

Dunja Popović¹

Grammar School Kruševac/Serbia

Ana Vuković Vimić²

Faculty of Agriculture, University of Belgrade/Serbia

Dragiša Todorović³

College of Applied Studies of Technics and Technology, Kruševac (retired)/Serbia

Iris Borjanović Trusina⁴

Technical College of Applied Sciences in Zrenjanin/Serbia

CLIMATE CHANGE AND ENERGY EFFICIENT ENGINEERING IN EDUCATION

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Abstract:

In this paper, we present dynamics of the development of knowledge about climate change and energy efficiency, especially in engineering, as an answer to rising issues brought by climate change, in the way they have been treated in two published textbooks: "Climate change" for university education and "Energy efficiency" for higher education. Both textbooks are published by Academic Mind, Belgrade as pioneering higher education literature in the Serbian language in the relevant areas of expertise and we discuss their importance for third-level education in these fields in Serbia. We further outline the latest discoveries in the rapidly growing field of climate change.

Keyword: Education, Climate change, Energy efficiency, Textbooks

Introduction

Climate change and energy efficiency are developing interdisciplinary scientific fields. Direct evidence for the growing carbon dioxide amount in the atmosphere starts in 1958. when the recording of the Keeling curve began [1], anomalous behavior of the global temperature in the last two decades of the 20th century was first stated by Mann et al. in 2008 [2] and by the year 2016. NASA was able to present clear global warming trends in several climate indicators over the past decades [3]. Climate change was in the year of publishing of the "Climate Change" university textbook (2019) [4] studied in undergraduate studies, master and doctoral academic studies in the rising number of faculties in Serbia.

¹ dunja.popovic.autor@gmail.com

² pazisadana@gmail.com, ORCID: [0000-0003-2528-3169](https://orcid.org/0000-0003-2528-3169)

³ todorovic.dragisa@gmail.com

⁴ iris@ipb.ac.rs, ORCID: [0009-0001-5276-338X](https://orcid.org/0009-0001-5276-338X)

As an answer to the global warming challenge, the scientific community has come up, among others, with energy efficiency plans. [5] One of the main ideas behind energy efficiency is to increase useful energy obtained in devices, installations, and processes without changing the total energy input. This is possible when process organization and principles of work are improved. When combined with the use of renewable energy sources, energy efficiency can lead to a significant transformation of the energetic sector and all related sectors of human activity, diminishing the carbon footprint we leave on the environment. Energy efficiency was in the year of publishing of the "Energy Efficiency" high-school textbook (2024) [5] studied at many colleges of applied studies and some faculties in Serbia. One of the indicators of the growing importance of energy efficiency in our country in the past 6 years is the significant development of legal regulations in this field.

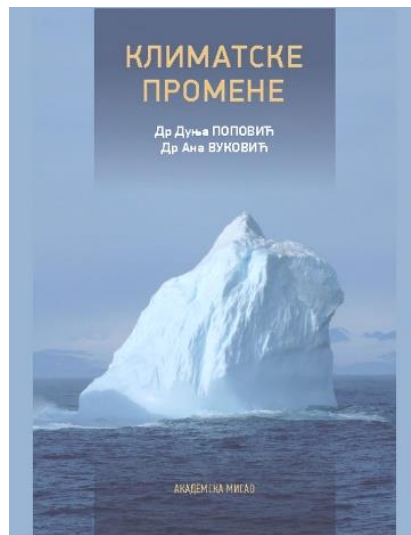
In 2019. our textbook "Climate Change" was the first university textbook and the first book written in Serbian language about this topic. In 2024. our textbook "Energy Efficiency" was the first college textbook written in Serbian language about this topic. In the following text, we present the contents of these two textbooks and discuss their importance for third-level studies in Serbia and their contribution to the developing ideas in these fields.

1. "Climate Change" textbook

The textbook "Climate Change" was published in 2019. by Academic Mind, Belgrade (ISBN 978-86-7466-770-5). Authors are Dr. Dunja Popović and Dr. Ana Vuković. The textbook has been reviewed by Dr. Borivoj Rajković, Dr. Mirjam Vujadinović Mandić, Dr. Duško Latas, Dr. Iris Borjanović and Dr. Lazo Manojlović. It is written in the Serbian language (Cyrillic) and contains 13 chapters.

In the first chapter "Climate" differences between climate and weather are explained and physical quantities that serve as climate indicators and means of their measurement are introduced. Climate is defined over the observed period of at least 30 years. In the second chapter "Exchange of energy and matter", the absorption and emission of energy is analyzed; water and carbon cycles existing in nature are outlined and the greenhouse effect is introduced. In this chapter, the reader learns how to determine the planet's temperature using black-body radiation laws. In the third chapter, "Atmospheric gases with

greenhouse effect” systematic treatment of carbon dioxide, methane, nitrogen-suboxide, ozone, water vapor, and aerosols is offered. The focus is on the change of their amounts in the atmosphere with time, and on their global temperature change potential. At the end of the chapter, the feedback loops of the climate system are analyzed and their role in the warming and cooling processes is explained. ”Natural climate change” is the fourth chapter, where all natural factors of climate variability are presented and their influence is analyzed in the paleoclimate data. This kind of order of presentation of different facts was meant to introduce us to the state of our planet relevant to climate and early knowledge about climate variability.



Picture 1. Cover of the “Climate change” textbook

In the fifth chapter “Hockey-stick controversy” the controversial conclusion published in the extensive study by Mann et al. (2008) that global temperatures in the past few decades have been anomalously high is discussed, especially related to concentrations of greenhouse gases carbon dioxide and methane in the atmosphere. In the following chapter “Anthropogenic factor” human activities are enumerated, which contribute to the greenhouse effect through the accumulation of greenhouse gases in the Earth’s atmosphere. All regional and global indicators of climate change are presented in the chapters “Indicators of climate change” and “Climate extremes”. These indicators for global

changes are primarily taken over from NASA's website. As for the climate extremes, proof is presented that their more frequent and more intense occurrences are directly caused by global warming. Through these chapters, we learn how climate change has become a valid international concept.

The ninth chapter "Climate modeling" is about the numerical approach to climate studying. Climate change causes many effects on nature and society, which are outlined in the tenth chapter "Impact of climate change on nature and society". The most important consequences appear in biodiversity, infectious diseases, food availability, and welfare. The eleventh chapter "Climate change engagement" deals with human efforts to cope with climate change on different levels. Organizations that deal with this issue are listed, the Climategate affair is covered and different international agreements are presented. The central part of this chapter is the presentation of the IPCC (Intergovernmental Panel on Climate Change) reports, with a special focus on the fifth report, which was the last published of the IPCC reports at the time of the publishing of the textbook.

The twelfth chapter "Climate Change in Serbia" covers observed data and future climate modeling for our country. It is the study conducted by Vuković et al [6], which shows data that confirms that world global warming trends also exist in temperature and precipitation changes in Serbia and predict even more radical changes until the year 2100. National measures to mitigate climate change are presented, especially the ones that we owe to the UN and EU. The last chapter, "How can an individual help?" dictates a list of personal actions that can be of help in this global battle.

The principle of exposition in this textbook is to follow the historical path of knowledge development about the climate on our planet and then zoom from global to local effects, finally focussing on our own country and ending with citizen actions that each of us can implement to help against global warming, following the motto "Think globally, act locally".

The bibliography used to write the textbook "Climate Change" contains 115 items. Most of the claims in this textbook are supported by publications from renowned scientific journals and in that sense this textbook presented an accurate picture of the state of knowledge at the time it was published.

2. "Energy Efficiency" textbook

The textbook "Energy Efficiency" was published in 2024. by Academic Mind, Belgrade (ISBN: 978-86-6200-005-7) and authored by Dr Dunja Popović and Dr Dragiša Todorović. Reviewers were Dr Jasmina Pekez, Dr Saša Dmitrović and Dr Iris Borjanović. It is written in the Serbian language (Cyrillic) and contains 14 chapters.



Picture 2. Cover of the "Energy efficiency" textbook.

In the first chapter "Energy efficiency" the indicators of population growth and energy reserves at the end of the 20th century are depicted and analyzed, the concept of energy efficiency is introduced and the basic terms related to it are explained. In the following chapter "Energy efficiency – physical meaning" energy, entropy, and exergy are defined, principles of thermodynamics are cited, and the energy efficiency of different processes is considered. The first part of the third chapter "Energy sources" is devoted to unrenewable energy sources with a focus on fossil fuels and the pricing of electric energy, while the second part is devoted to renewable energy sources, namely: sun, wind, water, green hydrogen, bioenergy, biomass and concepts of energy storage and sustainable energy development. For each renewable energy source, the energy efficiency of its exploitation is considered and it is concluded that most renewable energy sources we still don't know how to use efficiently.

It has been very early noticed that it is rather difficult to implement energy efficiency measured broadly if this idea is not properly supported by legal regulations. In the fourth chapter "Legal regulations about energy efficiency," the development of energy efficiency empowering laws is historically and geographically followed in Japan, the USA, China, the EU, different European countries, and Serbia, and international initiatives are described. In the fifth chapter "Energy efficiency labels" the different sorts of energy efficiency labels are introduced and special attention is devoted to energy efficiency labels in the EU and Serbia. Energy efficiency labeling of products is also a legal regulation kind of energy efficiency measure.

In the following eight chapters, the implementation of energy efficiency measures is analyzed in different sectors: buildings, heating systems, lighting systems, water consumption, traffic, industry, agriculture, and recycling. Buildings today can have an energy passport, which is an energy efficiency ID for that building, with significance for the real estate market. Energy efficiency in buildings covers the energy efficiency of walls, roofs, windows, doors, building materials. The newly invented procedure to obtain transparent wood is being presented, as well as the concept of passive houses, first developed in Germany. We further discuss the energy efficiency of all available heating systems in Serbia. Then we move over to the timeline of light sources and then to water consumption, prioritizing different physical means to measure water flow, as the principal indicator of water consumption. As an example of good practice, we present the water system in Kruševac. In traffic, we systematically treat known fuels, exhaust gases, and their purification via three-way-catalysis, electric cars, lithium-ion batteries, and MAGLEV technology. In industry, we speak about carbon dioxide emission allowances, electric plants, and cogeneration. When taking into consideration trends in agriculture, we present Biosense Institute from Novi Sad, Serbia, and their active projects about the implementation of IT tools in food production. Recycling can also be conducted in an energy-efficient way, where examples of good practice are Wiena and Ražanj.

The final, fourteenth chapter "Energy Efficiency, Internet of Things and Smart Cities" brings insights into the modern organization of urban life with the help of the Internet of Things and possibilities for energy efficiency measures in this kind of controlled environment. Energy efficiency measures are presented in more detail for the Serbian city of

Kruševac and the chapter is concluded with the list of individual energy efficiency actions recommended for our citizens by the Energetics Agency of the Republic of Serbia.

The bibliography used to write this textbook contains 124 titles. One large part of this bibliography are cited legal regulations in our country (about 32).

3. Importance of textbooks

Climate change is being studied at several faculties at the University of Belgrade in Serbia, as listed in Table 1.

Table 1: Presence of Climate change courses in higher education at the University of Belgrade

No.	Faculty	Level of studies	Course
1.	Faculty of Physics	Master academic studies of meteorology	Climate change
2.	Faculty of Physics	Undergraduate academic studies of meteorology	Climatology
3.	Faculty of Geographics	Undergraduate academic studies of geography	Climate change
4.	Faculty of Archeology	Undergraduate academic studies of archeology	Archeology of the living environment
5.	Faculty of Agriculture	Master academic studies of pomiculture, viticulture and vinification	Climate change and fruit adaptation
6.	Faculty of Forestry	Undergraduate academic studies of forestry	Climate change and forest ecosystems

Source: Data from references [7-12].

It has been noted in 2016. that the literature in the Serbian language is missing for these courses and the first edition of "Climate Change" was published as a college textbook, which was then upgraded and published as a university textbook in 2019. It is recommended course literature for undergraduate students at the Faculty of Geography, University of Belgrade, and master students at the Faculty of Agriculture, University of Belgrade. In fact, at the time of publishing, there was no Serbian literature about climate change except for some translations, which made this textbook interesting also for a wider audience.

Energy efficiency is a college course that both authors (D. P. and D. T.) have been teaching at the College of Applied Studies of Technics and Technology in Kruševac. It also exists as a module in Electrical Engineering and Computing master studies at the Faculty of Electrical Engineering, University of Belgrade. Our textbook is a college textbook. This textbook was also written in the absence of adequate course literature in the Serbian language at this level but can be interesting to the wider audience, especially due to the popularity of the topic in modern society.

4. Climate change – a rapidly developing field

The latest - sixth IPCC assessment reports have been published in 2021-2022. Working group I was in charge of Physical science basis. Working group II treated Impacts, Adaptation, and Vulnerability. Working group III treated Mitigation of climate change. A summary of the most important findings is given in the Synthesis Report published in 2023. [13] We outline here the most relevant findings from the Summary for Policymakers and present comparison with the statements from the previous report presented in the "Climate Change" textbook.

It has been established with high confidence that global temperature anomaly with respect to the 1850-1900 period has reached 1.1 °C in 2011-2020 and that this has been caused by human activities, primarily through the emission of greenhouse gases, which was in annual average values during 2010-2019 higher than in any previous decade. It has further been established with high confidence that climate change has caused deep changes in the atmosphere, ocean, cryosphere, and biosphere. The sea level rise occurred at the rate of 3.7 mm/year 2006-2018, compared to 1.9 mm/year 1971-2006 and 1.3 mm/year 1901-1971. The intensity of climate extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones has increased since the fifth assessment report. It is claimed with high confidence that about 3.5 billion people are highly vulnerable to this change and most of their communities have historically contributed the least to the current state. It is stated with high confidence that the consequences of global warming and intensified climate extremes have caused mass mortality events, local losses of species, reduced food and water security, ocean warming, and acidification, and increased occurrence of food-borne, water-borne, and vector-borne diseases. It is claimed with high

confidence that sectors exposed to climate change such as agriculture, forestry, fishery, energy, and tourism have suffered economic damages. It is also stated with high confidence that climate change also affects urban life.

As for future climate change, it is predicted with high confidence that if greenhouse gas emissions continue, the global temperature anomaly will reach 1.5 °C in the near term – 2021-2040. To obtain a considerable slowdown in global warming in this period it would be necessary to cut greenhouse gases emissions. If a very high greenhouse gases emission scenario takes place, we could be facing a global temperature increase of up to 4.4 °C by the year 2100. It turns out that many climate-related risks are higher than presented in the fifth assessment report. The likelihood of irreversible changes rises with the increase of global warming. Mitigation actions in industry and transport include the increase of energy and material efficiency, use of biofuels and low-emission hydrogen, as well as electric cars, while mitigation actions in urban areas require adequate design and planning of land use, settlements and infrastructure, efficient buildings, proper energy – especially electric, and materials use, which opens wide field for engineering solutions.

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