

Energy key performance indicators for research infrastructures equipped with optimized HVAC system

Indicatori cheie de performanță energetică pentru infrastructurile de cercetare echipate cu sistem HVAC optimizat

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ABSTRACT: In the context of the effort to find the right key performance indicator that allows comparing the energy efficiency of the ELI-NP research infrastructure equipped with a unique HVAC geothermal system with other similar infrastructures, the paper presents key performance indicators used to evaluate the energy efficiency of buildings. The end goal is to optimize and make the infrastructure energy efficient while maintaining the operating parameters imposed by the research activity.

Key words: energy key, HVAC System

CONTEXT

Building energy efficiency, together with energy supply security and the fight against energy poverty, are top priorities in the EU's energy and climate change policy.

One of the key principles of the EU's energy policy, according to the European Strategy for the Energy Union, is to increase energy efficiency, decrease reliance on energy imports, cut emissions, and promote economic growth and job creation.

Strategies for cutting energy consumption, utilizing renewable resources extensively, and lowering CO_2 emissions have been and are being developed by stakeholders in the context of the present focus on the efficient use of energy resources. Therefore, evaluating buildings is very important in order to set reference values for energy consumption for different building categories and activities and to categorize them into energy efficiency classes.

There are regional variations in the way that different countries address the energy performance of buildings and other energy-related issues.

The ELI-NP research infrastructure viewed in terms of:

- the complexity of its built environment
- the activity carried out within it - cutting-edge research

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- the HVAC geothermal system with heat pumps units with which it is equipped - the largest in Europe

offers opportunities for studying the behavior of research infrastructures from the point of view of energy consumption, to identifying ways of energy efficiency and equally for studying the optimal control and energy efficiency of shallow geothermal HVAC systems.

Considerations on the energy efficiency of research infrastructures in the context of the high share of energy consumption of HVAC systems in the total consumption

Whereas assessment of the performance of residential buildings or regular buildings is considered in terms of ensuring the comfort of the users at low rates of energy consumption, the environmental parameters are of significant importance for the processes carried out in buildings with specific uses (hospitals, industrial buildings, research laboratories).

Most of the time, a high stability of the parameters is required. At the same time, ensuring the parameters requires high energy consumption.

The share of consumption of HVAC systems in the total energy consumption of these buildings is very high, reaching 70% of the total.

Consequently, HVAC systems represent a significant component in the economics of building energy efficiency measures. It's time-consuming and resource-consuming to optimize their operation when operating manually, and difficult to accomplish. Automatic operating and control systems provide conditions for optimization.

The energy consumption of applied research laboratories, especially those that include clean rooms, is very high. Their reduction is possible through optimization, and a substantial reduction in consumption is possible through the use of renewable energy.

For example, laboratories / research infrastructures typically consume 5 to 10 times more energy per square meter than office buildings.

The use of a research infrastructure is different from the use of a conventional non-residential building. The large equipment, the large built area of the cleanrooms, the need to keep the very high stability of the operating parameters, imply a very high energy consumption for heating, ventilation and air conditioning. Some specialized laboratories, like clean rooms or laboratories with significant technological consumption, can use up to 100 times the energy of an institution or commercial structure of the same size.

Due to the fact that activity carried out inside research laboratories requires high stability of the environmental parameters constraints of the HVAC systems operation must be taken into account. Listed below are some of the requirements and conditions that impose constraints on operation:

- requirements for high relative humidity and temperature stability in most laboratories
- relatively low temperatures in clean rooms
- requirements for high air change rates
- multiple operating conditions
- pressurization requirements

- limited options to use energy recovery strategies to avoid cross-contamination
- the difficulty of anticipating equipment thermal loads and evacuation requirements
- high energy consumption of the process and research equipment.

Key Performance Indicators for evaluating the energy performance of buildings

Most frequently, indicators of the "specific energy consumption" type are used to evaluate the energy performance of buildings, in the case of buildings, they are expressed by relating energy consumption to the area of the building's surface.

Akville et al. extensively discussed the topic in [1] and provided their conclusions on the definition and differential treatment of this indicator. The authors state that despite the frequent use of the Specific Energy Consumption (SEC) indicator when benchmarking with the aim of improving energy efficiency, clear and detailed descriptions of the assumptions on which the SEC calculation is based seem to be missing from both scientific literature as well as international standards.

The authors concluded that the calculation of SEC is based on assumptions that are rarely presented or highlighted after analyzing scientific publications and standards that address and use SEC. Therefore, a significant improvement is needed in terms of the reliability and comparability of SEC, which is impacted by several factors.

In order to critically analyze SEC in relation to industrial energy efficiency, Akville et al. formulate the following conclusions:

- SEC is of greater use if a longitudinal benchmarking (i.e. same company, same sector or same country, over time) is undertaken.
- In order to benchmark correctly, special attention is recommended when using SEC for comparative assessment between companies, sectors or countries,
- The use of SEC for comparisons is optimal in the case of a unitary calculation of it.
- As there is a gap in both research and international standards regarding the use of SEC, a plan for the future use of SEC, accompanied by monitoring activities, would be needed.
- The SEC calculation can be significantly influenced by the conversion factor from primary energy to final energy.
- SEC is a more optimal KPI within the same study when the underlying assumptions are the same.
- The authors also suggest that the abbreviation SEC would be more correct for specific exergy consumption than specific energy consumption. Alternatively, the term specific energy use could be used.
- Before using SEC from other studies, it is recommended to study the assumptions behind the calculations. SEC is a convenient indicator with potential for use in various valuation applications, provided that the assumptions used to make the calculations are appropriate.

Specifically, it is recommended to consider the following aspects:

The origin, availability and quality of the information and data that were used to calculate the SEC

- o Accuracy of system boundaries, for example, energy used by main equipment, auxiliary equipment used in production and/or parts thereof
- o Conversion factors from primary energy to non-primary energy
- o Energy calculation mode
- o Other factors such as equipment specifications (i.e. age).

Romanian legislation ("Methodology for calculating the energy performance of buildings, Mc001-2022) that implements European directives, also provides for the use of a "specific consumption" type indicator. Energy classes are defined by utility and by building category, a disadvantage of the methodology being that it does not cover important categories of energy-consuming buildings. For example, the methodology does not treat industrial buildings.

In the United States of America, energy efficiency is a central theme both within the Department of Energy/US Department of Energy (US DoE) and within the Environmental Protection Agency/US Environmental Protection Agency (US EPA). Thus, EPA administers the Energy Star platform, launched in 1992, which together with EPA, provides energy efficiency solutions that deliver cost-saving energy efficiency solutions that protect the climate, improve air quality and protect public health.

Portfolio Manager is an interactive management tool that enables the assessment of the energy consumption of any type of building, all in a secure online environment. Nearly 25% of the US commercial building space is already actively benchmarking in Portfolio Manager, making it the industry's leading benchmarking tool, comparing the energy performance of buildings to similar buildings. [2] The indicator with which buildings are compared in Portfolio Manager is Energy Use Intensity / the intensity of energy consumption / the intensity of energy use or EUI. Essentially, EUI expresses the energy consumption of a building according to its size or other characteristics [3, 4].

For property types in Portfolio Manager, "Energy Use Intensity" - EUI (Energy Use Intensity) is expressed as energy per square meter per year.

It is calculated by dividing the total energy consumed by the building in a year (measured in kBtu or GJ) by the building's total gross floor area (measured in square feet or square meters).

Source Energy represents the total amount of energy / raw fuel that is required to operate the building and includes all transmission, delivery and production losses. Considering the entire amount of energy used provides a complete assessment of the energy efficiency of an assessed building/object.

Site Energy is the annual amount of energy (for heating, lighting, etc.) consumed by a building, as reflected in utility bills.

Energy at the point of consumption can be delivered to a building in one of two forms: primary energy or secondary energy.

Primary energy represents the amount of raw fuel used to obtain heat and electricity (e.g. natural gas or fuel oil used to produce energy at the point of consumption).

Secondary energy is the energy product (heat or electricity) created from a raw fuel, such as electricity purchased from the grid or heat received from a centralized (district) system.

A unit of primary energy and a unit of secondary energy consumed on site are not directly comparable because one represents raw fuel while the other represents transformed fuel.

Therefore, in order to assess the relative efficiency of buildings consuming primary and secondary energy in various proportions, it is necessary to transform these two types of energy into equivalent units of raw fuel consumed to generate a single unit measure of energy consumed at the point of consumption.

Thus, any form of primary or secondary energy consumed at the point of consumption (on site / at the location) is calculated unitarily, because the calculation of energy at the source takes into account the losses incurred in its production, transport and delivery to the building.

To achieve this equivalence, the EPA uses the quantity "source energy".

Portfolio Manager presents/recommends national median source EUI reference values for building types. The median is more appropriate for analysis than the mean (arithmetic mean) for comparing relative energy performance, as it more accurately reflects the middle values of energy consumption for most property types. This data is centralized and published on the platform, the database being continuously updated according to the results of The Commercial Buildings Energy Consumption Survey (CBECS), which is referenced in the Portfolio Manager. This is a national study, conducted by the U.S.

Energy Information Administration (EIA) and collected the information on the building stock in the United States. The U.S. The Energy Information Administration (EIA) is an agency of the U.S. Federal Statistical System that collects, analyzes, and disseminates energy information.

The CBECS study analyzed 11,000 research laboratories totaling

711,000,000 ft2 (approximately 66,000,000 m2).

Energy efficiency of the ELI-NP research infrastructure. EUI assessment

A large HVAC system uses unconventional geothermal energy to provide cooling or heating for the ELI-NP research infrastructure.

The thermal source is a low-enthalpy source that is captured through drilled wells, and then capitalized by heat pumps units. The geothermal system at ELI-NP is installed on a plot with a total area of approximately 27,000 m^2, has a length of 135,000 m and fully provides the energy required for heating and cooling the infrastructure, having an installed capacity of 6.2 MW (4.2 MW heating and 6 MW cooling).

The ELI-NP geothermal HVAC system serves a built-up area of approximately 33,000 m^2.

The energy efficiency of the HVAC system installed at ELI-NP has been monitored, at different degrees of occupancy, after the installation of the research equipment, starting with the testing period and then during the period of conducting the experiments.

The geothermal HVAC system with heat pumps units maintained the stability of the required parameters (temperature and relative humidity). At the same time, the ISO 7 cleanliness class (according to standard 14644) of the clean room in the building housing the high-power laser and the other laboratories was preserved.

The lack of data for similar infrastructures makes it difficult to evaluate ELI-NP. Health infrastructures, more commonly assessed and classified, are somewhat similar in terms of the need for HVAC, but in the case of ELI-NP the rooms housing the research equipment are single-volume rooms with large areas and heights. Moreover, there are areas where the basement of buildings communicates directly with the ground floor. Also an area 8,200 m^2 of research laboratories with high lighting level requirement has no natural lighting. In addition, research buildings have continuous operation, at least in terms of heating/cooling ventilation and air conditioning, the environmental parameters stability in these buildings being mandatory.

Benchmarking the ELI-NP research infrastructure would be relevant if comparisons with similar infrastructures ("peer group of facilities") were possible.

The monthly site electricity consumption of the infrastructure is around 500,000 kWh (technological consumption is included). Figure 1 shows the total electricity consumption of the infrastructure for the year 2022, and the figure 2 shows the data from the year 2022 for the research buildings.

The data source for the total plant consumption is the monthly reading of the electricity supplier. The recorded monthly consumption is relatively constant throughout the year, in winter and summer months being approximately 12% higher than the average consumption, "in money."

Also, the electricity consumption is known for all important consumers in the research infrastructure, individually for buildings and systems, and can be read in real time from the network analyzers installed on the electrical switchboards.

As expected, building heating, cooling and air-conditioning use accounts for the largest proportion of building use, around two-thirds of total energy use.

In 2021 and 2022, three of the five infrastructure buildings were 100% occupied, and the Laser and Laboratory research building had 100% occupancy in 2022.

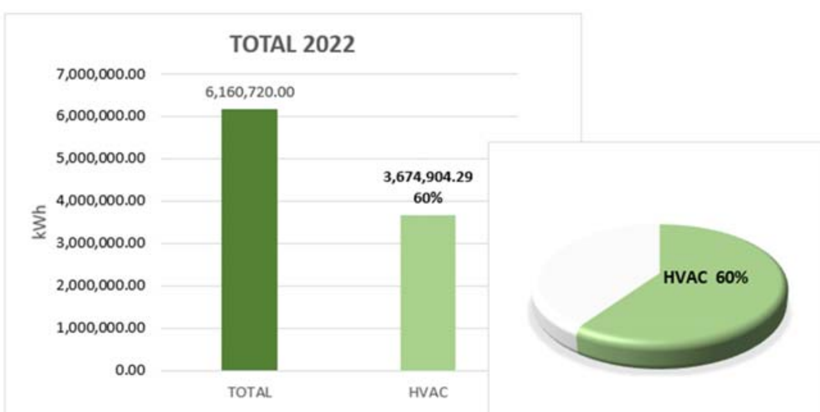

Figure 1 Energy consumption – ELI-NP Research Infrastructure 2022

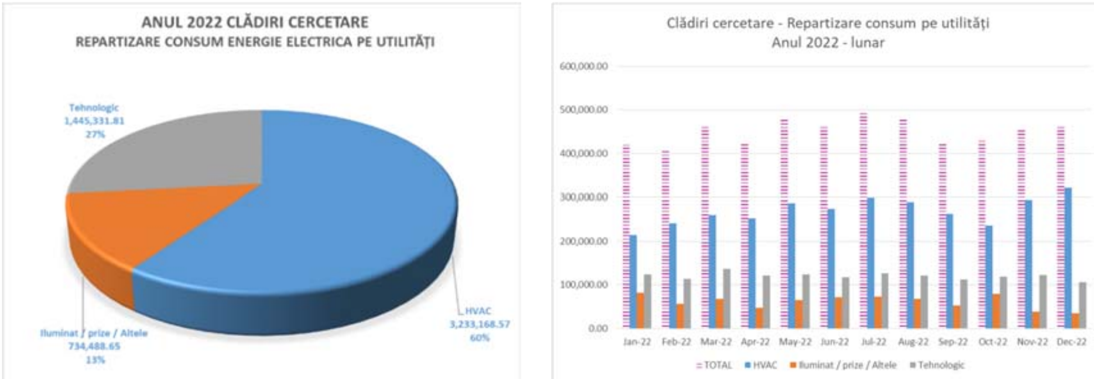

Figure 2 Research Buildings consumption 2022 out of total

Figure 3 shows values of the EUI indicator for the entire ELI-NP research infrastructure, respectively only for the research falls related to the years 2021 and 2022.

In 2021, at around 70% utilization, the EUI of the ELI-NP research infrastructure is less than half of the median EUI of 1,004 kWh/m2/year published on the ENERGY STAR platform, both for the entire infrastructure and for the research buildings. In 2022, the value of the EUI increased, along with the increase in electricity consumption, but without approaching the median value of EUI Energy Star. The conversion factor from site energy to source energy used for calculations is 2.5 according to SR EN ISO 52000-1.

EUI Energy STAR				EUI ELI - NP - Research Infrastructure						
kBTU/sf/an		kWh/m2/an		AN	Conversion factor	Total electrical energy consumption	kWh/m2/an		kBTU/sf/an	
SOURCE	SITE	SOURCE	SITE			kWh	SOURCE	SITE	SOURCE	SITE
318.20	115.30	1,003.79	363.72	2021	2.50	5,495,840.00	405.60	162.24	128.57	51.43
				2022	2.50	6,160,720.00	454.67	181.87	144.13	57.65

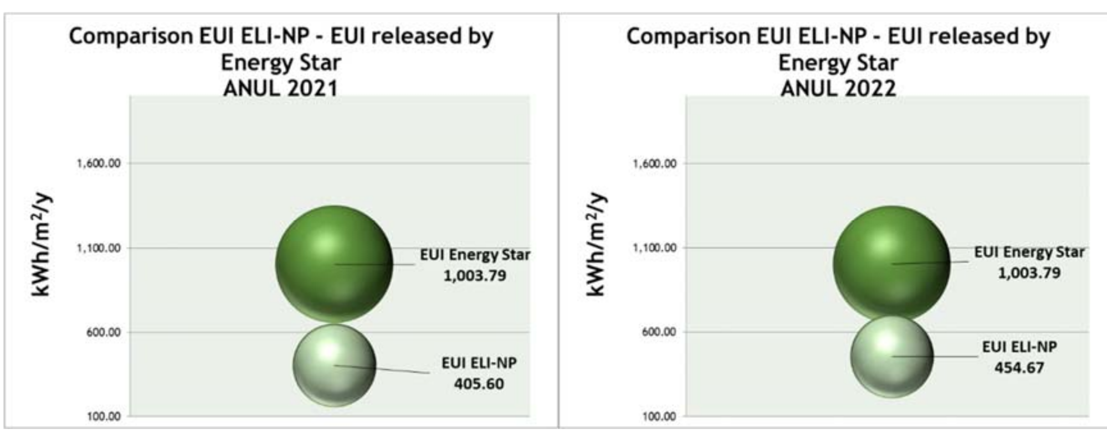

Figure 3 EUI ELI-NP Infrastructure – Comparison with the EUI published by Energy Star

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[2] *https://www.energystar.gov/buildings/benchmark Benchmark Your Building Using ENERGY STAR Portfolio Manager.*

[3] *https://portfoliomanager.energystar.gov/pm/glossary.*

[4] https://www.energystar.gov/buildings/benchmark/understand_metrics/what_eui, „ENERGY STAR a voluntary U.S. Environmental Protection Agency (EPA) program - What is Energy Use Intensity (EUI)?”.