

Evaluation of development prospects of renewable energy: agent based modelling

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Abstract. The paper describes the agent-based model usage to evaluate the dynamics and the perspectives of alternative energy adopting in the Eastern regions of Russia. It includes a brief review of the agent-based models that can be used for estimation of alternatives in the process of transition to “green” economics. The authors show that active usage of solar energy in Russia is possible at the rural household level, when the climate conditions are appropriate. Adoption of solar energy sources decreases the energy production based on the conventional sources and improves the quality of environment in the regions. A complex regional multi-agent model is considered in this paper. The model consists of several private models and uses GIS technologies. These private models are a demographic and migration model of the region and a diffusion of the innovations model. In these models, agents are humans who live within the boundaries of the agents-municipalities, and agents as well are large-scale producers of electricity that pollutes the environment. Such a structure allows us to determine the changes in the demand for electricity generated by traditional sources. A simulation software will assist to identify the opportunities for implementation of alternative energy sources in the Eastern regions of Russia.

1. Introduction

Development of low-carbon energetics is intended to solve the problems of environment pollution caused by usage of traditional sources to produce electricity. Having a significant share in the electricity production, Siberian and Far Eastern coal power stations are not exclusions. Their emissions consist of such components as soot, sulfur dioxide, nitrogen oxides, carbon monoxide, and also benzopyrene that is a carcinogen and makes negative impact on human health [1]. While the amount of emissions being decreased in Russia and other regions in the last years, the quality of atmosphere air is still not appropriate in many territories.

The increasing interest to energy production is caused by the fact that this industry is the main source of pollutions while it still remains the foundation of all productive forces. Currently, one of the world priorities is the strategy of “green” growth that should help to save natural assets. To evaluate changes in this field of ecological economics we develop the regional multi-agent model that provides a tool to calculate some economic and environmental indicators. Work [2] suggests a concept of direction and “color” of economic growth. In paper [3], it is noted that this model can be used for the temporal and spatial analysis. We will consider this conception in detail and show how to apply it to



the modeling of processes by the example of the energy sector of the Trans-Baikal Territory. Let us apply the graphical method for this purpose.

As the point of origin I_0 (figure 1) we take the ecological and economic state of the system at the initial time. The X axis will contain the economic result (ER) obtained as the main indicator of the economic development of the region that is the gross regional product measured for the economic activity «Electricity, gas and water supply». The Y axis contains specific indicators of negative impact on the environment per one unit of economic result. In this case we used the eco-intensity of air emissions from stationary sources that is calculated as the ratio of the corresponding environmental pressure to the economic result.

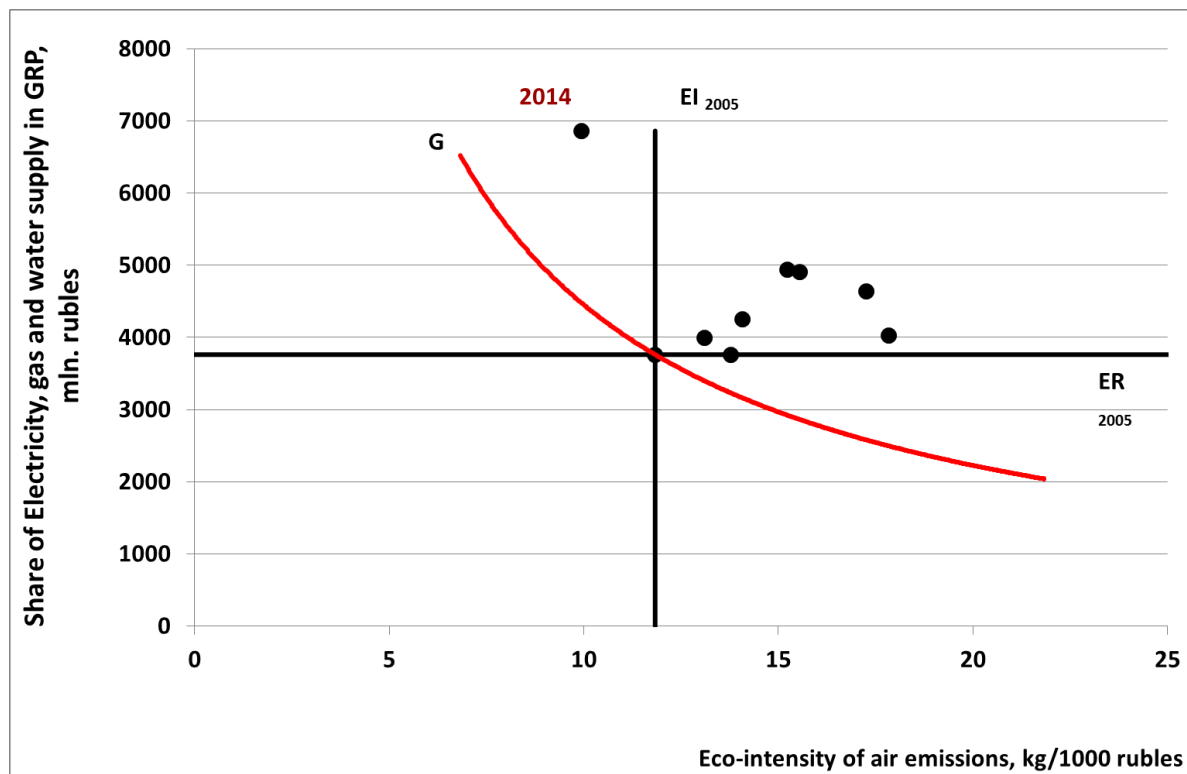


Figure 1. Air emissions from stationary sources of the energy sector in Trans-Baikal Territory: color growth in 2005–2014 (Russian Ruble, 2005)

The curve named G is the geometric place of points that characterizes the continuous negative impact on the environment. The further trend of the system development in time is analyzed and is defined accordance to the vector of “green” growth depending on the ecological economic zone that contains next points. As the result, it may be concluded that the economic growth (from 2005 to 2013) in the energy sector of the modeled region is characterized by “black” color. It means that the increasing of the economic result corresponds with increasing in both the eco-intensity and the total impact on the environment. In 2014, the transition to brown growth zone was detected. It means the decreasing of the environmental pressure indicators and also increasing of the both the economic result and emissions. Consequently, there is no any evidence of the transition in the near future to the green growth zone, where increasing of the economic result is accompanied by reduction in both the eco-intensity and the total impact.

A huge task of alternative energy development in the regions of Siberia and Far East was set in the Russian Federation. However, financing of this task is insufficient. In the spite of the absence of government support, the intensive usage of solar energy in Russia is possible at the household level in case there are the appropriate climate conditions. The ABM based modeling experiment provides the

opportunities for evaluation of a potential benefits from usage of alternative energy sources. This approach is reasonable due to high cost of the equipment and its installation. The modeling will help to show the benefits that can be achieved by decreasing environmental pressure. Thus, both recipients of the technology and population on the whole will be considered in the role of beneficiaries.

2. ABM Methodology

At present, agent-based modelling (ABM) is one of the perspective research methods that is appropriate for finding a solution to many different tasks. ABM is actively used in most of social sciences from 1990. In papers of Russian scientists [1], it is noted that a large number of models has been developed recently in different fields of research (and most of them were developed abroad). This raised a problem of standardization of these models. The acting agents in these models may be humans, manufactures, transport, equipment and even non-material objects. They have a specific properties, behaviour and can communicate with each other and also with environment (figure 2).

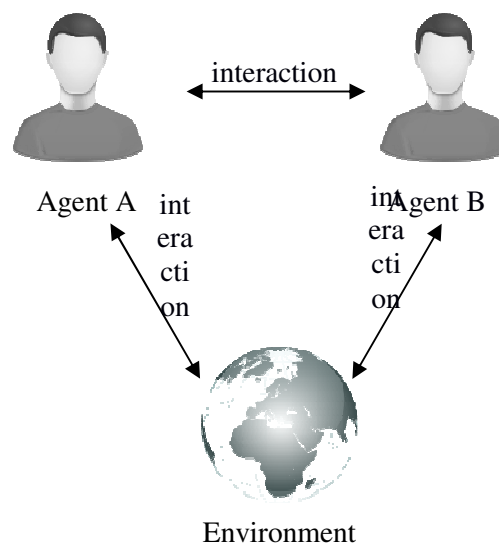


Figure 2. The scheme of interaction between agents and environment

Modeling of the processes of human activities with usage of the agent approach is of particular interest. Thus, the first models were demographic models. e. g., in paper [4], the model of the structure and dynamics of the household is considered. This model is developed in order to investigate the interactions between demographic processes and the process of epidemic spreads. More complex models imitate activity of economic system [5]; in particular, paper [6] develops the multi-agent model of the fundamental economic system that includes manufactures, consumers and banks. The most important aspect of this model is self-regulation mechanisms of costs, production and investments. Complex models cover several aspects of human activity, e. g., the model of Mayan society considered in paper [7] investigates relations between population increasing, agricultural production, soil degradation, climate change and changes in the ecosystem.

Also, there are models that may be applied for investigations of transition to green economy in order to decrease the degradation of environment. Paper [8] models processes of decision making by households with regard to the installation of photovoltaic cells across the city. This model takes into account demographic, social, ecological factors according to data about usage of alternative energy sources. Paper [9] discusses the hybrid agent-oriented model that makes it possible to evaluate the population demands for water, paper [10] focuses on sustainable groundwater management.

Applying ABM to the model of complex social, demographic and economic processes in the region, as well as to the model of interaction with the environment, means a specific advantage. In

works of Russian researchers, this approach is used to investigate demographic processes at the country-wide level. There are models that allow imitating the population, the economics and the environment interactions bounded by one region as well [1].

3. Description of the model

For developing of the model, the authors use the AnyLogic software product. The regional multi-agent complex model is based on GIS (Geo-informational system) technologies as well. It assumes the interaction with the environment and consists of two local models: the demographic model of the region where the migration intentions are included, and the model of diffusion of innovations.

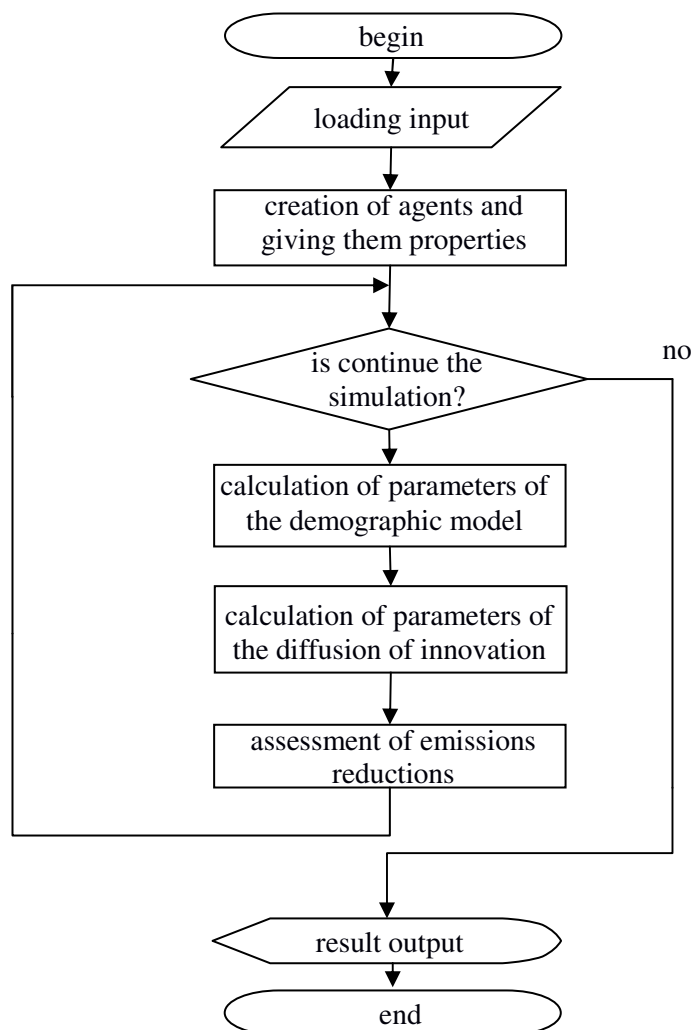


Figure 3. A flowchart of the regional mode

The agents of the model (figure 4) are humans who live in bounds of the corresponding agents-municipalities, and large energy manufactures having the negative impact on the environment. The demographic model describes fertility, mortality and migration. Agents are characterized by sex, age, income, willingness to adopt solar panels as an energy source and accommodation in some municipality. To determine the willingness of solar panels adoption and to form specific behavior of agents in the areas of the modeled region the sociological research was made. It allowed defining the needed parameters of the agents' behavior. The environment comprises some economic, institutional and other parameters that can influence the willingness of the population to pay for transition to

alternative energy.

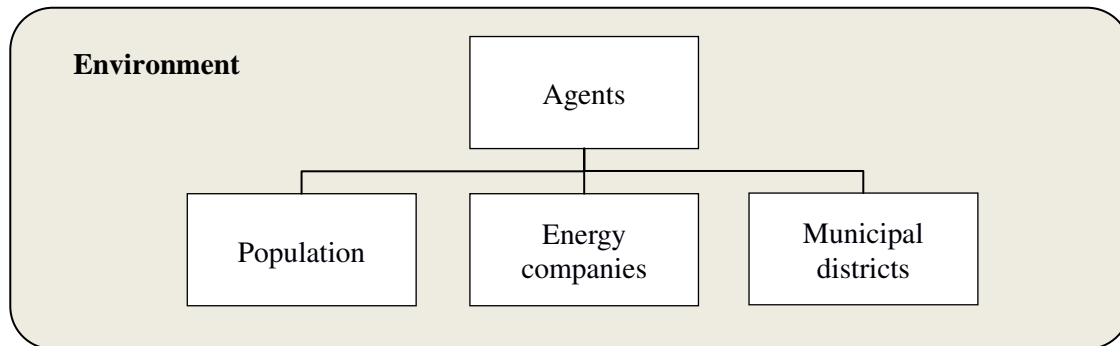


Figure 4. Agents of the regional complex model

Different combinations of the potential, decreasing the energy output caused by local adoption of solar panels, makes it possible to evaluate the reduction of the environmental pressure in the region and to define the optimal value of energy generation. The model experiment will show how much consumption energy produced by traditional sources will be reduced. The eco-intensity indicator will show changes in ecological and economic systems of the region, according to the conception of direction and “color” of the economic growth [2].

4. Conclusion

The actuality of the issues related to the transition to low carbon economics and to an increase of the economic growth quality is still significant in Russia. It is supposed that the agent-oriented modeling is the perspective approach to model different systems including economic systems. This model allows defining perspectives of adoption of alternative energy in the Eastern regions of Russia. It also makes possible to analyze scenarios and conditions required to elaborate recommendations for support of renewable energy in regions. To use this model further, a special software product (simulator) is being developed. It provides interaction with the model and runs the model experiments. The obtained ecological and economic characteristics of system functioning can be used in further evaluation of technological changes in the energy system of regions. e. g., will it lead to transition from “brown” to “green” growth of region's economics according to the “green” model of economics development.

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