

INFORMATION MODELLING OF SUSTAINABLE BIOENERGY AND BIOFUEL PRODUCTION

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ABSTRACT

The European Union's Circular Economy project aims to protect the environment and reduce dependence on raw materials. The present study examines the state and the perspective of the sustainable production and use of bioenergy and biofuels as key factors in the realization of a circular economy. For this purpose, an information model is presented. The methodology for building such a model includes a definition of target, scope and users; a generalized scheme of an information system for maintenance of criteria and certificates for sustainability of bioenergy and biofuel production; consideration of software platforms and resources for implementation and publication of the information model. On the base of the generalized schema, a prototype information system is developed consisting of a user interface, functional scripts and a database of bioenergy and biofuel production in Bulgaria. The analysis of data shows the necessity of developing unified standards and classifiers to resolve inconsistencies between bioenergy/biofuel production datasets in all European Union countries.

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Key words: bioenergy and biofuel production, information modelling, information system, sustainable certificate.

INTRODUCTION

The sustainable production of bioenergy and biofuels is an important factor in achieving a circular economy. Bioenergy is renewable energy produced directly from biomass or from biofuels derived from biomass. Unlike other renewable energy sources (from the sun, wind, and water), which are inconstant and variable, bioenergy is predictable and easier to balance and integrate into the national electricity grid. The origin, namely biomass, is trees and wood waste, energy crops and residues, and organic waste from industry, agriculture, and households. Achieving nature-friendly production and consumption of bioenergy and biofuels depends on the formulation of a long-term strategy for sustainability, including investigation of bioresources, the market, necessary investments, possible risks, etc. The biofuels and the bioenergy contribute to sustainable development in nature, economy and society only if:

- the source (biomass) was harvested sustainably or from waste/residues;
- are efficiently converted into energy products (heat, electricity, transport fuels, etc.);
- replace fuels that are intensively emitting greenhouse gas (GHG).

In the European Union (EU), the share of renewable energy sources (RES) in energy consumption for 2020 is, on average, 21.2%, and in Bulgaria, it is 23.3% (Eurostat 22.12.2023). Almost 64% of this share is of the bioenergy (European Council 2023). By Directive (EU) 2018/2001 (2018), by 2030, at least 27% of the energy in the EU should be from RES. By 2050,

the EU is committed to reducing GHG emissions by 80–95% compared to 1990 levels to ensure competitiveness and decarbonization of the economy and to guarantee security of energy supplies. Therefore, the importance of RES energy production, including bioenergy, is increasing.

Since 2012, the Bulgarian Agency for Sustainable Energy Development¹ issues and maintained guarantees of renewable energy origin. Under the project "Regional policies for sustainable bioenergy" (BIO4ECO)², financed under the INTERREG³ Europe program of the EU, a National Action Plan for Energy from Forest Biomass (NPDEGB) 2018-2027 (Focus Systems Dan-Tea 2018) was developed and adopted. Generally, in accordance with Directive 2010/75/EU, a Sustainable Energy Development Strategy for the Republic of Bulgaria for 2030/2050⁴ has been developed.

Information models are composed to analyze and assess the sustainability of bioenergy and biofuels effectively.

INFORMATION MODELING ESSENCE

There is no one definition of information modelling, but in general, it is a set of activities for a description of the content and structure of metadata about the studied domain, determination of mathematical and statistical methods for data processing and analysis, argumentation of resources and technologies for building the respective software application. Information models are presented differently – informally (descriptively), with tables, diagrams, and specialized modelling languages, and in software engineering – with metadata or schemes of software applications (information systems (IS), scripts, ontologies etc.). The information model is independent of the practical software implementation but ensures a unified format of data collection and processing. For example, information modelling of sustainable production of bioenergy covers the description of bioenergy types and origin, production process, sustainability requirements and evidence, technologies for the respective IS building etc. Further, IS information model includes metadata about its database (DB) and functionality. DB information model is a description (metadata) of its architecture (tables, key values, graphs, attributes, relationships).

It can be said that each software application is based on a preliminary created information model. Accordingly, information modelling is the construction and operation of information models and is an essential part of the study, structuring, processing and analysis of data for them (Ivanova, Deliyska, Popova-Terziyska 2020).

RESEARCH, CERTIFICATES AND INFORMATION SYSTEMS IN THE FIELD OF SUSTAINABLE PRODUCTION OF BIOENERGY AND BIOFUELS

In the accepted global framework (Global Indicator Framework 2018) of sustainable development goals (SDG) does not explicitly mention biomass, biofuel and bioenergy, but they have the potential to influence all 17 goals, especially SDG 7, 3 and 13. There are linkages between the indicators of the SDG targets (Fritsche *et al.* 2018) and the bioenergy sustainability indicators (BSI), which are themselves considered a suitable normative framework for the sustainable bioeconomy (Fritsche *et al.* 2020). According to GBEP (2020), 24 BSI exist as

¹ <https://portal.seea.government.bg/>

² <https://projects2014-2020.interregeurope.eu/bio4eco/>

³ <https://interreg.eu/>

⁴ <https://3e-news.net/en/a/tags/39069/>

quantitative or qualitative minimum parameters for measuring the achievement of sustainability criteria. Concerning Directive (EU) 2018/2001 and Directive (EU) 2023/2413 known as RED II and RED III, sustainability criteria and indicators for bioenergy, biofuels and biomass are differentiated by environmental, economic and social aspects (European Parliament and Council 2018; European Parliament and Council 2023). The environmental ones cover air (including GHG emissions and other air pollutants), water, soil quality, land and forest use and biodiversity safety. Economic BSIs are concerned with energy use, balance, distribution and diversity, productivity, gross value added, and workforce training. Social BSIs are about land rights for new bioenergy production; support of a national food basket; income, jobs, and salaries in the bioenergy sector; protection of female and child labour; access to modern energy services, change in mortality, injuries, burden of disease attributable to indoor smoke and etc. Concrete indicator limits and values are clarified by national regulations.

Standard ISO 13065⁵ on bioenergy sustainability criteria published in 2015 and revised in 2021, specifies principles, criteria and indicators for the bioenergy supply chain to facilitate assessment of environmental, social and economic aspects of sustainability. The European certificates associated with it are:

- SBP⁶ – Sustainable Biomass Program.
- ISCC (International Sustainability Carbon Certification)⁷ – voluntary certification scheme for sustainable biofuels. ISCC EU covers the raw materials and fuels as stated in the RED II, ISCC PLUS (for plastics and chemicals, food and feed markets, as well as biofuels outside the European Union) and ISCC Corsia (for GHG emissions from air transportation) (DQS Holding 2024).
- GGL⁸ (Green Gold Label n.d.).
- 2BSvs⁹ – French biomass, biofuel, bioliquids sustainability voluntary scheme.
- ENplus¹⁰ – world-leading certification scheme on the quality of wood pellets for domestic boilers and stoves.
- INS¹¹ – Italian National Scheme for biofuels and bioliquid sustainability.
- FSC¹² – Forest Biomass Certificate.
- PEFC¹³ – Program for the Endorsement of Forest Certification etc.

These certificates are linked to the so-called voluntary scheme, an EU sustainability certification system designed to demonstrate compliance with biofuel sustainability criteria.

The sustainable technologies for the conversion of biomass into biofuels are widely represented in numerous studies and projects. The strategies of the IEA (International Energy Agency) for ETP (Energy Technology Perspectives) 2°C Scenario (2DS) and ETP Beyond 2°C Scenario (B2DS) are well-known. As a whole, they establish tolerable values of the GHG emission intensity during the collection and transport of biomass, the production of biofuels and the final consumption of bioenergy.

⁵ <https://www.iso.org/standard/52528.html>

⁶ <https://sbp-cert.org/>

⁷ <https://www.iscc-system.org/>

⁸ <https://greengoldlabel.com>

⁹ https://www.2bsvs.org/lg_en.html

¹⁰ <https://enplus-pellets.eu>

¹¹ <https://transcert.com.my/nis/>

¹² <https://bmcertification.com/fsc-forest-management-certification>

¹³ <https://pefc.org/discover-pefc/what-is-pefc>

On 15.01.2024, the European Commission (EC) confirmed the Union Database for Biofuels (UDB) based on the Clean Energy for all Europeans package and on Article 28 (2) and (4) of the Renewable Energy Directive (RED II) to improve the traceability of gaseous and liquid fuels in the transport sector with the objective to avoid double counting and mitigating the risks for irregularities/fraud. Economic operators in individual EU countries must register with the UDB and enter their data themselves. By EC, UDB must cover the entire supply chain from the first point of collection of the raw material to the final consumption, including information about the origin of the material.

Nachhaltige Biomasse System (Nabisy), the governmental sustainable biomass system web application, operates in the Federal Office for Agriculture and Food (Bundesanstalt für Landwirtschaft und Ernährung, BLE), Germany, serving to prove the sustainability of bioliquids and/or liquid or gaseous fuels from biomass, pursuant to EU Directive 2009/28/EC. Where liquid or gaseous fuels from biomass are concerned, Nabisy also serves to prove their double counting. Another free EC database is BIOMASS data set of ENSPRESO – about the energy potential of wind, sun and biomass (Ruiz 2019).

The goals of the present work are to:

- present a methodology for building an information model of IS for bioenergy and biofuel production;
- test the model with a prototype web-based IS including data of Bulgarian firms producing bioenergy and biofuels;
- analyze the results.

The rest of our work is organized as follows. The next section presents the methodology. In the third section, the prototype IS is described, and in the fourth section, the results of the obtained results, their publication, and their dissemination are discussed. The conclusion includes a summary of the achievements and directions for future research and elaboration in the area.

METHODOLOGY FOR BUILDING INFORMATION MODEL OF SUSTAINABLE BIOENERGY AND BIOFUEL PRODUCTION

The methodology covers the following steps:

- defining goals and range of the information model;
- defining users;
- compilation of generalized scheme of IS;
- formulation of requirements for the sustainability of bioenergy and biofuels;
- defining user preferences for DB queries;
- research and selection of resources and technologies for IS implementation.

DEFINING GOAL AND RANGE OF THE INFORMATION MODEL

The information model aims to investigate, suggest and systematize data, methods, algorithms and technologies for creating IS of bioenergy and biofuel production, accounting for the availability of the respective certificates and indices for sustainability. The model is independent of a specific business area, location or range.

DEFINING USERS

Users of this information model are firm managers, marketing specialists and organizations, investors, business analysts and institutions determining the sustainable

development of firms and industries in the area of bioenergy and biofuel production. Moreover, an administrator is provided for data support.

COMPILATION OF GENERALIZED SCHEME OF IS

Given the above goals, a common three-layered architecture of the information model of the respective web-based IS is developed (Figure 1).

The first layer (frontend) is the client interface for users and data administrators having different accessibility rights. The users submit queries and receive results while the administrator supports firm and system data, including their introduction, editing and deleting. The functionality layer comprises business logic – algorithms and software scripts implementing queries and exchanging data and messages between DB and the interface. The third layer (backend) is bioenergy and biofuel firm DB.

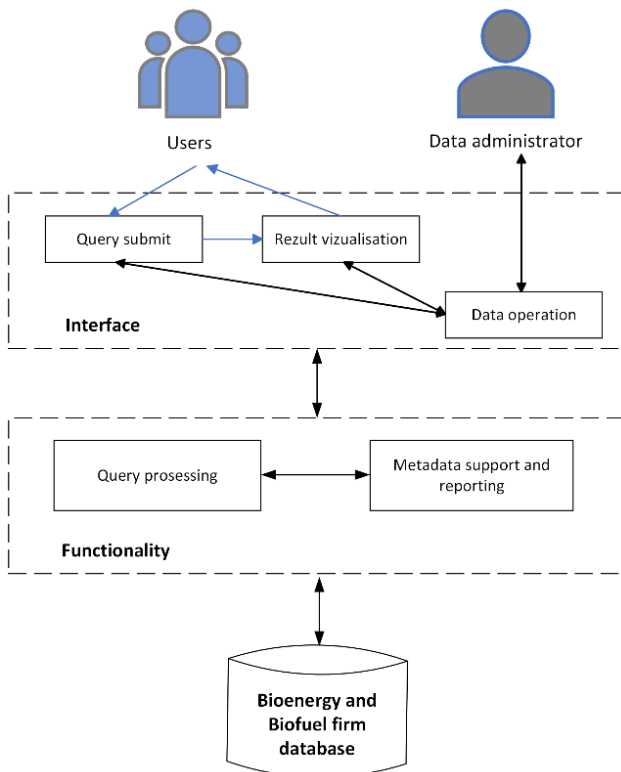


Figure 1: Common model of IS

Interface layer

The layer of the client interface is a set of main and linked dynamic web pages providing menus for users and administrator access to the IS functionality and database. The common principle is that the user access is free while the administrator has own account.

Layer of functionality

Given the user and administrator preferences, the functionality layer (or server layer) includes a set of scripts implementing DB queries.

Database layer

The backend layer is represented by the DB scheme (Figure 2). Main DB tables named Basic Firm Data и Year Firm Results contain basic bioenergy/biofuel firm data (firm ID, name, address, start year etc.) and data for year production and certification, respectively.

The remaining tables are samples of Bulgarian and European classifiers:

- BioProduct codes and Biomass codes – samples of combined European classifier CN of stock and products (European Parliament and Council 2023) and Bulgarian classifier CPID, harmonizes with CPA (Statistical classification of products by activity)¹⁴ classifier.
- Measure units for bioenergy, biofuel and biomass.
- Place codes – sample of Bulgarian classifier EKATTE of the settlements и their geographical coordinates.
- Economic activity (EA) codes – sample of Bulgarian classifier of economic activities KID-2008¹⁵, harmonized with NACE (Statistical Classification of Economic Activities in the European Community)¹⁶ and ISIC (International Standard Industrial Classification of All Economic Activities)¹⁷ classifiers.

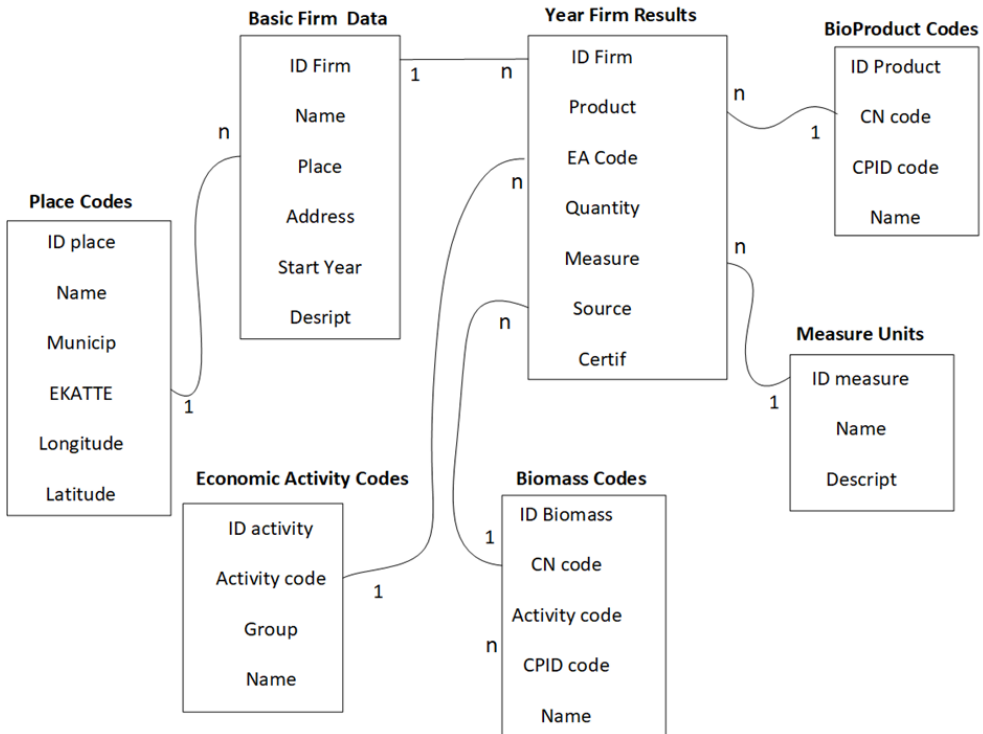


Figure 2: Database scheme

¹⁴ [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Statistical_classification_of_products_by_activity_\(CPA\)](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Statistical_classification_of_products_by_activity_(CPA))

¹⁵ https://www.mi.government.bg/files/useruploads/files/sme/_2008.pdf

¹⁶ <https://ec.europa.eu/eurostat/web/metadata/classifications>

¹⁷ <https://unstats.un.org/unsd/classifications/Econ/isic>

FORMULATION OF REQUIREMENTS FOR THE SUSTAINABILITY OF BIOENERGY AND BIOFUELS

Currently, in order to guarantee the sustainability and quality of bioenergy and biofuel production, the availability of EU certificates – ISCC (for sustainable biofuels), FSC (for sustainable biomass) and PEFC (for sustainable managed forest plantation), are enough.

DEFINING USER PREFERENCES FOR DB QUERIES

Users employ and browse DB by queries necessary for their own analyses. The following DB queries are considered:

- ranking firms by production capacity and produced quantities of bioenergy and biofuels;
- availability of sustainability and quality certificates;
- geographical allocation of firms;
- availability of closed cycle with waste assimilation;
- production types;
- biomass types, etc.

RESEARCH AND SELECTION OF RESOURCES AND TECHNOLOGIES FOR THE IMPLEMENTATION

For implementing the three-layered model, a set of modern technologies are selected that ensure high performance, reliability, and flexibility of IS with monolithic architecture. In more detail:

- The interface is created by Visual Studio Code with TypeScript (superset of JavaScript) language and libraries React (for interactive interface components) and its extension Material UI, Axios (for HTTP queries), and Chart.js (for graphical visualization).
- Functionality – by ORM (Object-Relational Mapping) tool Entity Framework Core (EF Core) and C#.
- DB – with Microsoft SQL Server (MSSQL), relational database management system (RDBMS) and Azure Data Studio for SQL queries.

PROTOTYPE IS

On the basis of the methodology, a prototype web-based IS for Bulgarian firms producing bioenergy and biofuels will be used. The main screen of IS is shown in Figure 3.

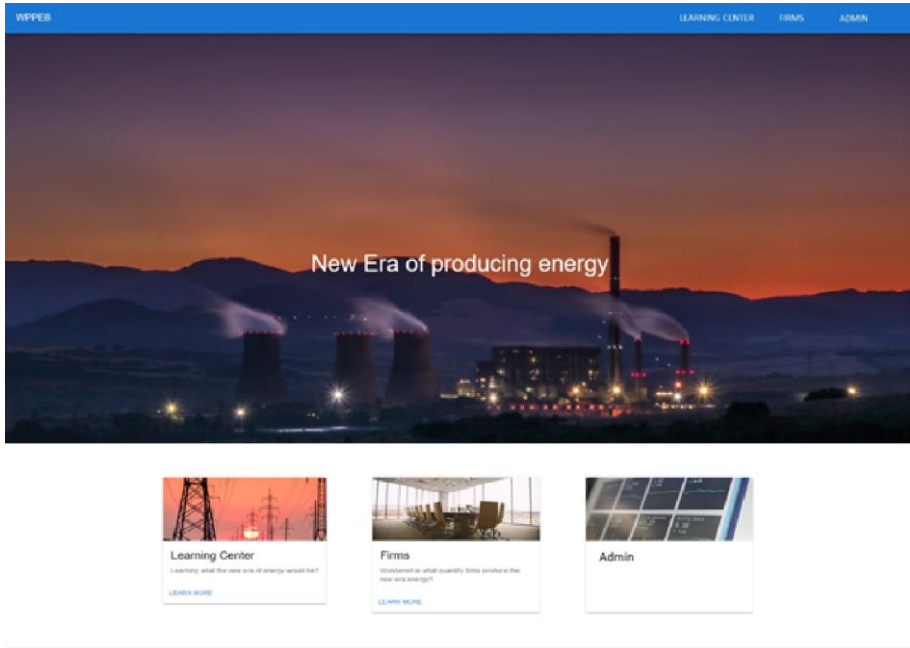


Figure 3: Home page of IS

It contains three sections for user actions – "Learning Center", "Firms", and "Admin". "Learning Center" provides resources and information about bioenergy and biofuel production technologies and methods. "Firms" includes DB queries, and "Admin" is for administrator activities. DB includes about 50 Bulgarian firms producing bioenergy and biofuels for 2022. For example, in Figure 4, a reference to bioenergy production capacity (electrical and thermal) of more than 1 MW for 2022 is shown. Obviously, only three firms have installed a capacity of more than 15 MW.

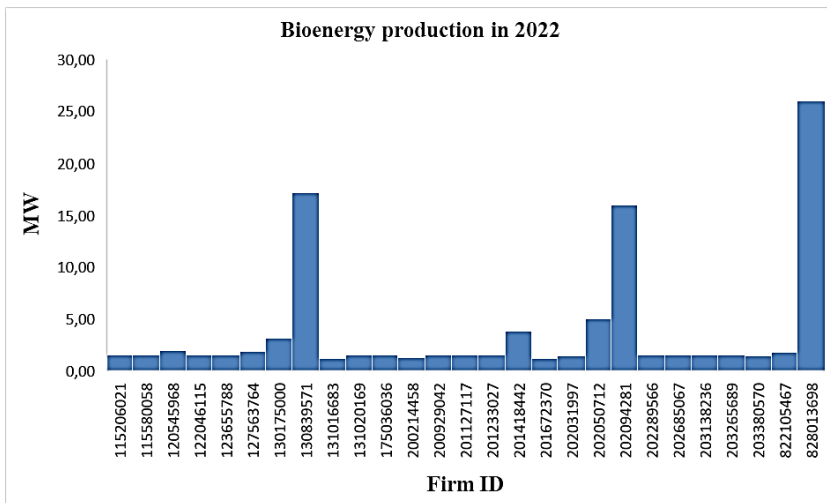


Figure 4: Bulgarian bioenergy production in 2022

PUBLICATION AND DISTRIBUTION OF THE PROTOTYPE IS

The codes of the prototype IS are free and available at GitHub address: <https://github.com/Nikolov0412/web-portal-energy-from-biomass/>. Its online publication is coming.

DISCUSSION

The proposed methodology suggests a universal approach to information modelling. On the basis of the information model created, a prototype IS is developed to study the sustainability of bioenergy/biofuel production in Bulgaria. There is a problem with harmonizing standards, certificates, and classifiers for data presentation between individual EU countries and different organizations in the sector. Measures should be taken to address the inconsistencies between the different data sets for biofuels and bioenergy, according to the Fuel Quality Directive (European Parliament and Council 2023).

CONCLUSION

The use of information modelling in the field of sustainable development of RES, and particularly in bioenergy, allows a complex multi-layered study and analysis of the efficiency and profitability of this sub-sector. The creation and study of an information model will expand the possibilities of providing accurate and timely information for the analysis and assessment of the current state, as well as trends in the development of specific activities of the sub-sector.

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