# Application of Web Services for Visualization of the Results of Environmental Studies

*Roman* Ivanov[1*], *Nikita* Maksakov[1], and *Alexandr* Izhbuldin[2]

[1]Melentiev Energy Systems Institute of Siberian Branch of the Russian Academy of Sciences, 664033, Irkutsk Region, Irkutsk, Lermontov St., 130, Russia
[2]Asia Pacific Energy Research Centre (APERC), Inui Bldg. Kachidoki 11F, 1-13-1 Kachidoki, Chuoku, Tokyo 104-0054, Japan

**Abstract**. The paper provides a description of web services for displaying environmental effects when implementing scenarios for the development of energy supply in various territories and categories of energy sources. Scenarios include the transition to environmentally friendly fuels, the introduction of low-carbon technologies, and the use of renewable energy sources. The following indicators were selected as displayed: emissions of pollutants and carbon dioxide into the atmosphere, as well as the amount of ash-and-slag waste generated. The principles of formation of tabular, cartographic and graphic material are presented. The technologies used to create web services are presented. The organization of navigation in the service and updating of information is described.

## 1 Introduction

An integral part of any scientific research is an adequate display of initial and resulting information. Two web services for visualizing the results of environmental studies for various territories of the eastern regions of the Russian Federation are at different stages of development. Unlike geographic information systems, the developed web services enable to display changes in any indicators when choosing development scenarios or changing the initial operating conditions of energy facilities. Moreover, visualization of changes in indicators, in this case environmental ones, is organized in tabular, graphical and cartographic form.

## 2 Description of Web Services

### 2.1 Environmental monitoring of thermal power facilities in the central ecological zone of the Baikal natural territory

This web service is designed to monitor changes in environmental indicators of the functioning of municipal thermal power facilities in the Baikal natural territory during the implementation of various development scenarios. For this purpose, a database was created that includes production indicators of power plants and municipal boiler houses which affect

---

* Corresponding author: crowndriver@yandex.ru

the natural environment of the coastal areas of Lake Baikal, as well as the volumes and quality characteristics of burned fuel. Currently, the service is implemented only for part of the information relating to municipal thermal power facilities in the central ecological zone of the Baikal natural territory [1]. In the future, it is planned to expand the displayed information by involving data on power plants in the zone of atmospheric influence and the buffer ecological zone, emissions from these plants, under certain conditions, reach the water area of the lake [2].

For each district included in the central ecological zone on the territory of the Irkutsk region and the Republic of Buryatia, the diagrams present data on the number and installed capacity of boiler houses using various types of fuel: coal, heating oil, gas, wood, and electricity. Cheremkhovo coal is highlighted separately as the most environmentally unfriendly. When the cursor hovers over an individual chart element, the corresponding value of the indicator is displayed.

The volumes of fuel burned and estimates of the mass of emissions of pollutants and carbon dioxide into the atmosphere, as well as the formation of ash-and-slag waste from municipal thermal power facilities, obtained on the basis of the developed mathematical model, are presented in tabular form. The pollutants shown include particulate matter, sulfur and nitrogen oxides.

To date, visualization of changes in environmental indicators has been implemented for four different scenarios for the development of thermal power engineering in the central ecological zone: transition to environmentally friendly combustion of coal, replacement of coal with natural gas, use of electricity for heat supply purposes and widespread use of renewable energy sources [3]. When one of the development scenarios is selected, the diagrams display the corresponding total figures for the number and capacity of boiler houses using the selected type of fuel. The cartographic part of the service shows the location of more than 100 municipal thermal power facilities of the central ecological zone, and the type of fuel used is indicated. After selecting one or another scenario, the map displays the color differentiation of boiler houses according to the types of fuel used in the scenario.

Figure 1 shows a general view of the web service with visualization of environmental indicators when implementing the most environmentally friendly scenario for using electricity for heat supply purposes in the central ecological zone of the Baikal natural territory.
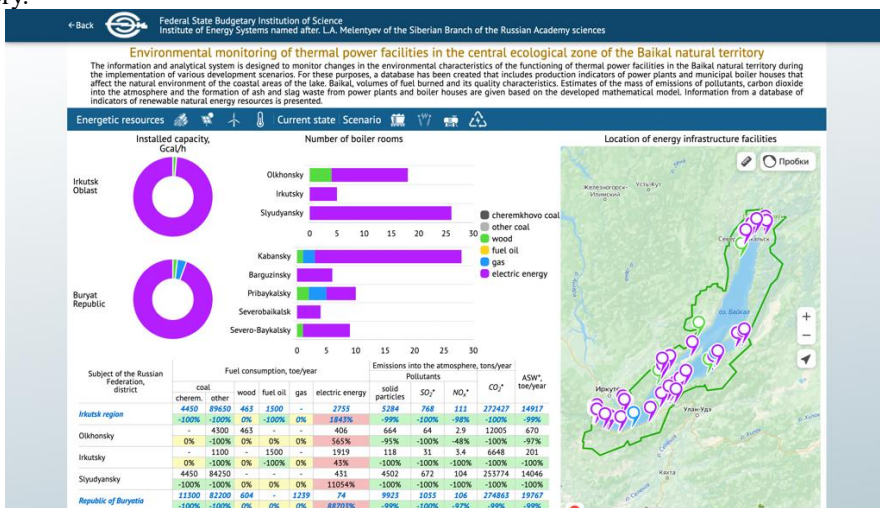


**Fig. 1.** General view of the web service "Environmental monitoring of thermal power facilities in the central ecological zone of the Baikal natural territory".

The table shows the change in environmental indicators under the selected scenario: green – changes for the better, red – worse from the current state, yellow – no changes. The value of fuel consumption and environmental indicators for the current state of thermal power facilities remain in the table when selecting a scenario, so that they can be compared with the values obtained when implementing the selected scenario.

Additionally, the cartographic material of this web service reflects information from the database of indicators of renewable natural energy resources: wind, solar, bio and geopotential in the Baikal natural territory. Each map contains an explanation of the symbols of the indicators presented on the map. The page of the developed service is located on the ISEM SB RAS website and is available at the link: https://isem.irk.ru/monitoring_bnt.
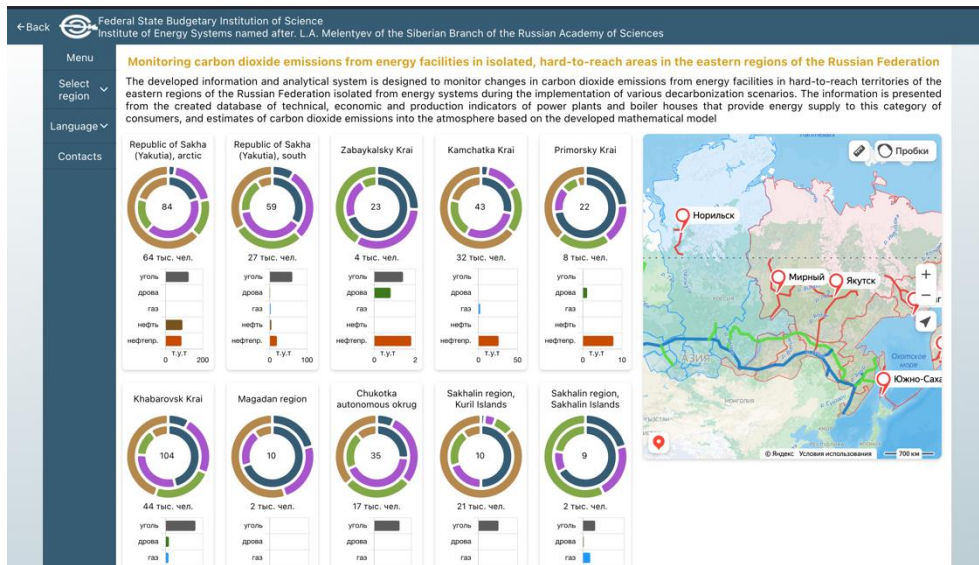
## 2.2 Monitoring of carbon dioxide emissions from energy facilities in isolated hard-to-reach areas in the eastern regions of the Russian Federation

This web service is designed to monitor changes in the release of carbon dioxide into the atmosphere from autonomous communal power plants and boiler houses in hard-to-reach settlements isolated from centralized power supply in the eastern regions of the Russian Federation during the implementation of various development scenarios. To present information, a database of technical, economic and production indicators of power plants and boiler houses, which are responsible for supplying energy to this category of consumers in the territory of 15 federal subjects of the Siberian and Far Eastern Federal Districts, was created. The database contains information on installed capacity, production of electrical and thermal energy, type, volume and quality characteristics of fuel consumed by municipal power plants and boiler houses. Due to the large difference in cost indicators, information for the Krasnoyarsk Territory and the Republic of Sakha (Yakutia) is presented separately for the southern and Arctic regions, for the Sakhalin region – for Sakhalin Island and the Kuril Islands.

The diagrams for each subject of the Russian Federation show information on the number of isolated hard-to-reach settlements, population, types and volumes of fuel consumed: coal, oil products, wood, gas, crude oil. Information on population and number of settlements is differentiated into four categories depending on the number of residents. Hovering the cursor over an individual chart element displays the corresponding indicator value.

The cartographic part of the service provides information on the total population in the subject of the federation, indicating data on isolated hard-to-reach territories: the number of settlements and the living population. The map highlights the Arctic zone and schematically shows the power transmission lines of power centers isolated from the unified power systems of Siberia and the East.

This web service is under development. Figure 2 shows a general view of the web service with visualization of the current state of energy supply in isolated, hard-to-reach territories of the Siberian Federal District of the Russian Federation. Due to the large number of represented subjects of the Russian Federation, the ability to select the displayed territory has been added: Siberian or Far Eastern Federal District. In the future, it is planned to visualize on diagrams the calculated estimates of carbon dioxide entering the atmosphere during the production of electrical and thermal energy based on the developed mathematical model. It is expected to organize a display of changes in carbon dioxide emissions depending on the selected development scenario: gas, nuclear, hydrogen, renewable energy, similar to that implemented in the above-described web service.

**Fig. 2.** General view of the web service "Monitoring of carbon dioxide emissions from energy facilities in isolated hard-to-reach areas in the eastern regions of the Russian Federation".

## 3 Technologies for developing web services

The main tools for creating web services were the hypertext markup language html and the JavaScript programming language [4]. For ease of development, the ReactJS framework was used [5], which made it possible to split the entire project into individual elements, manage their state and update them, thereby simplifying the development of web applications. The graphs display is implemented using the ChartJS library [6]. All graphics change dynamically in accordance with the selected scenario and are accompanied by animation. Hovering the cursor over a graph element brings up a tooltip with the data that the element displays. Dynamic change of scenario data in the form of graphs, tables and diagrams is carried out using internal tools of the ReactJS framework, namely useState and useEffect.

The useState tool is an internal state manager within an application, but the way it is used is not always convenient and cannot be optimized. For convenience, the Redux-Toolkit library [7] is used as a state manager. In addition to the state manager itself, the library contains a set of various tools for working with state, which are combined into a single system, which guarantees their joint operation and the absence of conflicts.

Maps with the location of energy infrastructure facilities were created using the free web service "Yandex Map Editor" [8], which accepts data in *.geojson file format according to a template and generates points on the map. The map is created by a script that draws an "iframe" html element in which the map is displayed. Similarly, maps with the distribution of indicators of wind, solar, bio and geoenergy resources were created based on the developed databases for the Baikal natural territory. Such systems for displaying data on a map are developed for various purposes, both using popular cartographic systems such as google maps, and specially created narrowly targeted systems. One of such systems is the monitoring of soil temperature and vegetation [9].

To switch scenarios and maps of energy resources in web services, a navigation bar is provided. When you select a scenario, its description is displayed indicating the total environmental effects (Fig. 3).
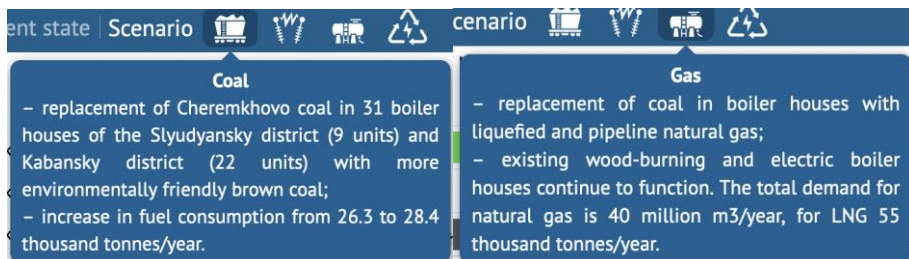
**Fig. 3.** Description of scenarios in the navigation bar.

Web services use icons from the free and open library "React Icons" [10]. Icons are presented in SVG format [11], which enables to maintain image quality when resizing.

The Webpack module bundler is used to compose Web services. Webpack compiles all ReactJS components and used libraries into a standard HTML document and JavaScript files. JavaScript files are compiled to the specified ECMAScript standard, which is the basis of scripting languages, including JavaScript. Webpack is configured by default for ES5 version, which is supported by most browsers.

Due to the fact that JavaScript is not a typed language and has only a few data types, complex types are just variations of the Object type. Strong typing helps in development. To implement it in JavaScript, TypeScript is used — a JavaScript variation [12], which is a programming language introduced by Microsoft. TypeScript extends the capabilities of regular JavaScript and adds data typing, which greatly simplifies development. There are many types of languages that extend JavaScript, for example Coffee Script adds built-in methods that JavaScript lacks and makes writing code more concise [13]. Since browsers don't accept languages other than JavaScript, running code written in TypeScript requires either using the internal tool that compiles TypeScript to JavaScript or setting up the aforementioned Webpack.

# 4 Conclusion

Two web services are presented at different stages of development. The services visualize the results of environmental research on energy supply to consumers in the central ecological zone of the Baikal natural territory and hard-to-reach areas isolated from centralized power supply in the eastern regions of the Russian Federation. These software tools are designed to display the current state of utility operation and environmental impacts during low- and zero-carbon transition scenarios. The displayed environmental indicators include atmospheric emissions of particulate matter, sulfur and nitrogen oxides, carbon dioxide, as well as the amount of ash-and-slag waste generated.

The created Web services visualize data in tabular and graphical form, which simplifies comparison. The map editor used enables to load and display data on maps, which complements the usual display with geospatial context. Such a diverse presentation allows the expert to gain a new perception of information and identify non-obvious patterns in the presented indicators. Modern technologies and popular libraries are used to develop Web services, which expands their functionality or makes it possible to change them quickly if necessary.

# References

1.  Russian Federation Federal Law No. 94-FZ of May 1, 1999 "On the Protection of Lake Baikal" (as amended on July 14, 2008), URL: http://www.kremlin.ru/acts/bank/13787 (Accessed on 28/1/2022) (In Russian)
2.  I. Ivanova, A. Izhbuldin, T. Tuguzova, E. Maysyuk, Ecological and economic efficiency of the use of alternative energy technologies including hydrogen to reduce the anthropogenic load in the central ecological area of the Baikal natural territory, *International Journal of Hydrogen Energy*, 2022, **47**, Is. 26, 26 March 2022, pp. 12823-12828.
3.  I. Ivanova, E. Maysyuk, Ecological effects of the implementation of scenarios for the development of energy supply systems in the central ecological zone of the Baikal natural territory, Proc. of the All-Russian scientific and practical conference with international participation "Socio-economic development of regional systems: problems and prospects", 2011, Electronic edition. Ulan-Ude: BNTs SB RAS, 2022, pp. 137-140. DOI 10.31554/978-5-7925-0622-0-2022-3-145 (In Russian)
4.  Description of the JavaScript language, URL: https://developer.mozilla.org/ru/docs/Web/JavaScript (Accessed 09/23/2023)
5.  Official website of the ReactJS framework, URL: https://reactjs.org/ (Accessed 09/23/2023)
6.  ChartJS library official website, URL: https://www.chartjs.org/ (Accessed 09/23/2023)
7.  Documentation for the Redux-Toolkit library, URL: https://redux-toolkit.js.org/ (Accessed 08/25/2023)
8.  Yandex map editor, URL: https://yandex.ru/map-constructor/ (Accessed 09/23/2023)
9.  C. Zhang, Z. Yang, H. Zhao, Z. Sun, L. Di, R. Bindlish, P. Liu, A. Colliander, R. Mueller, W. Crow, R. Reichle, J. Bolten, S. Yueh, Crop-CASMA: A web geoprocessing and map service based architecture and implementation for serving soil moisture and crop vegetation condition data over U.S, Cropland, *International Journal of Applied Earth Observation and Geoinformation*, **112**, 2022, 102902, ISSN 1569-8432, DOI 10.1016/j.jag.2022.102902.
10. Official SVG Portal of react-icons, URL: https://react-icons.github.io/react-icons (Accessed 09/23/2023)
11. Description of the SVG format, URL: https://ru.wikipedia.org/wiki/SVG (Accessed 09/23/2023)
12. TypeScript official website, URL: https://www.typescriptlang.org/ (Accessed 09/23/2023)
13. CoffeeScript official website, URL: https://coffeescript.org/ (Accessed 09/23/2023)