# Integration of Components of the Ontological Knowledge Space to Assess the Impact of Energy on Quality of Life of the Population

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***Abstract* — This paper examines an ontological approach to integrating knowledge to support interdisciplinary studies in energy and ecology in terms of quality of life assessment. These studies involve the integration of environmental and social components. The environmental component is determined by natural and climatic conditions and the state of elements of the natural environment of a particular territory. The social component implies meeting the electricity and heat demand of the population, which is necessary for comfortable living. Quality-of-life metrics are considered as a way to assess the positive and negative impacts of the energy facilities and population on the natural environment to compare these impacts. We present ontologies detailing basic concepts of the subject area of research into the impact of energy facilities and quality of life and reflecting their integration into a single ontological space of knowledge. The ontological approach provides a visual representation and integration of knowledge from different subject areas.**

*Index Terms*: **Ontological approach, anthropogenic impact, quality of life, energy, environment, ecology.**

## I. Introduction

The studies of the anthropogenic impact of energy facilities on the environment and humans are conducted at the Melentiev Energy Systems Institute SB RAS within the framework of the project supported by RFBR grant № 20-07-00195 "Methods for constructing an ontological knowledge space for intelligent decision-making support in energy and ecology, taking into account the quality of life." These studies rely on semantic methods (in particular, ontological and cognitive modeling) that represent the elements of such intelligent support. The ontological knowledge space for research includes a set of interrelated ontologies developed to ensure the consistency of terminology of subject domains, the integration of overlapping areas of knowledge, and their structuring [1]. Research and assessment of the anthropogenic impact of the energy sector on the natural environment and quality of life of the population require knowledge primarily in the subject domains of energy and ecology. The "Quality of life" concept is employed to factor in the requirements for the operation of energy facilities related to the living conditions of the population and the need to preserve the natural environment for present and future generations.

## II. Literature review

The problem of assessing the impact of energy facilities on the environment and quality of life is of importance due to the transition to environmentally friendly and resource-saving energy. Scientists are considering various aspects of the negative consequences of the functioning of energy enterprises for nature. For example, the studies presented in [2-6] focus on the environmental impact of the energy industry. In [3], methodological features of the risk assessment for the population health under the influence of chemicals that pollute the environment are analyzed. The authors of [4] make a comparative analysis of the pollution of landscapes adjacent to a high-capacity thermal power plant. The study presented in [6] is devoted to collecting, structuring, and searching for environmental data using a decision support system and knowledge management based on ontologies.

Semantic technologies and ontologies used for data modeling are proposed in [7, 8]. The book [9] is a comprehensive source of scientific information on the latest research on sustainable development from an interdisciplinary point of view. It offers an overview of innovative topics such as renewable energies, urban development, and green technologies.

## III. Environmental and social components of research into the anthropogenic impact of energy

The environmental impact of the energy industry is one of the most serious ones as it manifests itself in all stages of

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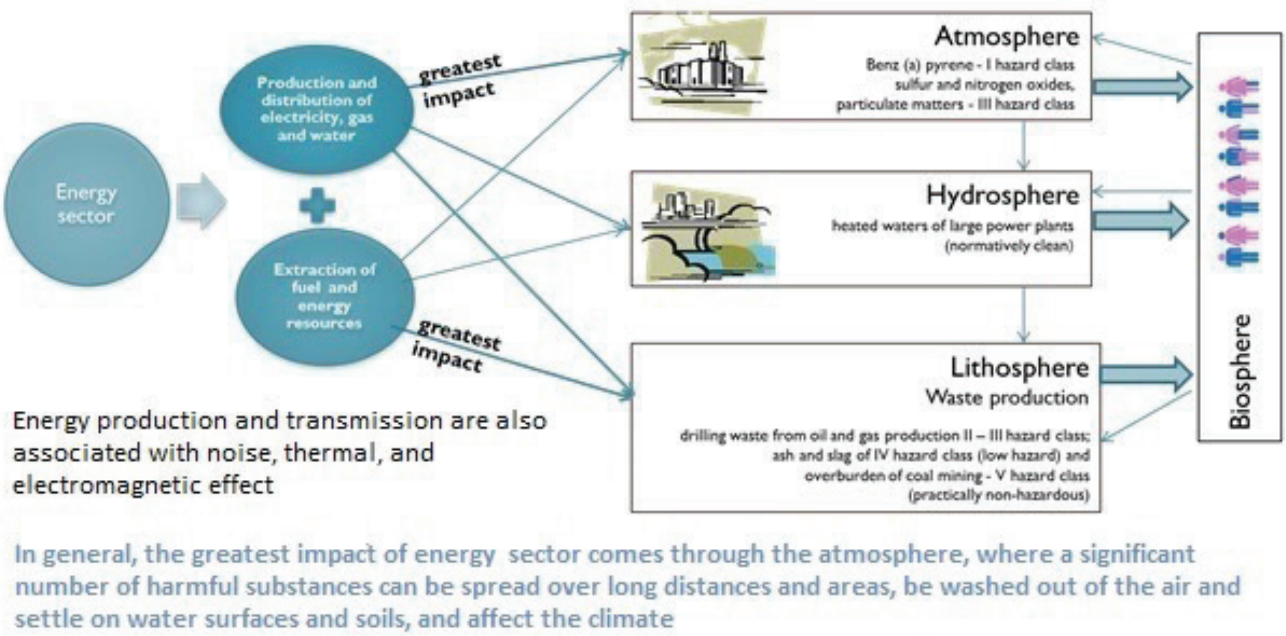


***Fig. 1. Diagram of the environmental impact of the energy industry.***

energy production and leads to pollution of all elements of the natural environment: the atmosphere, water bodies, and soil (direct impact) (Fig. 1). In addition, there is an indirect effect on vegetation, wildlife, and humans.

Extraction of energy resources has the most sizeable direct impact on soils and water bodies. It is related to the withdrawal of large areas during oil, natural gas, and coal extraction, especially by open-pit mining, and storage of tailings and sludge waste. Untreated storm and sludge water resulting from extraction usually enters water bodies. Fuel conversion into electricity and/or heat is characterized by the most considerable impact on the air basin (atmosphere) and soils. Pollutants of hazard classes I, III, and IV are released into the atmosphere, and ash and slag waste from coal combustion are deposited in significant quantities on the soil. The transport of energy resources in each stage, from fuel extraction to electricity and heat delivery to the consumer, has a direct impact on each element of the environment.

Previous studies provided a detailed description and presented the ontology of the concept of "anthropogenic factor," the properties of which depend on the energy facility type, fuel, and technology of its combustion [10]. For a more detailed study of the anthropogenic impact of energy facilities on the elements of the natural environment, it is proposed to systematize the interrelated concepts of "anthropogenic impact," "anthropogenic pollution," and "anthropogenic consequence," which are defined as follows:

- an anthropogenic impact is the consequence of an anthropogenic factor, the process of influence of economic or other human activity on elements of the natural environment;
- anthropogenic pollution is the result of changes in elements of the natural environment caused by an anthropogenic impact;

Table 1. Composition and properties of pollutants from energy facilities.

| Element of the natural environment | Pollutant | Hazard class | Type of exposure | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | B | C | T | A | L | S | Other |
| Atmosphere<br>Soils | inorganic dust | III | +<br>+ | | | | | | | physical |
| Atmosphere | benzo(a)pyrene<br>soot | I<br>III | +<br>+ | +<br>+ | + | + | +<br>+ | + | +<br>+ | |
| Atmosphere<br>Bodies of water | sulfur dioxide<br>nitrogen oxides | III<br>III | +<br>+ | +<br>+ | | +<br>+ | +<br>+ | + | +<br>+ | photochemical |
| Atmosphere | carbon dioxide | IV | + | + | | | | | | greenhouse effect |
| Bodies of water | petroleum products<br>Thermally enriched water | III<br>- | +<br>+ | + | | + | + | + | | thermal |
| Soils | ash and slag waste | IV | + | + | | | | | | physical<br>aesthetic |

Note: C - chemical, B - biological, C - carcinogen, T - toxicant, A - bioaccumulative, L - long-lived, S - synergistic

- an anthropogenic consequence is the result of anthropogenic pollution, characterizing the degree of change in elements of the natural environment.

Such detailing makes it possible to classify the types, properties, and a quantitative measure of these concepts following available methodological approaches to assess anthropogenic impacts.

These comprehensive studies imply the integration of environmental and social components in assessing the impact of the energy industry on the quality of life of the population.

The environmental component of the research is determined by the state of natural environment elements in a particular territory exposed to the anthropogenic impact and by the natural and climatic characteristics of this territory. We have analyzed the composition of pollutants from energy facilities entering various elements of the natural environment, see Table 1.

The anthropogenic impact is determined by anthropogenic burden, which depends on the composition of pollutants, their hazard class, and physical and chemical properties. In addition, the level of the anthropogenic burden is influenced by climatic, orographic, and background conditions of the territory that pollutants enter.

Hazard class is a harmful effect value intended for simplified classification of potentially hazardous substances. Attributes used to determine the class of danger are specified by a dedicated standard [11]. According to the relevant State Standard (GOST), a harmful substance is a substance, which, when in contact with the human body in case of violation of safety requirements, can cause occupational injuries, occupational diseases, or health deviations detectable by modern methods both in the work process and during the life of present and future generations in the long run [12]. For example, the main human diseases caused by air pollutants from coal-fired power facilities are shown in Table 2.

The social component is considered in two aspects. First, it implies meeting the needs of the population for electricity and heat, which are necessary for comfortable living. Second, the functioning of energy facilities should not adversely affect the health of the people living in the corresponding territory.

These aspects are significant parameters of quality of life [13]. In some countries, researchers consider the concept of "quality of life" as a set of objective and subjective parameters that characterize different aspects of human life, the satisfaction of a person with their position in society, financial and social well-being, health, and others [14-16]. Commonly, quality of life is characterized by indicators related to health care, education, demography, economic conditions, environmental conditions, living conditions, employment, and the ability to exercise constitutional rights [17-19].

## IV. The Structure Of The Ontological Space Of Knowledge

The main components of the ontological space of knowledge for research are ontologies reflecting the relationships between some areas of energy, ecology, and quality of life. The structure of the ontological knowledge space relies on the fractal approach, which assumes the presence of meta-levels for each area and their further stratification and detailing at each subsequent level [20].

Meta-ontologies contain descriptions of the basic concepts of the respective subject areas relevant to collaborative research. Such basic concepts are "Energy," "Ecology," and "Quality of Life." Ontologies detailing the description of the research sections at the lower levels are the description of facilities, resources, production processes in the case of the energy section; the description of elements of the natural environment, anthropogenic factors in the case of the ecology section; and the description of influencing factors and metrics of quality of life. The linking elements of these sections of the ontological space are the basic concepts of the "anthropogenic factor" induced by energy facilities and the "element of the natural environment," which is affected by the anthropogenic factor and influences the quality of life. The basic concepts of the meta-ontology are as follows:

Energy is the field of economy, science, and technology covering energy resources and production, transmission, conversion, accumulation, distribution, and consumption of various energy types [21].

Ecology is a branch of biology, a cross-disciplinary science studying the habitat of living beings and their interaction [22], including the structure and functioning of supra-organismal systems (populations, communities, ecosystems) in space and time under natural and human-altered conditions. This definition reflects, to a greater

Table 2. The main diseases from pollutants in the atmosphere.

| Pollutants | Diseases | | | |
|---|---|---|---|---|
| | Respiratory tract | Eyes | Cardiovascular system | Oncological |
| Benzo(a)pyrene | + | + | + | + |
| Soot | + | + | + | + |
| Inorganic dust | + | + | + | - |
| Sulfur dioxide | + | + | + | - |
| Carbon monoxide (with prolonged exposure) | + | + | + | - |
| Nitrogen oxides | + | - | + | rarely |
| Carbon dioxide | + | - | + | - |

*Energy resource*
  Type (coal, gas, oil)
  Property (renewable, non-renewable, calorie content)
*Energy object*
  Type (nuclear, hydroelectric, thermal power plants)
  Property (power, fuel consumption, incineration method, degree of capture)
*Anthropogenic factor*
  Type (waste, release, discharge, noise, radiation)
  Property (mass of waste, release, discharge, periodicity, state, migration)
*Anthropogenic impact*
  Type (physical, chemical, mechanical, biological, thermal, light)
  Property (frequency, duration, anthropogenic load)
*Anthropogenic pollution*
  Type (biological, chemical, physical)
  Property (accumulation, synergy, durability, pollution level)
*Anthropogenic consequence*
  Type (acidification, disturbance, destruction, formation, alteration, depletion)
  Property (reversibility, accumulation, exceeding the limit, degree of change)
*Element of the natural environment*
  Type (atmosphere, waterbody, soil, living organism)
  Property (renewable, non-renewable, calorie content)
*Energy object* creates *Anthropogenic factor*
*Energy object* uses *Energy resource*
*Anthropogenic factor* implements *Anthropogenic impact*
*The anthropogenic impact* creates *Anthropogenic pollution*
*Anthropogenic pollution* forms *Anthropogenic consequence*
*Anthropogenic consequence* manifests itself in *Element of the natural environment*
*Energy resource* is related to *Element of the natural environment*

***Fig.2. Ontology of anthropogenic impact of energy facilities on elements of the natural environment.***

extent, the current trend to study the consequences of industrial and other human activities for the environment.

Quality of life is an overall characteristic of the level of objective and subjective living conditions of the population, which determine physical, mental, and socio-cultural development of a person, group, or community of people [23]

The anthropogenic factor is the cause of anthropogenic impact on the natural environment, which is due to the process and operating conditions of the facility, its characteristic features [24].

The natural environment is a set of environmental factors that affect people, including natural factors and those slightly modified by human activities. It has the feature of self-sustaining and self-regulation without human corrective action [22].

## V. Components of the ontological space of knowledge

An earlier research [10] presented a meta-ontology of concepts related to the impact of energy on the natural environment, including those of energy facility, energy resource, element of the natural environment, as well as an anthropogenic factor, anthropogenic impact, anthropogenic pollution, and anthropogenic consequence. As a result of their more detailed consideration in line with the rules of ontological engineering, it is proposed to systematize the characteristics of these basic concepts by their type and property (Fig. 2).

These characteristics make it possible to establish relationships between the basic concepts of the meta-ontology. In particular, the type of energy facility is related, on the one hand, to an energy resource type used and, on the other hand, affects the type of anthropogenic factor generated. The type and mass of waste, emissions, and discharges produced depend on the properties of energy facilities that describe their technical and technological features (method of combustion or degree of treatment) and the quantitative measure (power, fuel consumption). The type of anthropogenic impact, the nature, and the magnitude of the anthropogenic burden depend on the type of the anthropogenic factor and its quantitative measure. Further, the type and level of anthropogenic pollution depend on the type of the anthropogenic impact (physical, chemical, and others) and its properties (duration or periodicity). In turn, the level of anthropogenic pollution, its type, and properties affect the type, properties, and quantitative measure of the resulting consequences of the anthropogenic impact of energy facilities on elements of the natural environment.

The presented ontology fragment does not fully reflect all the complex relationships between the concepts under consideration. For a more detailed assessment of the anthropogenic impact of an energy facility within a specific territory, one should consider the relationships between the characteristics of this facility and corresponding characteristics of all other components of the presented ontology at the next level of the ontological knowledge space. The proposed ontology reflects the structure of knowledge required to assess the ecological component of research.

## VI. Energy and quality of life of the population

To compare the positive and negative impacts of energy facilities on the population and the natural environment, quality of life metrics are considered as a means to assess these impacts. Quality of life is an interdisciplinary concept that captures multiple aspects of human activity. Research on quality of life is conducted by scholars in many countries, although there is no unambiguous definition of this concept. According to the World Health Organization, it includes the physical, social, and cultural development level and is characterized by the indicators related to health, education, economic conditions, environmental conditions, living conditions, and others [25]. The indicators for assessing the quality of life depend on the research field. In economics, the emphasis is on the extent to which basic material human needs are met, the level of human development, the degree of security, and others. Sociology explores cultural needs, access to education, quality of service, and the like. Medicine requires the evaluation of the quality of health care services and health parameters. The level of pollution and related consequences, which characterize the quality of elements of the natural environment, is of utmost importance for the ecology.

There are many techniques for assessing the quality of life, such as the calculation of metrics, sociological surveys, statistics on social phenomena, and others [26]. The main indicators of quality of life in different countries depend largely on the stage of their economic development. The central metric of quality of life is the Human Development Index (HDI) designed by the participants of the UN development program, which includes the following basic parameters: life expectancy, level of education, and gross domestic product (GDP) per capita. Objective and subjective metrics are considered to assess the quality of life. Objective metrics reflect natural and social aspects of life, such as the level of well-being and development of social infrastructure, the quality of elements of the natural environment, and natural conditions. Subjective metrics include cognitive and emotional assessments of a person's life satisfaction (working and leisure conditions, safety, confidence in the future). A comprehensive assessment relies on integrated indicators, which cover such components as welfare (income, housing, infrastructure), social sphere (working conditions, safety), quality of the population (family, education, qualifications, demography), quality of elements of the natural environment (air, water, soil, biological diversity), and natural conditions (climate, natural resources, circumstances of insuperable force).

We propose the following meta-ontology of knowledge to compare the positive and negative effects of energy facilities on the quality of life of the population (Fig. 3).

Fig. 3. Meta-ontology of basic metrics of quality of life

This structure of the components of the ontological space of knowledge reflects the basic concepts related to the quality of life and its main indicators. The heat and electricity generation, in particular, on the one hand, directly affects the economic development of the territory and quality of life through the improvement of living conditions and social infrastructure. Indirectly, there is a positive impact on living standards, provision of leisure and recreation through the economic development of the territory. On the other hand, the impact of energy on elements of the natural environment negatively affects health and safety, thereby compromising the quality of life. The presented scheme reflects the basic components of the ontological space of knowledge related to the ongoing research on the impact of energy on the quality of life.

## VII. Conclusion

These studies are a continuation of work on building the ontological space of knowledge to integrate it for interdisciplinary energy-ecology research in terms of assessing the quality of life of the population. This paper presents a group of ontologies related to the concept of the anthropogenic impact of energy facilities on elements of the natural environment. The anthropogenic impact is determined by its anthropogenic burden, which depends on the composition of pollutants, their hazard class, physical and chemical properties, and on the climatic, orographic, and background conditions of the territory. These studies require integrating the environmental and social components to compare the positive and negative effects of energy facilities on the population and the environment. We propose treating the indicators of quality of life as a means to assess these effects. The performed ontological engineering of the intersection of knowledge of different subject domains and the proposed ontological models provide a visual representation and structuring of the interrelated components of the knowledge.

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