Russian side. The illustrations of proposed approaches are presented: cognitive map of indicators for assessing the quality of life, taking into account the availability of energy resources, ontology of the energy sector impact on the environment and ontology of pollutants from energy facilities, as well as the developed architecture of the Web-based information system (WIS), which, together with the technology of its use, will be the final result of the project. The results were obtained with partial financial support of RFBR grants No 18-57-81001, No 19-07-00351, No 18-07-00714 and BRFBR No X18EA-003.

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МЕТОДЫ И ТЕХНОЛОГИИ ОЦЕНКИ ВОЗДЕЙСТВИЯ ЭНЕРГЕТИКИ НА ГЕОЭКОЛОГИЮ РЕГИОНА (НА ПРИМЕРЕ БАЙКАЛЬСКОГО РЕГИОНА (РОССИЯ) И БЕЛАРУСИ)

Массель Л.В., Массель А.Г., Зорина Т.Г.

В статье рассматриваются результаты международного проекта, осуществленного при поддержке Фонда ЕАПИ совместно с исследователями из Беларуси и Армении. Проект направлен на разработку методов и технологий оценки воздействия энергии на геоэкологию региона. Статья посвящена разработке инструментов для интеллектуальной поддержки принятия решений в этой области.

Ключевые слова: интеллектуальная поддержка принятия решений, энергетика, экология, качество жизни

Received 11.01.19