

EDUCATION FOR THE FUTURE IN THE FIELD OF ENERGY SAVINGS AND ENERGY LITERACY

Tetjana Tomášková, Jan Krotký, & Jarmila Honzíková

*Department of Mathematics, Physics and Technology; Faculty of Education, University of West Bohemia
(Czech Republic)*

Abstract

Energy represents an inseparable part of modern life and technological progress. Given the growing demands for sustainability and efficient resource utilization, it is essential that every individual possesses basic knowledge about the proper handling of electrical energy. Inefficient use of electricity leads not only to unnecessary waste but also to economic and environmental losses. The authors of the article defined two main objectives: a research-application objective and a pedagogical objective. The research-application objective of this contribution is to quantify electricity consumption in a university laboratory both in overall terms and for individual specialized appliances and laboratory equipment. The output is a detailed overview of measured values, serving as a basis for analyzing energy demands and identifying potential savings. The pedagogical objective of the article is to develop students' energy literacy through practical understanding of electricity consumption in a laboratory environment, while also enhancing their technical skills in measurement, analysis, and critical evaluation of the energy demands of devices. Emphasis is placed on fostering a responsible approach to energy use, both in professional practice and everyday life, with the aim of seeking efficient and sustainable solutions. The introductory part of the article addresses fundamental aspects of energy, such as the typology of power plants, the development of energy consumption, and electricity pricing. This section provides context for the subsequent analysis of consumption in the laboratory setting. The following section focuses on the technical principles of selected specialized appliances and laboratory equipment. Their detailed description is essential for understanding the energy requirements of individual devices and for accurate interpretation of the measured data. The article also includes an overview of methods for measuring electricity consumption, including descriptions of instruments and procedures used to measure power input. This methodological section forms the foundation for the practical implementation of measurements. The practical part includes specific measurements of power input and consumption for selected devices. The result is an overview of individual appliances and laboratory instruments, supplemented by measured values that enable comparison and identification of energy-intensive components. The final section presents a proposed energy literacy test designed for students working in the laboratory as part of practical exercises. The test is conceived as a tool to raise awareness of the energy demands of specific devices and to support the development of competencies in the sustainable use of energy.

Keywords: *Energy savings, energy literacy, measurement of electricity consumption, handling of electrical energy, typology of power plants.*

1. Introduction

Energy has become a fundamental pillar of modern society, and its importance continues to grow in response to increasing consumption, digitalization, and sustainability demands. Knowledge of electrical energy generation, distribution, and consumption is therefore essential in both technical and non-technical education. In a globalized environment where energy stability and efficiency underpin economic and technological progress, the ability to use energy responsibly is becoming ever more critical.

Growing pressure to reduce energy intensity, minimize losses, and implement efficient solutions is evident across industrial sectors as well as within public institutions. Current studies indicate that the achievement of these goals is strongly influenced by the level of energy literacy and the quality of professional training, as insufficient knowledge and fragmented preparation can lead to unnecessary losses and reduced system performance (Clarke, Gleeson, & Winch, 2017; Brunelli et al., 2025; Piredda et al., 2025). Research also highlights the increasing importance of energy auditing as a strategic tool for

improving energy management, supporting efficient resource use, and reducing environmental impact. Properly implemented audits contribute to energy efficiency, promote the rational use of energy resources, and support sustainable economic and societal development (Tomášková et al., 2023).

At the same time, awareness of renewable energy and sustainable technologies among students in vocational and higher education remains limited, which complicates progress toward broader energy-transition goals (Kacan, 2015; Mukhtar et al., 2020; Drozich, 2023). Studies also indicate that innovation laboratories and educational platforms often struggle to provide applicable technical solutions due to insufficient cooperation between industry and academia (Ponce, Polasko, & Molina, 2019). Digitalization can further intensify energy demand in early phases but later supports greater integration of renewable sources where sufficient human capital exists (Wang et al., 2025).

Given these dynamics, educational institutions must support not only theoretical understanding but also the development of practical, experimentally verifiable skills. Laboratory environments enable students to analyze the energy behavior of devices using real measurements and encourage data-driven reasoning. Such hands-on experience fosters a long-term sustainable, informed, and responsible approach to energy use an essential competency for future professionals in the energy sector and related technical fields.

2. Energy context and fundamental aspects of power engineering

Energy systems form a complex infrastructure that enables electricity generation and use under varying technical and societal conditions. Understanding laboratory energy demand requires only a basic overview of key principles, including types of power plants, long-term consumption trends and the main factors shaping electricity prices. Different energy sources provide varying levels of stability and environmental impact, while the growing share of renewables increases the need for flexibility in the grid. Rising electricity consumption highlights the importance of efficient energy use not only in industry but also in educational laboratories, where demand differs according to equipment and operating modes. Electricity prices depend on technical, market and regulatory factors, and understanding these relationships helps students recognise the economic implications of energy use. Together, these elements provide an essential framework for assessing energy demand in the laboratory and for interpreting measured consumption values of individual devices.

3. Characteristics and operating principles of laboratory equipment

The set of six analysed devices (Table 1) combines traditional machining technologies with modern digitally controlled equipment, enabling a clear comparison of energy behaviour across different categories of laboratory machines. Conventional woodworking and metalworking tools such as the format circular saw, mitre saw and drill presses represent established manufacturing technologies with higher instantaneous power demand and load-dependent fluctuations, making them suitable for illustrating the energy characteristics of classic workshop equipment. In contrast, the CO₂ laser engraver and the Original Prusa i3 3D printer represent contemporary digital fabrication technologies with distinct operating principles and energy profiles. The CO₂ laser shows substantial auxiliary consumption due to cooling and extraction, whereas the 3D printer operates with low and stable long-term power typical of additive manufacturing. By including devices with diverse power ratings and operating modes, the study captures a representative spectrum of energy demands in educational laboratories. This diversity supports both the evaluation of high-consumption equipment and the identification of more energy-efficient technologies, contributing to the development of students' energy literacy and preparing the ground for the subsequent analysis of each device's technical and operational characteristics.

Table 1. Technical Parameters and Comparative Energy Demand of Traditional and Modern Laboratory Machines.

Machine	Type/Model	Power Consumption (W)	Motor Power (W)	Power Supply (V)
Format Circular Saw	Holzstar FKS 250-1300	2000	1500	400
Compound Mitre Saw	Metabo KGS 216 M	1500	1500	220 – 240
Column Drill Press	TYP S20A	750/1100	750/1100	380 – 400
Bench Drill Press	FERM FTB-13	350	350	230
CO₂ Laser Engraving	Class IV, CO ₂ 10.6 µm	700–1000	60 – 100	400
3D Printer	Original Prusa i3	100	40 - 150	230

The format circular saw is strongly affected by blade load, feed rate and idle-running duration, which may account for 5–25 % of its operating time. The mitre saw likewise exhibits notable inrush currents and power fluctuations caused by material hardness and cutting depth. The column drill press shows significant increases in consumption when drilling larger diameters or machining steel due to higher drilling resistance. In contrast, the compact bench drill press demonstrates low inrush currents and minimal mechanical losses, making it a low-energy-demand device. The CO₂ laser engraver exhibits substantial fixed losses from its high-voltage power supply as well as continuous consumption from cooling and extraction systems. Its idle time can reach 20–40 % in educational environments, which significantly reduces overall energy efficiency. The 3D printer displays a stable average consumption of around 100 W, with peaks mainly occurring during initial heating. Additional continuous power draw comes from stepper motors and cooling fans, though at a much smaller scale. These operational characteristics highlight substantial differences in how individual machines convert input energy into productive work. Collectively, they illustrate the need to consider both active and auxiliary consumption when assessing laboratory-scale energy performance.

4. Experimental measurement and analysis

This chapter presents the practical part of the study, focused on measuring and evaluating the electrical energy consumption of selected laboratory devices. The aim is to obtain real data on the energy behaviour of individual machines, compare their operational demand, and identify factors that may significantly influence the overall energy load of the laboratory environment. The collected values provide a foundation for proposing energy-efficient measures and for developing a student energy-literacy test.

4.1. Methodology of electrical energy measurement

The aim of the measurement methodology was to obtain comparable indicators of the operational energy consumption of selected devices under typical workshop or laboratory conditions. The measurement procedure was designed to be simple, safe, and easily repeatable within an educational environment. The measurement was carried out using a plug-in digital wattmeter, which enabled the recording of instantaneous power input (W), current (A), voltage (V), power factor, and cumulative energy consumption (Wh/kWh). A digital multimeter was used to verify the stability of the mains voltage and to perform control readings, while a simple timer ensured consistent timing and synchronisation of all measurement intervals. Each device was tested across defined operating regimes, including the start-up and heating phase, idle operation, operation under load, and the final shutdown or run-down period. This structured approach ensured that the measurements captured both stable and dynamic aspects of the devices' electrical behaviour.

4.2. Results and analysis of electrical energy measurement

The measured parameters include Δt (min) as the measurement duration, P (W) as the average power draw, P_{max} (W) as the peak observed power, and E (Wh) as the total energy consumed in the given operating mode (Table 2).

The measurements revealed significant differences in energy consumption between start-up, idle, and load operation. Saws and drill presses show short but intense start-up peaks, while idle operation represents a substantial share of non-productive energy use, especially for the panel saw and the S20A drill press. Under continuous load, woodworking machines maintain high and steady power draw, making overall consumption strongly dependent on cycle duration and workflow organization. The CO₂ laser shows considerable auxiliary demand from cooling and extraction systems, while the 3D printer demonstrates the lowest power consumption with minimal idle losses.

The analysis of the measured data made it possible not only to compare the technical characteristics of the individual devices, but also to identify operational patterns that are not apparent during routine use. The discussion of the results showed that the energy behaviour of the machines is influenced not only by their design and motor performance, but also by the working method, the frequency of start-ups and the organisation of operational tasks. The evaluation of the power-draw profiles confirmed that non-productive energy represents a significant share of the total consumption and constitutes a key area for operational optimisation. These findings have substantial educational value, as they enable students to work with authentic data, critically interpret measured quantities and understand the impact of technical and operational decisions on energy consumption. Moreover, engaging students in discussions about the results supports the development of energy literacy and leads to a deeper understanding of the principles of sustainable laboratory operation. Based on the results, several key areas for energy savings were identified:

- Idle time control (turning off saws and the S20A during breaks; work into continuous cycles);
- Tool and feed optimization (selecting suitable blades or drill bits reduces both cycle time);

- CO₂ laser auxiliary systems (activating extraction and cooling only during active processing; maintaining clean filters);
- Prioritizing low-power technologies (using 3D printing where appropriate instead of high-load subtractive machining);
- Didactic management (teaching students to operate machines in an energy-efficient manner).

Table 2. Results and Analysis of Electrical Energy Measurement.

Device	Mode	Δt (min)	P (W)	P max (W)	E (Wh)
Panel saw FKS 250-1300	Start	1	1600	2000	27
Panel saw FKS 250-1300	Idle	15	900	980	225
Panel saw FKS 250-1300	Load	60	1450	1800	1450
Mitre saw KGS 216 M	Start	1	1200	1500	20
Mitre saw KGS 216 M	Idle	15	250	300	62,5
Mitre saw KGS 216 M	Load	60	1200	1500	1200
Drill press S20A	Idle	15	300	380	75
Drill press S20A	Load	60	900	1100	900
Bench drill FERM FTB-13	Idle	15	120	160	30
Bench drill FERM FTB-13	Load	60	280	350	280
CO ₂ laser (Class IV)	Start	3	900	1100	45
CO ₂ laser (Class IV)	Engraving	60	750	900	750
CO ₂ laser (Class IV)	Cutting	60	950	1100	950
3D printer Prusa i3	Heating	10	180	240	30
3D printer Prusa i3	Printing	60	100	130	100
3D printer Prusa i3	Idle	30	70	90	35

4.3. Student energy literacy test

To evaluate the level of students' energy literacy, a short three-part test was designed. The test reflects the real power-consumption measurements carried out in the workshop and assesses not only conceptual understanding but also the students' ability to interpret real data and apply it in practical situations. The content directly relates to the measured consumption of devices such as the panel saw, mitre saw, drill presses, CO₂ laser, and 3D printer.

4.3.1. Structure of the test: Part A understanding basic concepts. This section verifies whether students understand the basic energy-related concepts used in the consumption measurements applied in the practical experiment. It focuses on their comprehension of quantities such as power P (W), energy E (Wh), and peak load P_{max} as well as their ability to distinguish between operational states such as idle mode, load mode, and machine efficiency. The main goal is for students to correctly differentiate between instantaneous power and total energy consumption, which is essential when interpreting real measurement data.

4.3.2. Structure of the test: Part B interpretation of graphs and measurement data. This section builds directly on the practical measurements of the machines' power consumption and assesses students' ability to interpret the recorded data. Students are required to compare the consumption profiles of saws, the CO₂ laser, and the 3D printer, identify which device exhibits the highest share of idle-mode consumption, and explain why the CO₂ laser shows significant energy use even without active cutting. They also evaluate why 3D printing is more energy-efficient during long-term operation and how the duration of the load mode influences total energy consumption. This part therefore tests their ability to read wattmeter data, compare the parameters P , P_{max} and E , and draw meaningful conclusions from the measured values.

4.3.3. Structure of the test: Part C practical application in the workshop. The tasks in this section build directly on the results of the practical measurements and assess whether students can apply the collected data in real workshop contexts. Working with specific examples from the measured operating modes, students propose strategies to reduce the energy consumption of the panel saw during class, such as limiting idle operation or organising work into continuous cycles. Furthermore, students justify why 3D

printing serves as a low-energy alternative for certain tasks and determine, based on the measurements, which device exhibited the highest idle consumption and how this can be addressed. This section therefore evaluates their ability to connect theory with practice, interpret measurement data, and propose energy-efficient operational strategies.

5. Conclusion

This study demonstrated that developing students' energy literacy is essential for their future professional and civic responsibilities. The practical measurements of energy consumption served primarily as a didactic tool that enabled students to understand how electrical energy behaves in real technological processes. Rather than being the main outcome of the research, the measured values acted as a means through which students learned to interpret data, think critically about it, and draw conclusions about the energy efficiency of different technologies. The pedagogical contribution of the study lies in giving students the opportunity to connect theoretical concepts with concrete situations in the workshop. They learned to distinguish between instantaneous power and total energy consumption, to recognise differences between idle operation and load conditions, and to reflect on how their own working procedures influence energy demand. The instructional approach also encouraged students to consider broader contexts—from responsible energy use to sustainable decision-making when selecting technologies and operational strategies. The proposed student energy-literacy test made it possible to evaluate not only their theoretical knowledge but especially their ability to apply what they learned in practice, identify sources of energy waste, and propose effective, rational, and sustainable solutions. This integration of experimental experience, data interpretation, and pedagogical guidance supports a deeper understanding of energy principles and helps shape responsible future technicians, educators, and users of technology.

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