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METROLOGY AND QUALITY IN RELATION TO THE GREEN ECONOMY

Boško Ivanović
ORAO A.D. Bijeljina, Republika Srpska
e-mail: bosivano@yahoo.com

Dražen Jovanović
European University Brčko District, Faculty of Technical Sciences, Brčko
e-mail: jdrazen13@gmail.com
https://orcid.org/0000-0002-1218-6231

Aleksandar Petrović
First School of Economics, Belgrade
e-mail: alpetrovic84@yahoo.com
https://orcid.org/0009-0007-9299-6130

Apstract: The definition of a green economy is that it is an economy that aims to reduce risks to the environment and ecological resources, as well as to achieve sustainable development without destroying (polluting) the environment. What is the role of metrology and quality in all of this? Metrology is the science of measurement and deals with measurement units and standards, gauges, and includes all theoretical and practical problems related to measurements, while quality refers to the level to which a product or service meets user requirements, standards (e.g., ISO 9001, ISO 14001), and legal regulations. Metrology and quality are under the influence of a number of other sciences and fields, while simultaneously acting upon them. How do metrology and quality "act" on the green economy? Through practical examples, we show where metrology (quality) can be applied in the green economy, such as in the fields of ecology, energy efficiency, renewable resources, and others.

Keywords: *metrology, quality, green economy, ecology, energy efficiency, recycling, consumer protection.*

INTRODUCTION

The importance of the science of measurement (metrology) as a practical technical activity is of primary significance both in everyday life and in all areas of the economy and science, including the green economy. Wherever we go, we come into contact with measurement. In shops, goods are purchased by piece, length, or weight; water, electricity, and thermal energy are measured, and the consequences are reflected in our personal finances. Measurements of blood samples and the effects of surgical lasers must be precise so that a patient's health is not endangered (Zaimović Uzunović N., Lemeš S., 2022).

Many activities rely on measurement: the weight of a letter, room temperature, tire pressure, etc. A pilot determines parameters such as altitude, direction, fuel consumption, and speed – essential for flight safety – through measuring instruments in the aircraft. Food quality controllers measure food quality based on bacterial content and fat content, which is crucial for human health. Metrology has become part of our everyday lives. Wherever we go, we encounter measurement.

The EU has 210 million natural gas consumers supplied through 1.4 million kilometers of pipelines, with an annual consumption of 500 billion cubic meters. Gas is an expensive commodity, and it is very important that consumers (as well as importers/exporters and tax authorities) can trust that the measurements carried out are fair, reliable, and immutable (METROLOGY – IN BRIEF).

The basic concept of quality assurance is the calibration of measuring instruments. A quality system requires that measuring instruments be calibrated against standards whose accuracy is greater than that of the equipment being calibrated.

Industrial production requires frequent measurements. Without measurement, quality control of products – as a condition for their sale – cannot be imagined, and in most modern industries, measurement costs account for 10–15% of total production costs (Zaimović Uzunović N., Lemeš S., 2022).

Experimental testing and thorough analysis of test results are essential conditions for the successful and rapid development of science. Experiments lead to new scientific discoveries. In every experiment, measurements play a very important role. Without measurement, experiments would have far less significance. Measurements are carried out in laboratories, production facilities, or on automated production lines. The core activity of laboratories is measurement, from which new scientific knowledge emerges across various fields (Zaimović Uzunović N., Lemeš S., 2022).

Industrial production requires frequent and diverse measurements. After the design of a new product, the characteristics of the prototype solution are tested. Monitoring the production process and determining scrap rates are carried out using measurements with dedicated conventional or specialized measuring equipment. Without measurement, product quality control – as a fundamental condition for sale and for meeting customer needs and expectations – cannot be imagined (Zaimović Uzunović N., Lemeš S., 2022).

The largest number of measurements are carried out for the purpose of selling various types of goods. Measurements during the packaging of different food products are performed on automated lines as part of packaging processes. The sale of energy products – water, electricity, gas – represents the most common activity of automatic measurement of physical quantities and constitutes one of the most important economic categories.

1. The Link Between Metrology (Quality) and the Green Economy

The green economy is a model of economic development that reduces environmental risks, uses resources efficiently, promotes renewable energy sources, and focuses on sustainability, the circular economy, and low carbon dioxide emissions. In the green economy, quality does not mean only a good product, but also environmental responsibility, energy efficiency, durability (thus generating less waste), recyclability, and compliance with sustainable standards (e.g., ISO 14001). With the help of metrology and quality, life cycle assessment (LCA) is performed – a methodology for assessing the environmental impact of a product (or process) throughout all phases of its existence, from raw material extraction, through production and distribution, to use and disposal.

Metrology (quality) plays a key role in supporting the green economy through accurate and reliable measurements and analyses that enable:

2. Monitoring greenhouse gas emissions

Accurate measurements of emissions such as CO_2, CH_4, and other gases enable the implementation of environmental regulations (Figure 1).

Figure 1. Testo 535 – Digital CO_2 Measuring Instrument
Source: www.testo.com

3.3. Energy Efficiency

Measurement of energy consumption in buildings, machines, and devices. Development of smart meters (smart metering, Figure 2) and systems for optimizing energy consumption.

Smart Watering is a remote irrigation system that enables the optimization of water consumption, savings in time and money, and increased yields in the cultivation of fruits and vegetables. The system allows monitoring of parameters such as water quality measurement, soil moisture, and dosing of fertilizers and other substrates, as well as programming irrigation by zones. It is the result of the work of young creative professionals whose goal is to improve agriculture in Serbia (*Green Economy and Green Entrepreneurship*).

Figure 2. METER&CONTROL Sx405
– Electricity Energy Meter (www.meterandcontrol.com)

4. Support for the Circular Economy

Measurement of waste quantities (municipal, industrial, hazardous, medical, construction, etc.), recycling volumes (paper, plastic, metal, glass, bio-waste, etc. – Figure 3), and raw material consumption (e.g., increasing production efficiency).

Example of waste management: BlueCity is an entrepreneurial hub created in the abandoned complex of the Tropicana tropical swimming pools in Rotterdam. Hub1 serves as a testing ground for innovations in the field of recycling and reuse. It brings together more than 25 entrepreneurs of diverse profiles, united by the desire to create, explore, collaborate, and a shared passion for circular entrepreneurship. In addition to a common vision, infrastructure, laboratory and IT equipment, the tenants also share raw materials. For example, waste generated by the Aloha café-restaurant during coffee preparation is used by RotterZwam as a substrate for mushroom production. The CO_2 released during this process is used by the company Spireaux for the cultivation of algae known as spirulina. Mycelium is used in the BlueCity Lab to produce packaging materials, while the mushrooms naturally end up on the menu of the Aloha restaurant (*Green Economy and Green Entrepreneurship*).

Validation of recycling processes (e.g., assessing whether recycled materials are of sufficient quality to be reused in production, including sensitive sectors such as food production).

Figure 3. Recycling process

a) Municipal waste sorting

b) Waste transport by municipal vehicle

c) Battery material production and recycling center in Schwarzheide, Germany

5. Air, Water, and Soil Quality

Metrology enables accurate measurement of pollutants in the environment (Figure 4), such as the detection and measurement of a wide range of indoor air pollutants, volatile organic compounds (VOCs), carbon dioxide (CO_2), carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2), as well as the measurement of particulate matter (PM1, PM2.5, PM10, TPM, etc.).

Figure 4. AdvancedSense® XM Professional HVAC indoor air quality and toxic gas meter/monitor

Source: (www.graywolfsensing.com)

Support for environmental monitoring and data-driven decision-making (e.g., monitoring air, water, and soil quality, electromagnetic radiation, vibrations, waste, and noise – Figure 5, etc.).

Figure 5. Digital Sound Level Meter TK269PLUS

Source: (www.tekcoplus.com)

5. Fair Trade and Regulations

The green economy implies new market mechanisms (e.g., emissions trading, where central authorities set limits on the amount of gas emissions allowed to be released into the environment), which depend on accurate measurements. An example of regulation by public authorities is the prescribing of noise levels (by law, limit values of noise indicators in indoor and outdoor environments are defined and regulated). The purpose of measurement is to determine the relevant noise level in the environment, and the ultimate goal is to compare the measured values with the maximum permitted values prescribed by the Regulation on noise indicators, limit values, methods for assessing noise indicators, annoyance, and harmful effects of noise in the environment (*Official Gazette of the Republic of Serbia*, No. 75/10), and to issue reports in accordance with the Rulebook on noise measurement methods and the content and scope of noise measurement reports (*Official Gazette of the Republic of Serbia*, No. 72/10).

Metrology ensures reliability in the certification of "green" products (energy and raw material consumption, greenhouse gas emissions, waste quantities and recyclability, use of chemicals, product lifespan, and energy efficiency).

CONCLUSION

Metrology and quality on one side, and the green economy on the other, although seemingly different fields, function as inseparable partners in modern society. Without metrology (quality), it would not be possible to monitor the effects of climate measures, control energy consumption, or develop systems for verifying environmentally friendly technologies. On the other hand, the green economy stimulates the development and application of new measurement technologies that contribute to a better understanding and protection of the environment.

In the future, the integration of metrology and quality into all aspects of the green transition will be crucial for a successful shift toward a sustainable society. Only through reliable measurements can we build policies that preserve the planet for future generations.

Metrology and quality form the foundation of the green economy. Without accurate and reliable measurements, we would not be able to know how much we pollute or how much energy we consume. Therefore, metrology (quality) not only supports the green economy – it is its key tool.

The green economy and metrology (quality) are not separate concepts, but interdependent ones. Quality without sustainability becomes outdated, while sustainability without quality becomes ineffective.

The development of green technologies, products, and processes requires high quality standards in order to meet market demands and ensure a future in which economic growth does not endanger the planet.

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