Environmental assessment of energy efficient and energy saving technologies

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Abstract. For the purpose of using the residual or wasted heat, many scientists are currently conducting research on the possibility of using the wasted heat. At the same time, an active search is underway for new materials and new technologies that will improve the characteristics to increase ecological efficiency of the thermal module and heat accumulator. To guarantee the transition to environmentally friendly energy when searching for or creating new materials and technologies, it is necessary to conduct an environmental analysis and confirm the safety of materials for the environment based on a life cycle assessment. Without a life cycle assessment, the claim that a product or service is safe for the environment will be unfounded. In addition, the transfer of the environmental load to the stage of obtaining materials can lead to the fact that the use of new energy converters will be much more dangerous and less efficient in terms of consumed natural resources than not using "lost" heat. In this regard, before introducing into mass production, it is advisable to analyze the life cycle of a new material (prototype) with obtaining confirmation of safety for the environment, which was done in this work. Based on the obtained results conclusions were drawn about the advisability of using auxiliary technologies that increase the energy efficiency of a traditional thermal installation.

1. Introduction

Today it is difficult to imagine a world without energy. But reserves of traditional energy resources are limited. Their use has a negative impact on the environment. Therefore, alternative energy sources have already been developed and are being applied, the efficiency of energy machines is increasing, the world is in search of any ways of rational use of resources [1].

For the purpose of using the residual or lost heat, many scientists are currently conducting research on the possibility of using thermoelectric energy. And one of the ways to save energy can be attributed to the use of thermal energy accumulators (heat storage).

Thermoelectric generation is one of the most perspective, and in some cases the only available method of direct conversion of thermal energy into electrical energy. In such transformation, there is no intermediate link, as, for example, during the operation of a thermal or nuclear power plant, where thermal energy is converted into mechanical energy, and then mechanical energy is converted into electrical energy [2]. Among the advantages that determine the priority of the thermoelectric module when choosing, among other energy sources, there are no moving parts, and one of the consequences is the absence of vibrations, as well as the need to use liquids and / or gases under high pressure (conversion occurs in the thermoelectric substance itself). Efficiency doesn't depend on the spatial position and the
presence of gravity. Thermoelectric modules can be used at large and small temperature differences. Thermoelectric conversion is universal and allows the use of almost any source of heat flux, even with small temperature drops, when other conversion methods cannot be used. Thermoelectric modules are an alternative source of electricity, they allow you to receive electrical energy up to 40 watts from one generator module. In order to obtain 3.53 kW of energy, 10 thermoelectric modules of model TV-199-2.0-0.8 with a size of 55 - 55 - 3.7 mm are required [3].

A heat accumulator (heat storage) is a device or collection of devices that is used to store heat energy for future use.

The benefits of heat storage include:
1) providing the consumer with energy, which largely becomes independent of the unstable operation of the energy source;
2) covering peak loads and reducing the design capacity and, therefore, the cost of energy sources.

Despite the fact that the thermoelectric module and the heat accumulator can be attributed to alternative energy sources or devices that increase the energy efficiency of the system, throughout the entire life cycle of these products, from the extraction of necessary materials to disposal, there are processes that carry environmental aspects. For example, metal mining is a process that negatively affects abiotic resources.

Thus, it can be concluded that the thermoelectric module and the heat accumulator are perspective devices that increase the energy efficiency of energy sources. But not at all stages of the life cycle of these products there is ecological cleanliness. Therefore, there is need to analyze each stage of the product life cycle.

At the same time, environmentally friendly energy is energy that, during its production, has a minimal impact on the environment. The fact that energy is ecologically friendly can only be confirmed with the environmental declaration, which is based on a life cycle assessment. Without a life cycle assessment, the claim that a product or service is safe for the environment will be unfounded [2].

Therefore, when assessing the life cycle of a thermoelectric module and the heat accumulator, the main task will be to assess the impact on the environment. This takes into account the impact not only at the stage of final disposal, but also at the stages of production and use of this product. In addition, LCA has identified key environmental aspects of the product life cycle and increased efficiency at different stages of the product life cycle.

Based on previous, the purpose of the proposed project is aimed to analyze new energy efficiency technologies using Thermoelectric Energy Converters and electricity economy using thermal energy accumulators based on a life cycle assessment [3].

2. Methods and materials
As a methodological base of the study, the methods of statistical analysis, problem-oriented approach, back-casting with the participation of stakeholders, resource efficiency analysis (REA), environmental life cycle assessment (LCA), allowing one to develop a multi-step procedure for the environmental assessment of the choice of the best available technique of alternative energy source (Figure 1).
Figure 1. The procedure of environmental assessment of the effectiveness of alternative energy sources

In turn, the objective of the impact assessment is to determine the main components of pollutants and the level of negative impact of the production, transportation, operation and disposal of thermal modules and heat accumulators on the components of the environment – atmospheric air, surface and underground water bodies, soils and land resources [4].

The study of the heat accumulator object and its life cycle stages showed that they include: production of materials and parts; heat storage assembly; its use, including maintenance; recycling or disposal of waste after the end of its life (Fig. 2).

Figure 2. Heat accumulator life cycle stages and production system boundaries
The structure of the unit processes for the manufacture of thermal is shown in Fig. 3. The inputs are steel, magnesium, polyurethane, rigid polypropylene, energy, water and packaging material. Contaminated waste water, air emissions, waste are output streams.

Studied of the thermoelectric generation and its life cycle stages:
- Extraction of natural gas
- Production and transportation of heat and electricity
- Extraction of metal minerals (Al, Bi, Cu, Sb, Se, Sn, Te)
- Electrode production
- Copper conductor production
- Production of ceramic heat transfer devices
- Semiconductor manufacturing
- Production of lead wires

The boundaries of the production system are shown in Figure 4.
Figure 4. The boundaries of the production system of the thermoelectric generation

The general block diagram of the considered product system, indicating the inputs and outputs, reduced to a functional unit, is shown in figure 5.

Figure 5. Block diagram of the thermoelectric generation’s product system

3. Research results
Input flows of resources in the life cycle of products, namely material and energy, are considered in the analysis of resource efficiency (RES). In creating products, the MIPS analysis method (from the English Material Input per Product or Service Unit) will allow one to determine resource efficiency. The set of MIT-coefficients, characterizing the average resource intensity of the material, makes it possible to
calculate MIPS at different stages of HA [4]. Also, the data obtained allow us to speak about the most resource-intensive and water-intensive processes in the chain of product creation [5].

The most resource-intensive ones, i.e. consuming the largest amount of abiotic resources, are the processes of obtaining technical steel - 44%, electricity - 40%, polyurethane - 15%, propylene - 1%. Materials with a share of less than 1% are negligible (fig. 6).

![Figure 6. Structure of water resources consumption during the production of heat accumulators](image)

Figs. 3-4 show the structure of the flows of abiotic resources and water consumption at the stage of battery production according to the data of the completed ARE. The most water-intensive processes at the production stage are the production of polyurethane - 50%, electricity - 30%, steel - 16%, propylene - 3%, cardboard - 1% and water - less than 1%.

![Figure 7. Structure of abiotic resources consumption during the production of heat accumulators](image)

Output flows from the production stage are shown in Figure 8. Waste generation is not shown due to the large difference in values with other categories. It can be seen from the diagram that the highest value is for the indicator “eutrophication potential”, the lowest – for the acidification potential. Data was collected using LCA Light Tools software.
Based on the results of the LCI of the thermoelectric generator presented above, the diagrams are shown in Figs. 9, 10, 11.

**Figure 8.** The indicators of outputs during the production of heat accumulators

**Figure 9.** The indicators of outputs during the production of thermoelectric modules

**4. Conclusion**

In the course of the work, the LCA of the heat storage and thermoelectric module, their environmental aspects were used. Product Life Cycle Assessment was carried out using the MIPS methodology to determine the streams and the software product - LCA Light Tools with the current output stream.
The scientific novelty of the research is due to the fact that the following results were obtained for the first time in the Russian and foreign practice of the development of thermoelectricity and heat accumulators within the framework of the project. We developed:
- a methodology for assessing environmental characteristics in the development of new thermoelectric materials and thermal energy accumulators;
- an assessment of the environmental aspects of new materials and technologies has been carried out, allowing to check their safety for the environment [5].

The performed work has shown a low energy consumption of heat accumulators and thermoelectric generators in power systems, which should reduce the use of resources.

References
[1] Bagdasaryan V A 2017 Science and education: new time Scientific and methodological journal 3(4) 33–37
[2] Ilyina M E, Sennikova G N 2010 Collection of materials of the III anniversary international scientific-practical conference Ecology of regions pp 187–190
[3] Trifonova T A, Ilyina M E 2016 Life cycle and its assessment as a tool for environmental management (Vladimir)
[4] GOST R ISO 14044-2019. Environmental management. Life cycle assessment. Requirements and guidelines. Introduced: 01.01.2020. National Standard of the Russian Federation. 2020.
[5] GOST R ISO 14020-2011. Environmental labels and declarations. General principles. Introduced: 01.07.2021. National Standard of the Russian Federation. 2012.