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INTEGRATION OF HYDROPOWER, WITH SOLAR AND WIND RENEWABLE SOURCES. INTELLIGENT ENERGY SYSTEM IN VANATORI -NEAMŢ NATURAL PARK, ROMANIA

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ABSTRACT: *In Romania there are hundreds of isolated areas with limited access to utilities, most of them being protected natural areas: national and natural parks, Nature 2000 Ecological Network areas for which the biodiversity conservation is a high priority.*

This article aims to present an environmentally friendly solution for providing energy in protected natural and mountain areas. The developed model is a smart energy system based on increasing the use of energy potential from renewable sources: hydropower, solar energy, wind energy, in an isolated area of Vanatori Neamt Natural Park, Romania, by using low energy power sources to potentiate a higher energy power source.

The model allows energy conservation and includes a distribution network. The challenges were to find an optimal solution for energy storage and to minimize environmental impact. The purpose of developing this model was to capitalize renewable energy sources within protected areas in order to secure the electricity needed for those consumers who either cannot be connected to the national energy system or their connection is very expensive or the quality of the provided energy would be very low. Both in the construction phase and in the operational phase, it will not cause any environmental impact, as demonstrated in the Environmental Impact Assessment Study

Keywords: *hydropower; pumped-storage; renewable electricity; energy management system*;

1. Introduction

The background of this research is the worldwide increase in the use of renewable sources inside of hybrid power generation systems. As mentioned in the Energy Strategy of Romania 2016-2030, *"the environmental impact of the energy sector is a basic concern of the Strategy, reflected in the strategic objective of sustainable development through the protection of the environment and the limitation of global warming"*[1]

Within the context of the strategic objective of sustainable development and in order to respond to the need for energy supply in isolated areas, we are seeking a model of a renewable energy system based on the potential of the area - hydropower, wind energy and solar energy.

SEI - Intelligent Energy System in Protected Areas was a Romanian-Norwegian research project in the field of renewable energy, funded by the European Economic Area Financial Mechanism 2009 - 2014. The promoter of this project was "Gheorghe Asachi" Technical University of Iasi, along with partners from Norway: SINTEF Energy Research (Trondheim), Norwegian University of Science and Technology and partners from Romania: Polytechnic University of Timisoara, Polytechnic University of Bucharest, Administration of Siret Water Basin, Bacau, ROMSILVA - Vanatori Neamt Natural Park Administration[2].

In Romania there are hundreds of isolated areas with limited access to utilities, most of them being protected natural areas: national parks, natural sites, Nature 2000 Ecological Networks, areas for which the biodiversity conservation is a high priority and where there are restrictions on infrastructure development regardless on its purpose.

According to the National Strategy and Action Plan for Biodiversity Conservation 2014-2020, one of the threats to biodiversity in Romania is the execution of extensive hydro-technical works for the building water accumulations and protection against floods.

The surface of the national protected areas reported to the surface of Romania is 7% (1,663,360 ha) and the total surface of Nature 2000 sites, compared to the surface of the country, is 22.68% (5.406.000 ha) [3].

The measures stipulated in the management plans of the protected natural areas are designed to take into account the economic, social and cultural requirements, as well as the regional and local particularities of the area, priority being given to the objectives that led to the establishment of the protected natural area – biodiversity conservation.

The aim of the research was to identify an intelligent energy system model, that: a) allows the use of small, renewable energy sources to potentiate a higher power energy source, b) allows the energy conservation, including a distribution network. The role of this model is to provide the necessary electricity for consumers, who either cannot be connected to the national energy system, or their connection would be very costly or the quality of the delivered energy would be very low.

The intelligent energy system for Vanatori Neamt Natural Park in Romania includes hydropower, solar energy and wind energy, as renewable energy sources, defining both the infrastructure and the equipment needed to produce green energy.

If the main objective of the research was to identify a system model that would allow to increase the use of energy potential from renewable sources in isolated areas located especially in protected areas by using low power energy sources to potentiate a more energy, the specific objectives are: (i) to develop a smart environmental friendly energy management system model that can be applied in the protected area; (ii) carrying out a study of the hydropower potential of the permanent natural water course in the context of climate change; (iii) development of alternative energy storage methods; (iv) the development of a smart dispatcher energy system and of a distribution micro-network; (v) developing a management strategy for the intelligent energy system; (vi) development of systems that integrate several types of electricity generators - micro-hydropower plants, wind turbines, solar panels, diesel generators; (vii) the development of a high-power electricity generation system for short periods of time using low-capacity, but long-term power sources.

This is a complex approach to respond to the needs for sustainable development in a protected natural area through a solution without significant environmental impact and which does not affect the conservation status of protected species and exploits the existing energy potential in the area, in the pursuit of economic efficiency.

The hydropower component is essential in the developed model, being necessary the storage of the produced electricity as water potential energy. According to the model, the water is captured from the river during the high flow and stored in ponds. Later in sunless and / or windless periods the potential energy of the water is transformed into electricity, passing water from the upper basin into the lower basin by means of a reversible turbine or an SHP (figure 2).

Hydro-energy is a renewable energy source based on water drops, with special features, not only providing clean energy but also providing indispensable services to the energy system.

Advantages of using hydropower: economic advantage, high yield, low cost, long life; ecological advantage, does not pollute the environment.

Disadvantages of using hydropower: sometimes hydro facilities can generate conflicts when placed in national / natural parks or when the water level of the dam covers localities; the modification of the surrounding biotope, the necessity of building areas land expropriations, droughts that may dramatically decrease the lake level [4].

Hydropower production is based on efficient and reliable energy production technology in terms of clean energy. In particular, the essential benefits of micro-hydro potential compared to wind, wave and solar energy are [5]:

- high yield (80-90%);
- high transformation factor (generally> 70%), compared to 18-22% for solar energy and 30% for wind power;
- high predictability, varying annually with the amount of rainfall;
- energy produced varies only daily (not from minute to minute);
- good correlation of demand and supply;
- long-life, robust lifecycle technology that can be up to 50 years old or even longer.

Actually, the general perception in Romania is that micro-hydropower plants situated on mountain rivers destroys biodiversity in protected areas; habitats, fish, otters and wildlife are generally threatened.

The energy system model obtained is a compromise between: 1. the benefits of the hydroelectric infrastructure in terms of electricity generation, 2. the combination of several types of renewable energies, allowing them to be stored, 3. the development needs of the communities in protected areas and 4. the impact in terms of territory, ecology and human values.

Globally, there are multiple energy storage solutions. The most common form of storage involves pumping water to a reservoir located at a height when demand for electricity is low and its release into hydro generators when electricity consumption increases.

In Ireland, a think tank called Spirit of Ireland is working on such a project, a 3.6 billion-dollar business that will use the pumping storage method to make the most of the country's intermittent winds. "Inappropriate" energy from large wind farms will be used to transport sea water to a high-pitched tank [6].

At the Dinorwig power plant in the UK, for example, water is pumped into a reservoir on top of Mount Elidir Fawr during periods of low consumption. When energy consumption reaches high levels, water is released from the mountain to start the turbines that supply the power grid. But not every country can rely on pumping storage, which is overwhelmingly dependent on existing geographic features [6].

The Canadian company Hydrostor invented a system of underwater balloons under pressure that could store renewable energy until needed, which could reduce the need for gasoline or gas as an alternative calorific source. This solution could conserve energy for a time twice as long as the most powerful battery we have today and at a much lower cost. The first experiment was already set up in Lake Ontario near Toronto in Canada with a series of balloons set at 55 meters deep and connected to the grid through a duct [7].

Battery storage is a widely-used method based on ever-developing and evolving technologies. Batteries and accumulators have a limited life span and at the end of their operating cycle they become hazardous waste.

In Romania there are hundreds of isolated areas where access to utilities is limited. Energy storage technologies and technologies for integrating renewable energy sources at a global level make it possible to develop autonomous systems based on renewable sources for rural communities or small residential complexes.

2. Materials and methods

The Intelligent Energy System model developed for Vanatori Neamt Natural Park in Romania, puts together:

- exploitation of the renewable energies potential - hydropower, wind energy, conventional energy (conventional diesel), integrating several types of electricity generators;
- alternative energy storage - storage by pumping and storage in batteries;
- intelligent energy dispatcher type system;
- micro-distribution network;
- producing high power energy for short periods of time using low-capacity, but long-term power sources.

The model is adapted to regulations on protected natural areas and topology specific to isolated, mountainous areas with limited access to resources and infrastructure.

The key elements that define the areas of interest for the implementation of intelligent energy management systems are: (i) geographical isolation; (ii) lack of telephone networks; (iii) the location in protected areas of human settlements in need of electricity and access to information; (iv) the lack of the possibility of linking to the national energy system or the very high cost of the connection; (v) topography favorable to the installation of the system in the protected area.

Following the application of the above criteria, it was identified as a location for the model development the Vanatori Neamt Natural Park, the area taken into account in the research, belonging, from a territorial-administrative point of view, to the Crăcaoani commune, the Neamt County, the North-East Region.

Coordinates of the site are: Lat. 47º.04'.38,00 "N, Long. 26º.08'.59,00 "E.

Beyond technical details, which are linked to dozens of concrete items (capture threshold, top basin, bottom basin, micro-hydropower, emergency diesel generator, solar panels, wind turbines, energy storage elements, network distribution system, radio system, research laboratory building, pipelines, consumers, accessories and control and actuation elements), we underline that the aim is to fully ensure the role of the intelligent energy management system, namely the monitoring and control of the flow required for the micro hydro power plant in relation to the demand for energy, but also the flow compensation between pools in relation to the volume requirement of the upper basin. At the same time, monitoring covers the energy stocks in the batteries and the distribution and compensation of energy production among the system's energy sources (micro-hydropower, solar panels, wind turbine etc.).

The role of the system in question cannot exceed the consumer interrogation with regard to the required energy demand and providing safe operation conditions in the absence of the required amount of energy.

From the practical point of view, it can also produce electricity by using the water drop from the upper basin in the lower basin. The fall is generated by the opening of a controllable solenoid valve that allows a variable flow rate. The amount of energy produced and, incidentally, the volume of water used will vary with the consumer demand dictated by a final consumer (group of consumers). If the upper basin flow falls below a minimum allowable level, it will be pumped (using renewable energy - solar, wind) from the lower basin.

As far as the distribution management is concerned, it will be achieved by using all the system energy sources (micro-hydropower plants, solar panels and wind turbines), including storage batteries. In the event of an emergency, a diesel generator will operate; the control of the water flow in the system is based on the action of electric valves, fully automatic, in relation to the energy requirement at a given moment.

The constructive solution of the model includes 3 infrastructure objectives (Fig.1):

1. Intake and supply with the following objects:

Object no. 1.1. Water intake in the river bed Bouletul Mic at elevation 770.25;

Object no. 1.2. Adduction with PEHD pipe, underground

2. Storage tanks and energy laboratory with the following objects:

Object no. 2.1. Supply water basin: upper basin, drainage system 1, drainage system 2;

Object no. 2.2. Lower storage basin (water elevation at level 767.00);

Object no. 2.3. Penstock PEHD pipeline, underground;

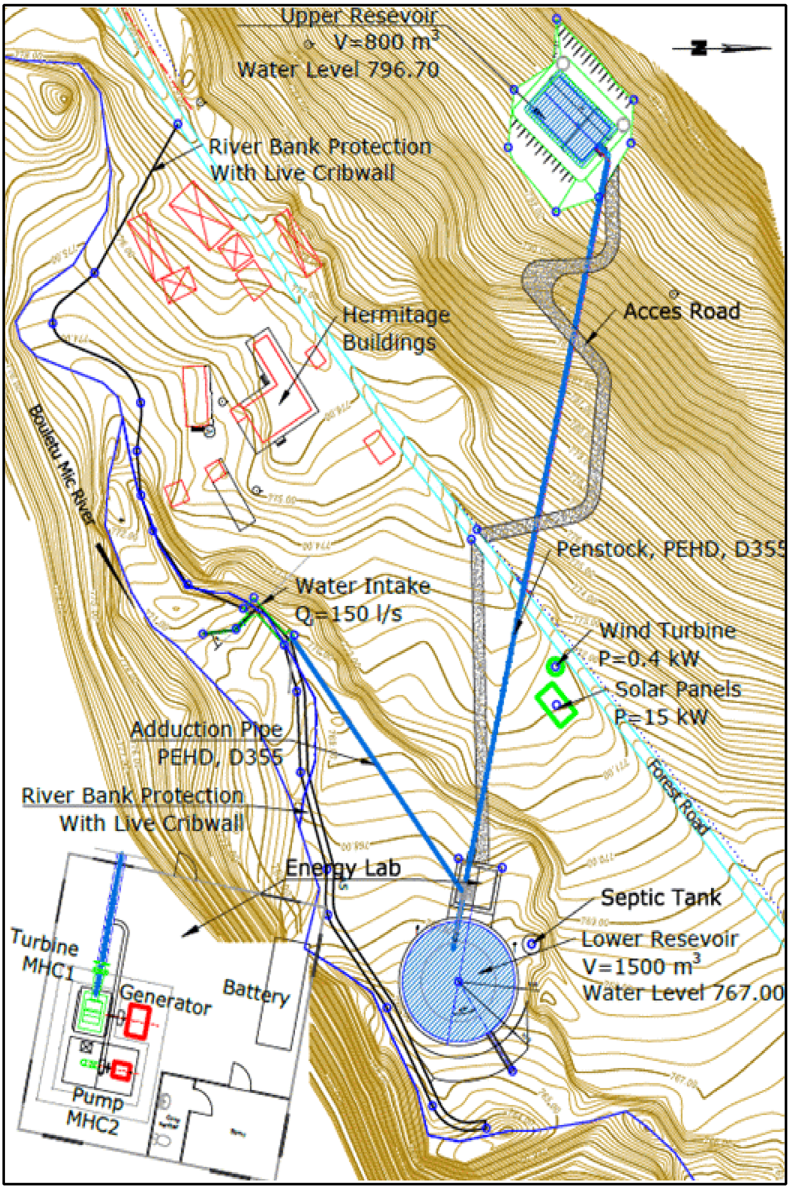

Fig. 1. Building solution - Situation plan

Object no. 2.4. Energy laboratory located near the lower basin: Infrastructure, superstructure, sanitary and electrical installations, equipment (including turbine micro-hydropower / reversible pump, storage batteries, monitoring equipment, command / control equipment and power distribution panel);

Object no. 2.5. Protection of the left bank of the river Boulevul Mic with bio structures (live cribwall):

Object no. 2.6. Technological road

3. Energy system based on renewable energy sources with the following objects:

Object no. 3.1. Solar panel batteries and interconnection equipment;

Object no. 3.2. Wind turbine and interconnection equipment.

Intake: the water captured at elevation 770.25 in the Bouletul Mic river bed will be led through the underground pipe to the lower storage basin. The length of the feed will be 78 m. The pipe path will be straight from the exit of the loading chamber to the lower basin near the laboratory. The adduction leaves the loading chamber at elevation 769 and flows into the laboratory dorm, then into the lower basin at the level 767.00.

The lower basin (level 767.00) shaped as a cone trunk - in the basin axis will be fitted with a PEHD D315 pipe for emptying / washing the basin. The water inlet into the duct will be through a drainage hole provided with a plug and chain anchored by a float. The volume of water that can be stored in the lower basin is about 1500 m3.

The laboratory, located near the lower basin, is a construction with metallic structure. Inside the laboratory will be installed the functional equipment:

- reversible turbine / pump, SHP2, which will also be able to measure the amount of water that will circulate in the PEHD D355mm pipe, by falling / pumping - we will use a reversible pump with low output as turbine, approx. 80% of pump power;
- LPG-based heat generator group;
- batteries for electricity storage;
- SHP1 power micro-power plant;
- an array of monitoring, control and command equipment;
- dispatcher - hard - data processing equipment, with data transmission / acquisition boards;
- distribution panel;
- appropriate furniture.

The upper water storage basin will have the shape of a rectangular pyramid trunk. The long side of the basin will be parallel to the level curves. The water level at NNR will be 796.70. The volume of water stored in the pool will be about 800 m3. The height of safety between the NNR and the upper edge of the basin will be 30 cm.

The penstock, 198m long underground PEHD pipe, will lead from the upper basin to the energy lab.

The parameters of the model project are: the installed flow rate, Qci = 150 l / s, the upper basin will have a capacity of about 800 m3 - the equivalent of 70 KWh, the turbine / reversible pump will have the installed power Pi = 2,5kW / 3,0 Kw , the lower basin will have the capacity of 1600 m3, the installed flow rate of the reversible pump will be Qi = 45 l / s, the wind turbine will have the power Pe = 400 W, the solar panels will have the power Ps = 15 kW.

It will produce energy through the fall of the water stored in the upper basin (volume 800 m3), using the wind turbine to produce wind energy and using the solar panels. Part of wind and solar energy is consumed for rising water by pumping it from the lower basin into the upper basin

In the area of the project site dominates the natural environment, and on a limited area, there are the buildings of the monastic settlement Bouleţ hermitage. The site is located on the surface of the Vânători Neamţ Natural Park, which has an internal zoning according to the Government Emergency Ordinance no. 57/2007 approved with amendments and completions by Law no.

49/2011, as amended and supplemented.

Thus, the surface of the Vânători Neamţ Natural Park is divided into three areas:

- full protection area - 615.5 hectares;
- buffer area - sustainable management area - 27,785.3 hectares;
- sustainable development area - 2,230.2 hectares.

According to zoning, the research site is largely in the area of sustainable development - the Bouletul Mic Hermitage which includes part of the meadow of Crăcăoani commune and has an area of 1.3 hectares. The projected objectives occupy an area of approx. 3509 m² in habitat 6520 Mountain meadows (Figure 2)

The consumer community that addresses the developed model will have a relatively atypical consumption profile due to the fact that the necessary energy will also be used for energy-producing but not continuous activities. Due to the fact that the system is proposed to be a 100% autarkic, 100% reliable and at the same time one that by means of monitoring, remote control and creation of the possibility to simulate different situations from the computer terminal, is at the same time a subject of study accessible to groups of students in the field laboratories.

In line with the current requirements aiming to reduce pollutant emissions and integrate this symbiotic system into a natural setting, the following concepts were the basis for the concept:

- Electricity to be generated by 3 independent energy sources (hydro / wind / solar);
- In case of exceeding the estimated consumption during the study period and in the idea of not leaving the community without energy, a diesel-electric generator will be provided.

Fig. 2. Habitat 6520 Mountain meadows in Vanatori Neamt Natural Park in Romania

3. Results

The proposed smart energy system includes:

- The equipment solution - transposed into the block diagram of the system;
- Energy system management – dispatcher and software solution

The equipment solution for the model is shown in Fig. 3.

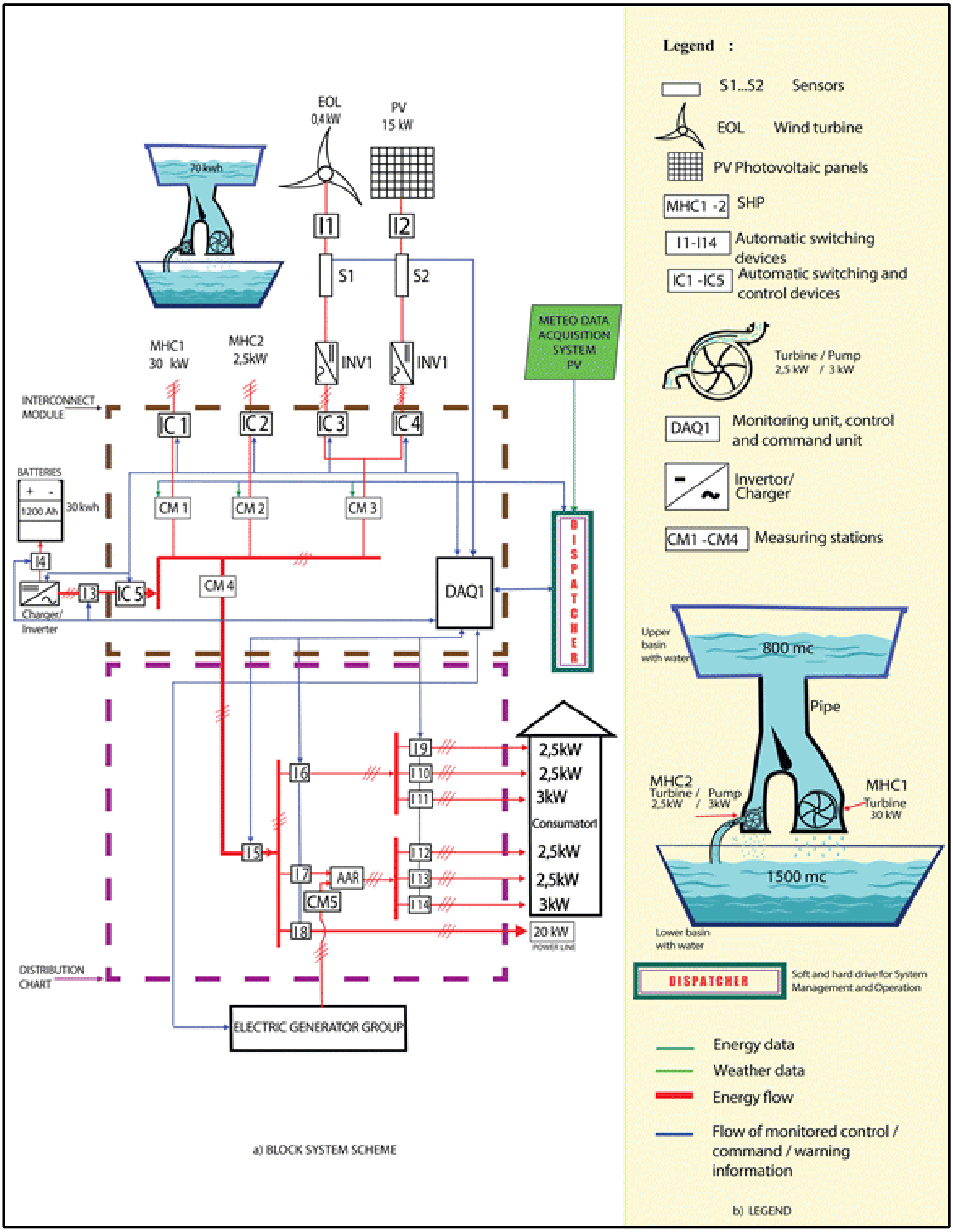

Fig. 3. Intelligent Energy System Block Scheme

Provision of two buffer water reservoirs located at approx. 30m level difference one from another, needed from two points of view:

- due to the fact that the river flow will not allow a constant high-power hydroelectric production and sporadic consumers may overcome, for a short period, up to 15 times the usual consumption;
- due to the environmental impact (in terms of the use of classical mineral

resources) we will try to reduce the capacity of the batteries to the minimum possible (1200 Ah).

As a result, water in the upper basin, with a capacity of 800 m3, will train, falling in a 150 mm diameter pipe, a micro turbine, SHP1, with a capacity of max. 30 kW (which will operate in the 5 - 30 kW range). This can cover any peak of consumption for a specified period. This water tank will be filled from the bottom tank, which has a capacity of 1500 m3, through a 3kW pump that will use surplus energy from the system (from sources: solar, wind, generator or energy in batteries).

The second micro-power plant, SHP 2, of very low power, about 2.5 kW, will also have a non-permanent operating mode. It will be placed on the same pipeline but in a deviation from the first turbine and will actually be the pump that will work in a reversible sense between 1- 2.5 Kw.

So we avoided installing an SHP - a restrictive condition imposed by environmental authorities- directly on the existing water course. Because of the efficiency and the redundancy required, the power inverter will be a cluster of 6 units. Studying climatic conditions and the wind map at the proposed location, the use of a small wind power plant (400W) to operate at low wind speeds specific to the locations where they could be located was adopted.

A power monitoring system will be connected to all of this power plant, enabling intelligent energy production, management and distribution of energy to consumers.

The solar panels (about 15Kwpp) are proposed to be multilayered (last generation) technology that will generate current even under more diffused light conditions, specific to mountain areas).

All of this power-plant has a heat-laboratory in which the mentioned equipment as well as the rest of the monitoring, control, command and distribution equipment will be installed.

4. Conclusions

We can assume that the hydroelectric component, as estimated, has a potentially important contribution within the smart energy system model in Vanatori Neamt Natural Park: a. as a renewable energy source, b. As a renewable energy storage solution of the area's energy potential; b. as an optimal alternative to provide energy in an isolated area, with biodiversity conservation regulations, being an environmentally friendly solution (without impact on the environment and biodiversity conservation status).

Economic aspect

By comparing the two methods of energy storage: energy storage by pumping water and storing energy in batteries, we estimate that there are no big differences between the depreciation periods of the two investments.

Environmental impact

From the environmental perspective, medium and long term environmental impact, the pumped storage solution is the recommended solution given that the environmental impact is insignificant in this case. By comparison, energy storage in batteries is a method generating hazardous wastes with significant potential for the environment.

The developed model brings together the two storage methods in optimal proportions so as not to generate significant environmental impact in the protected natural area.

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