The steps towards an infrastructure with minimal impact on the environment: the ELI-NP model of good practice

Paşii către o infrastructură cu impact minim asupra mediului: modelul de bună practică ELI-NP

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ABSTRACT: The paper presents steps taken to minimise the impact of the ELI-NP research infrastructure on the environment, on a roadmap towards a green facility.

The current crisis highlights the need to invest in strong renewable infrastructure and sparks interest in using cleaner, more sustainable energy sources.
As a result, stakeholders' interest is to maximise the infrastructure's initial potential while simultaneously enhancing key performance metrics and energy efficiency.
The primary aim of the ELI-NP decision makers is to enhance the efficiency of the current infrastructure in order to minimise its energy consumption.
Reducing the carbon footprint of the infrastructure is also a major goal in minimising its effects on the environment. To make the switch to green infrastructure, future investments are scheduled.

Key words: model of good practice, environment

Current state and context of the project

In the subject of photonuclear physics, the Extreme Light Infrastructure Nuclear Physics (ELI-NP) project is a sophisticated research infrastructure in the world, at the moment.

The ELI-NP high-power laser system (also known as HPLS) test results, which were released on March 13, 2019, constituted a significant step towards the establishment of a first-rate research infrastructure. These results verified the achievement of a power of 10 PW.

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The ELI-NP laser system is the most powerful ever created, with two laser beams that each have a power of 10 PW.

The HPLS must function properly under certain environmental conditions. High stability is essential for variables like humidity, pressure, and temperature.

Two research purpose buildings with a high-power laser system (HPLS) and sophisticated experimental sets are supplied with thermal load by the shallow GSHP system. The design of the system, as outlined below, aims to supply the optimum energy consumption while supplying the necessary air exchange rates.

To mention some operating constraints given by the research equipment, the building where the HPLS is located has more than 3000 m^2 of ISO 6 and ISO 7 clean rooms, out of which the laser room has around 2400 m2. The system has to provide or deliver 20 air changes per hour with a vertical air flow of 435,000 m3/h, at a constant temperature of 22^{o}C in order to maintain the required humidity and cleanliness. Only +/- 0.5^{o}C variations are allowed.

To operate the building where combined experiments are carried out, a flow rate of 80,000 m3/h of fresh air is required.

Details of the building that houses the high-power laser system:

- The building houses the HPLS
- The building is technically complex, being served by a wide variety of HVAC equipment.
- The building has high energy consumption.
- The usage and occupation of the building is 100%
- The ambient parameters (temperature and relative humidity) have a high stability, the ambient temperature of 22^{o}C +/-0.5^{o}C is a mandatory requirement for the functioning of HPLS.

Additionally, at present a 1.2 MW photovoltaic system will be installed in the ELI-NP infrastructure, which is anticipated to be finished by the end of 2025.

Milestones towards an infrastructure with minimal impact on the environment

A geothermal HVAC system is being installed in the ELI-NP infrastructure - 2016

When the ELI-NP research infrastructure was designed, it was outfitted with the largest shallow ground source heat pump (GSHP) system in Europe to provide the energy needed for air conditioning, heating, ventilation, hot water, and technological cooling.

Among the considerations that went into choosing this solution for the infrastructure's HVAC and technological cooling were the need to meet the operational parameters within the restrictions set by the cutting-edge research equipment. The infrastructure includes five buildings:

- Two buildings having research laboratories of 11,500 m^2 and 13,500 m^2
- Three buildings for support activities (office building, restaurant, guest house) of 7800 m^2.

The GSHP System was installed on a plot of 27,000 m^2 and has a length of 135 km. The total installed thermal capacity is above 6.2 MW.

The GSHP System is a closed-loop system made of 1070 boreholes with a depth of 120 m each.

The primary and secondary thermal agents are circulated within the closed loop by means of 185 circulating pumps.

The required primary thermal agent (water) is pumped from the manifolds to nine thermal plants equipped with water to water heat pumps that carry out the heating and cooling of the buildings.

The secondary thermal agent (water) for cooling and heating prepared with the water to water heat pumps is delivered to the HVAC equipment (air handling units, fan coil units).

The required thermal load of 6.2 MW is provided by 129 water-to-water heat pumps. In addition, 46 water to air heat pumps directly carry out the cooling or heating of the indoor air in some rooms.

The heating, ventilation, and conditioning of the buildings is performed by air handling units. Energy recovery is used wherever possible.

The shallow GHSP system at ELI-NP is unique due to its size and technical requirements.

The constraints considered in the design and implementation of the GHSP system at ELI-NP are reviewed here:

- precise humidity control requirements in many of the laboratories, low temperature and relative humidity being required
- the high air change rates requirements
- multiple operating conditions
- the pressurization requirements

- the limited options to use the energy recovery strategies, in order to avoid the cross-contamination
- the difficulty to anticipate the equipment thermal loads and exhaust requirements,
- the high energy consumption of the process and of the research equipment

The use of high-efficiency equipment has ensured a good balance of energy recovery and ventilation requirements.

The design of the system is intended to guarantee the required air change rates while minimizing energy consumption.

Since the requirements for heating and cooling are covered by the Shallow Geothermal System with Heat Pump Units (the largest in all of Europe), the infrastructure is free of fossil fuel consumption.

1. Extensive, long-term monitoring of the infrastructure in operation

Extensive, long-term monitoring of the infrastructure in operation is necessary to observe the results in terms of energy efficiency and environmental impact.

Working at full capacity, the Shallow GSHP System and the technological cooling account for almost two-thirds of the electricity consumed.

Surveillance showed that environmental parameters were stable and easy to manage, staying within the limits necessary for the research activity.

The most significant outcomes are those obtained when usage and occupancy are in the vicinity of 100%.

The project's focus is on highlighting the outcomes of the evaluation of the Shallow GSHP System in operation after long-term monitoring.

Four of the five buildings are, at present, occupied with a maximum occupancy rate of 100%.

Digital control of the Shallow GSHP System is done by the DDC system. Continuous monitoring, recording, and adjustment of temperature and humidity is done, and the information is sent to the BMS system.

The activities follow three main directions:

The performance of the Shallow GSHP System is assessed. Metrics considered for evaluation are Energy Intensity Use and the performance coefficient.

The EUI for the infrastructure, expressed as energy per square foot per year, was computed by dividing the total energy consumed by the infrastructure in one year (measured in kBTU or GJ) by the total gross floor area of the building (measured in square feet or square meters).

To evaluate the Shallow GSHP System, its performance coefficient was estimated in the next step, by comparing the electrical energy consumed by the system with the actual thermal load required for the building.

Groundwater and the ground are being observed continuously to determine the effects of the Shallow GSHP System.

Two sets of parameters are being measured, collected and compared with quality indicators of the groundwater set before the commissioning of the facility, to monitor the impact on the ground and groundwater:

- Physical parameters – piezometric levels, temperature (automatically measured on daily basis
- Hydro-geo-chemical and microbiological parameters (water sampling is performed each semester)

Simulations and studies both regarding the evaluation of the thermal loads introduced by the HVAC systems and the long-term response of the ground to the action of these loads, are of particular importance for the determination and evaluation of the possible consequences on the ground and groundwater.

Fine adjustment, optimization, and future optimal control of the shallow GHSP system are possible due to the recordings of operation consumption patterns and the high stability of the ambient parameters.

An important consequence of this fact is that it will be possible to carry out studies and simulations useful for making predictions and forecasts for the behaviour of similar systems, in order to evaluate the impact of the systems on the environment, their continuous innovation and optimization.

2. Optimisation of the geothermal HVAC system in operation

Given that the previously mentioned equipment and constraints have significant energy consumption, achieving the highest energy efficiency with the least amount of environmental impact has been taken into consideration.

Optimizing the operation of large consumers brings significant energy savings. Identifying and implementing efficient and inexpensive optimization techniques can bring great benefits to the society, especially in the long run.

Testing integrated optimization techniques for large shallow GHSP systems is an innovation in itself, and it adds value to the existing ELI-NP shallow GSHP system. Furthermore, the future results could contribute to the development of optimization criteria for large shallow geothermal systems.

Observing the system's performance and consumption patterns over the previous five years, revealed that there is space for improvement in both control and energy efficiency.

To achieve the ideal balance between consumption and technological requirements, the ultimate goal is to optimise the Shallow GSHP System.

Reducing the carbon footprint of the infrastructure is also a major goal in minimising its effects on the environment.

Given that the consumption of the circulating pumps has an impact on the overall performance of the Shallow GSHP System's an experimental optimization methodology is being developed for the circulating pumps operation, to obtain the values of the optimal frequencies of the circulating pumps.

An experimental methodology is under development to optimize the Shallow GSHP System, at the same time.

The optimization of the Shallow GSHP System is in progress. There have been steps taken to obtain an accurate pattern of the system's behaviour and to develop an optimal control strategy.

3. Installing a photovoltaic system

To make the switch to green infrastructure, future investments are scheduled.

At present a 1.2 MW photovoltaic system will be installed in the ELI-NP infrastructure, which is anticipated to be finished by the end of 2025.

The photovoltaic installation for the production of electricity will be connected to the network of the existing medium voltage of the ELI-NP infrastructure without grid discharge

The photovoltaic system will consist of a number of around 2000 PV modules, each of them having the power of 540W.

Photovoltaic panels will have a minimum nominal efficiency of 20.89% in

The system will be equipped with three-phase string inverters of the string inverter.

The installed power of the photovoltaic system will be of around 1.2 MW.

Expected results

Finding the optimisation technique to maximise the performance coefficient of the shallow GHSP system to the maximum value achievable within the limitations imposed by the research activity conducted is anticipated.

Good estimates of the buildings' behaviour with 100% usage and occupancy are possible, at this stage of the project.

A complete and optimized picture of the behaviour of the Shallow GSHP System will be provided by gradually expanding the analysis throughout the entire infrastructure.

The HVAC system and the hydrogeological monitoring station are in their 5th year of operation. By means of the statistics and monitoring, data are available to highlight the real behaviour of the system by comparison with the predictions made based on the physical model.

Data are available regarding the energy consumption of buildings and their systems, as well as the consumption of the processes carried out in the buildings.

The published median source EUI (energy use intensity) for technology and science is 1004 kWh/m^2/year. In contrast, the source EUI of the ELI-NP facility is 489 kWh/m^2/year.

A comparison between the electrical energy consumed and the actual thermal load required for the building yielded an average value of 3.8 for the Shallow GSHP System's performance coefficient.

Groundwater and the ground were also observed for effects of the Shallow GSHP System, but none have been found as of yet.

The heat transfer models will be refined and calibrated based on real data and considering the operation in both directions (yielding or receiving heat from the HVAC system in the environment).

A significant reduction of electricity consumption is anticipated by the end of 2025 as a consequence of the system's optimisation and the installation of the photovoltaic plant.