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Calculation and Optimization of Biomass Energy Production by the Dignet Energy Platform

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Abstract: This paper discussed the possibilities of using the developed Dignet Energy Platform (DEP) for modeling and optimization of bioenergy production. The DEP presents a set of software tools based on a mathematical model to calculate the desired output and the profitability of investments in a renewable energy source based on input parameters. By using Multi-Criteria Decision Analysis (MCDA), the DEP selects an optimal variant of energy or fuel production from biomass. This tool enables the simplification of complex and biomass energy production-related calculations while facilitating the customization of each individual element in the bioenergy production process. The user could use a simple procedure to "simulate" the production parameters and choose the best option from a set of biomass-based projects. Criteria describing the various projects were selected by the users and calculated by the DEP. These criteria helped select the appropriate optimal project by multi-criteria optimization. In this paper, several chains of biomass fuel/heat/electricity production applicable to the settings in the Republic of Croatia and the region were analyzed. Results in this research provided selection of optimal chains for the production of solid fuels and energy, including heat and combined heat and power (CHP) from different categories of biomass. The DEP is proved to be a practical and effective tool in selecting the optimal project of biomass energy production.

Keywords: Dignet Energy Platform (DEP); Modeling, Bioenergy production, Optimization

1 Introduction

The economic profitability of using energy from biomass and biofuels requires several factors that need to be analyzed, such as production costs (i.e. direct and indirect), technological progress, government policies, market dynamics, and environmental impacts. The prices of raw materials, the logistics of their supply, and human labor are the biggest direct costs for the production of biofuels. Indirect costs include environmental impacts. Return on investment and efficiency of resource use are decisive for the long-term sustainability of biomass projects. Achieving economic profitability and long-term sustainability is a key aspect to be met in projects that use biomass for energy and fuel production [1]. Taking into account the environmental challenges in the production of biofuels, the life cycle assessment (LCA) approach used during the production of biofuels is of great importance in the quality assessment of such types of projects [2, 3]. The production of fuels and energy from biomass includes supply, logistics, pre-processing, storage, and conversion of biomass into fuel or energy. Achieving sustainable energy production processes from biomass can be linked to the execution of optimized processes, as well as the development of more efficient technologies. The main trends and directions considered in connection with the modeling of biomass supply chains refer to methods such as Geographic Information System (GIS), Linear programming (LP), artificial neural networks, Multi-Criteria Decision-Making (MCDM) Methods, simulation methods, heuristic methods, fuzzy modeling, etc. [4]. Implementing a sustainable concept in biomass supply chains is a complex goal. It requires interaction among different disciplines, to focus on relevant aspects such as energy transformation, feedstock properties, assessment of energy transformation pathways, distribution and supply networks, as well as environmental, economic, and social analysis. Therefore, inter-disciplinary study becomes indispensable when it comes to assessing the quality of biomass-based projects. The development of platforms that enable interaction among different mathematical and methodological tools is a valuable and complex approach to obtaining, processing, and analyzing the many aspects that must be taken into account in bioenergy production [5]. MCDM uses mathematical modeling to evaluate optimal solutions. In supply chain management, it is used for sustainable supplier selection and evaluation of green suppliers. MCDM methods are characterized by a set of alternatives that are described with specific criteria for their evaluation and normalized weights that reflect their importance in decision making [6]. Such approaches are of great importance in the assessment and ranking of bioenergy projects. Supply chain optimization based on simulation of chains in reality enables a relatively accurate prediction of the impact on the biofuel supply chain through highly accurate models. Although this requires a significant effort in modeling and large computing resources for implementation, simulation-based optimization methods are expected to gain wider acceptance in the future [7].

As the most important part of bioenergy production is played by biomass fuel supply chains, fuel conversion technologies into heat or electricity must be taken into account. Cogeneration, or combined heat and power (CHP) systems, has great potential for the simultaneous production of electricity and heat in a single process [8]. In this process, waste heat can be used in parallel to produce another form of energy or product, for the production of steam, hot water or process heat [9]. This operating principle distinguishes CHP plants from other centralized power plants that are used only for the production of electricity. It also enables more efficient fuel use in terms of overall efficiency up to 90% [10]. Increased efficiency directly means less environmental pollution and reduced CO_2 emissions. This paper presented some of the possibilities of using the Dignet Energy Platform (DEP) for the modeling and optimization of both biomass fuel supply chains and biomass energy production chains (Heat plants and CHP plants). The details of the DEP and the methodology used in this study are provided below.

2 Dignet Energy Platform (DEP)

For the optimization of bioenergy production, the DEP is a platform which presents a set of software tools based on a mathematical model that calculates the desired output and the profitability of investing in this type of renewable energy in accordance with input parameters. The DEP is developed as an online system for calculating basic elements, energy efficiency, and investments needed for various production chains for renewable energy production. It is anticipated that the use of the platform does not require knowledge of any mathematical and calculative analyses. With a simple procedure, "simulate" is the best option for your desired biomass-based projects after selecting the available raw materials and ultimately the bioenergy production chain. This is how the DEP concept functions.

Biomass presents stored solar energy in the process of photosynthesis in the form of chemical compounds that form the structure of trees and plants, i.e., binding carbon dioxide (CO_2) to their structure. If the biomass is not used and stays in the woods or in the meadows, then it can decompose naturally, and in that way produce nutrients that are returned to the soil (hummus). Biomass, when used for energy, is considered "clean" or CO_2 neutral. By burning different types of organic origin biomass, no more CO_2 is released into the atmosphere than was consumed from the atmosphere during the relatively short life cycle of biomass growth. Biomass refers to a wide spectrum of different raw materials and can be distinguished into different categories:

- Forest residues from biomass, residues from primary and secondary wood processing;
- Agricultural residues, residues of animal origin, all organic waste;
- Energy cultures.

Different types of biomasses can produce different types of fuel, heat, and electricity as finished products, depending on the technology used. From this point of view, projects based on biomass have to be evaluated according to several parameters that will define their adequate sustainability.

This type of platform serves for the evaluation of different types of projects based on commercial technologies for the production of fuel, heat, and electric energy from biomass. The user of the platform can choose several desired production chains of fuel, heat and/or electricity from various biomass resources. Every one of those chains represents one type of projects. Quality assessment for the chosen projects based on biomass is possible according to multiple aspects described by defined criteria that are calculated for each desired type of project. These criteria refer to: energy efficiency f_1 (dimensionless value), total investment in the production chain f_2 (in EUR), fuel, heat and/or electricity production price f_3 (expressed in Euro (EUR)/ton or in EUR/kWh), CO_2 emissions in the chain of fuel production from biomass, heat and/or electricity f_4 (expressed in kg CO_2/ton or in kg CO_2/kWh) and the exergetic quality factor of the chain f_5 (dimensionless value). Exergetic factor f_5 refers to the quality of the form of energy that is obtained as a finished product from the production chain (in this context it means fuel, heat and/or electricity) [11–13].

It should be noted that the emission of CO_2 in projects based on biomass comes from the activation of all machines, mechanization, and energy plants that use fossil fuels. On the other hand, biomass as a fuel is CO_2 neutral and this is to be considered the main difference in this analysis. In order for a project based on biomass to gain a dimension of sustainability, it must be optimized and compared with several aspects described by the aforementioned criteria from f_1 to f_5. The choice of the optimal project is within the multicriteria space and this explains why in this process Multicriteria Optimization and Compromise Solution (the VIKOR method), one of the Multi-Criteria

Decision Analysis (MCDA) tools [14], is used to rank projects from optimal to lower-ranked variants. This way, by using the VIKOR method in this platform, it is possible to compare a maximum of 5 projects described previously with the aforementioned four or five criteria. In addition to the VIKOR method for the selection of the optimal project, the Entropy method [15] is also used as one of the objective methods for determination of the weight factors of the criteria used (f_1, f_2, f_3, f_4 and f_5). If only one category of energy form produced from biomass (i.e. only fuel, only heat or only electricity) is compared, then the number of criteria for mutual comparison of projects is reduced to four (f_1, f_2, f_3 and f_4) by the DEP. The exergetic factor in the previous case will not be taken into consideration. Exergetic factor considers the quality of the product gained from a specific production chain with the highest quality being assigned to electrical energy, a lower quality to heat, and the lowest to fuels. In any chain for producing fuel, heat and/or electricity, the user has the opportunity to choose among biomass characteristics, technologies used, capacities, modified transport distances, set fuel prices, technology prices, investment values, human labor participation prices, etc. Because of the great number of variables that are adaptable and require expert knowledge in this field, users are given the opportunity to choose pre-defined chains for the production of energy from biomass on which the analyzed projects are based. Apart from that, there are also different types of warnings that track the modification of the corresponding values through the creation of each individual project. A basic schematic representation of the running of the platform is illustrated in Figure 1:

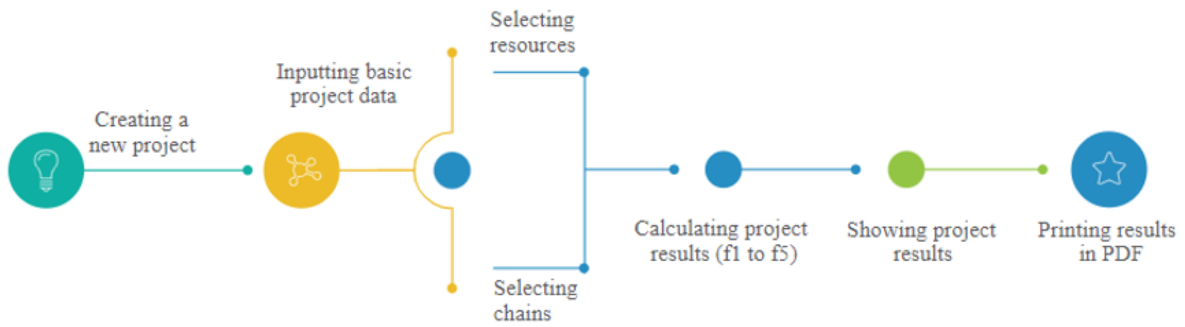

Figure 1. Schematic representation for the operation of the DEP

By using the VIKOR/Entropy method with the DEP, there are possibilities to compare up to 5 previously described projects with the mentioned four or five criteria. The projects are ranked from the optimal to the lower-ranked options, as in Figure 2.

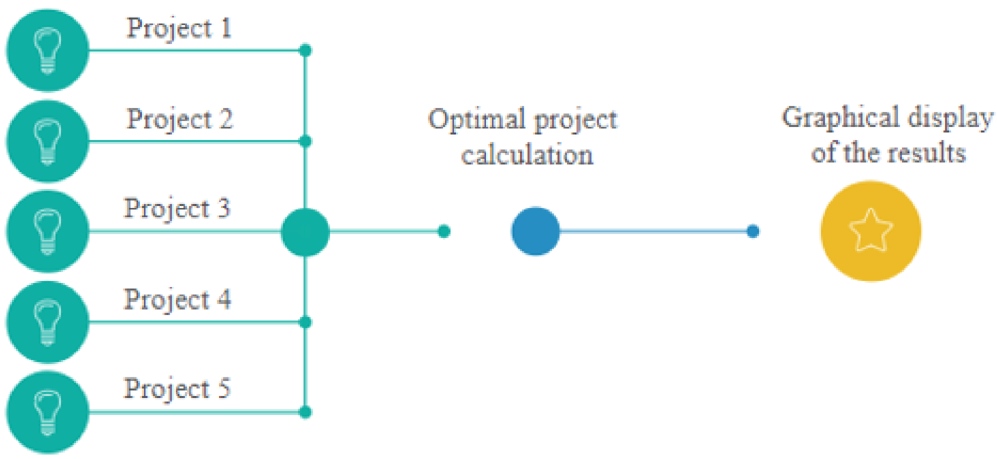

Figure 2. Optimal project selection by using the DEP

It should be noted that for every production chain, project is created from different elements that are specifically defined for every type of biomass or fuel. The user can change the characteristics of each individual element in the project (e.g., chainsaws, tractors, trucks, plants for the production of fuel, heat and/or electricity, etc.) given that it does not violate the logic of the functioning of the element, for which there are appropriate notifications. Apart from the budget values of criteria from f_1 to f_5, each individual element provides the user with more information in terms of the required number of elements for execution, resource information, consumption of human labor, fuel and more. The user can also create a new chain in his own terms but has to be careful with the choice and compositions of elements which he includes in it as there exists a corresponding warning. The chosen optimal chain variant in this platform is the first step the user can achieve towards completing his biomass-based project. The user gets a list of his preferred results in a PDF file for all biomass-based project cases he selected and created. The DEP is envisioned as a tool that enables complex calculations related to energy from biomass to be done much more easily, and at the same time allows each individual element that makes up the bioenergy supply chain to be changed as needed. The user is enabled to "simulate" the best option for his own set of desired biomass-based projects with a simple procedure.

3 Methodology

In this paper, the developed DEP [16] was used for the analysis of supply chains for solid fuels and energy from biomass. The paper presented a method of using the DEP, which integrates modeled chains related to fuel, heat, and CHP production. The biomass resources used in the platform are related to forest (wood biomass), agricultural biomass, and energy crops. The methodology integrated in the platform for defining a supply chain refers to the structured guidance for the user, based on the hierarchical level of the chain being defined. Practically, the basic unit of the DEP is a chain element such as chainsaw, tractor, boiler, and plant. A more complex unit on the DEP is a chain with an established logical structure between the elements, among which the user can choose as desired. It should be emphasized that the energy production chain should previously have a defined supply chain for specific fuel. The most complex unit on the platform is a complete project that includes one or more chains. Changing of chain elements is possible in the project, only if the user knows the logical structure of the chain used for energy or fuel production. This paper analyzed two categories of chains. Fuel supply chains include chips, pellets, and pressed bales. Energy supply chains include heating plants and CHP plants. All categories of chains were described with the following criteria: energy efficiency, total investment in the production chain, fuel, heat and/or electricity production price, CO_2 emissions in the chain of fuel production from biomass, heat and/or electricity, and the exergetic quality factor of the chain [11–13]. Defined conditions and prices for all chains are related to the Republic of Croatia and the region. Through the DEP, ranking and optimization of supply chains, or projects, was performed using the VIKOR method [14], while the Entropy method was used to determine weights [15]. In addition, the rank and order of optimal chains was independently confirmed by the Preference Selection Index (PSI) method [17].

4 Options for Selecting Biomass Resources on the DEP

The biomass resource represents a large spectrum of different raw materials and it is possible to distinguish the following most important categories of biomass:

- Forest residues from biomass and residues from primary and secondary wood processing;
- Agricultural residues, residues of animal origin, all organic waste; and
- Energy crops.

Depending on the aggregate state, fuels obtained from biomass processing can be divided into the following categories:

- Solid biofuels from biomass (shredded biomass, briquetted biomass, and pelletized biomass);
- Liquid biofuels from biomass (bioethanol, biodiesel, and pyrolytic oils); and
- Gaseous (biogas and synthetic gas).

Generally speaking, from the aspect of further energy conversions into thermal and electric energy, fuels from solid biomass are used the most. The most prominent representatives of solid biofuels are wood chips, pellets, briquettes, and powdered wood, which will be described in more detail below. Solid biofuels represent biomass fuels in a solid state at the moment of energy use. These biomass fuels, primarily wood, can replace a significant amount of applied fossil fuels in energy systems and thus contribute to the decrease in greenhouse gas emissions. The production of thermal and electric energy, as well as the profitability of these processes, will greatly depend on the composition of the energy chain for the production of solid biomass.

Based on different characteristics, the following can be distinguished: wood, straw, and other solid fuels [8]. Table 1 offers an overview of different biomass resources, categorized into three categories: wood biomass, energy crops, and agricultural biomass and residues. Four categories of fuels in a solid state can be obtained from the aforementioned types of biomasses: chips, powdered fuel (sawdust and wood dust), pellets, and pressed bales. Table 1 also provides a scheme of the possibility of converting wood biomass, energy crops, and agricultural biomass into wood chips, pellets, powdered fuel, and pressed bales, depending on the biomass resources (green colored cells in the table) incorporated in the DEP. The technology that will be used for its further conversion into usable heat and/or electricity will depend on the type of biomass resources i.e., its humidity.

The calorific value of any kinds of fuel is expressed through the upper and lower heating power. The thermal power of biomass depends on its chemical composition as well as the amount of moisture it contains. The most significant characteristic of biomass in relation to combustion and other thermochemical processes, is the moisture content, as its increase decreases the thermal power of biomass.

Table 1. Categorization of biomass resources and the possibility of their conversion into solid biofuels incorporated in the DEP [16]

Biomass Resources	Chips	Powdered Fuel	Pellets	Pressed Bales
Wood Biomass				
Forest waste (fir, beech, poplar, all trees)	1	0	1	0
Sawmill waste (gross waste)	1	1	1	0
Sawmill waste (sawdust)	0	1	1	0
Energy Cultures				
Fast-growing trees (poplar, willow, etc.)	1	1	1	0
Energy plants (miscanthus, reed, etc.)	1	0	0	0
Demolition waste (residue from the demolition of various types of buildings)	1	0	0	0
Agricultural Biomass				
Corn, corn stalk	1	0	1	1
Seeds and peels from fruit	1	0	0	0
Grain straw	0	1	1	1
Grass	0	1	1	1

The lower heat value of the wet biomass resource [9] can be calculated by Eq. (1):

$$ehv_w = \frac{ehv_0 \cdot (100 - w) - (2.44 \cdot w)}{100} \tag{1}$$

where, ehv_w is the lower heating value depending on the moisture content (MJ/kg); ehv_0 is the heating value of completely dry biomass (MJ/kg); 2.44 is the energy needed for the evaporation of water at a temperature of 25°C (MJ/kg); w is the moisture content in the total mass (%) [9].

Apart from the heating value, wood density, one of the most significant factors, helps identify different types of biomasses. Volumetric mass or density of biomass is defined as the relationship between the dry mass of biomass (kg) and the volume occupied by that mass (m^3). This value varies widely depending on the type of biomass. The heating value per unit volume of biomass [10] can be calculated, considering the following heating value and biomass density by Eq. (2):

$$ehvv_w = ehv_w \cdot \rho_w \tag{2}$$

For moisture content on a dry basis of biomass greater than 30%, the density of wet biomass is presented by Eq. (3):

$$\rho_w = \rho_0 \cdot \frac{\left(1 + \frac{u}{100}\right)}{\left(1 + \frac{\alpha_v}{100}\right)} = \rho_0 \cdot \frac{10^4}{(100 - w) \cdot (100 + \alpha_v)} \tag{3}$$

where, ehv_w is the heating value per volume unit (MJ/m^3); u is the moisture content on a dry basis (%); ρ_0 is the density of dry biomass (kg/m^3); ρ_w is the biomass density depending on the moisture content, w (kg/m^3); α_v is the swelling percentage (%) [10].

Basically, the correlation of biomass density and moisture content only influences the volume, which that amount of biomass is going to take up while unloading, transporting or dosing in the energy production system. It should be noted that the form of biomass and biofuel resources during their transport and handling is a highly important factor in the supply of biomass and biofuel resources. For this reason, the solid volume fraction (SVF) content filled with the biomass resources, was defined by Vasković et al. [11] and it is integrated in the DEP.

5 Protocol for Using the DEP

The following steps describe the use of the DEP on the examples of selected chains for optimization. Two categories of chains or projects were taken. The first category was chains for the production of fuel from biomass and the second category was chains for the production of heat and CHP from biomass. Examples of biomass fuel chains include wood chips production chain, mobile chipper on a tractor, production and transport of wood chips from sawmill, wood pellet production, miscanthus chips production, and straw bale production chain. Examples of biomass energy production chains are combined CHP-Organic Rankine cycle (ORC), CHP-Steam engine, CHP-Steam turbine, burner for bales (cigarette burner plant), and hot water boiler with a slanted grid (District Heating (DH)-District Heating Plant). In the chains for heat production and CHP, only two previous fuel supply chains are used, namely the wood chips production chain for all chains except the bale burner (cigarette burner plant) where the straw bale production chain is used.

5.1 Elements of the Value Chain on the DEP

The elements of the value chain are the basic elements on which input variables or parameters are defined and transformed through numerous calculations into output data that are then combined to form a single value chain. Elements can be, for example, chainsaw, tractor, truck crane, truck for transporting logs, sawmill, forklift, mobile chipper, truck for transporting wood chips, hot water boiler, grain harvester, etc. Figure 3 shows the list of elements built into the platform. In the dialogue box, all available parameters related to that element can be changed.

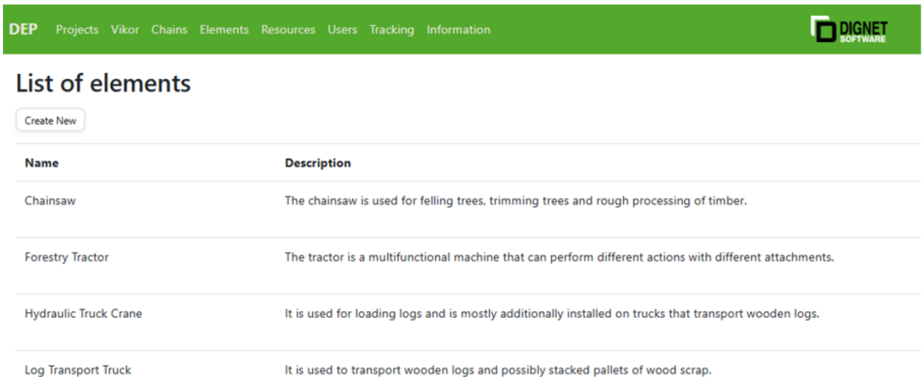

Figure 3. List of elements incorporated in the DEP

5.2 Value Chains on the DEP

As already mentioned, several elements can be combined to obtain one complete production value chain which is an independent whole and forms the technological basis of the project that the user is observing. Figure 4 below shows the list of created value chains in the DEP system. Each value chain is created in such a way that the initial amount of necessary raw materials is defined (minimum amount of raw materials required for the value chain), and the elements necessary for its running are included. By selecting the Projects link on the main menu, the user can view projects created in the system, create a new project, and modify or delete an existing project.

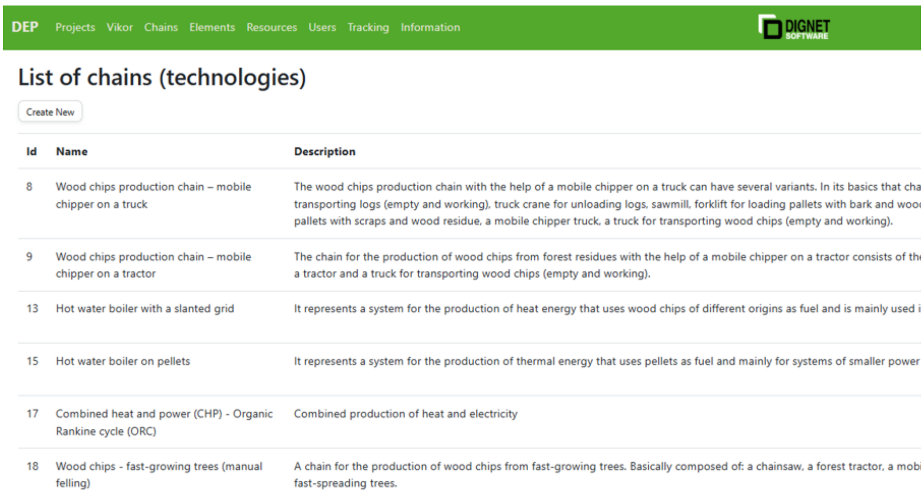

Figure 4. List of chains and their description in the DEP

5.3 Creating and Calculating Projects on the DEP

To create a project on the DEP, a chain for the production of wood chips was taken. This production was realized using a mobile chipper driven by tractor. Other fuel supply chains can be defined in a similar way. Figure 5 shows the user interface when defining the wood chips project in a simple manner. In the dialogue box, on the left side, there is general information about the project, i.e., name of the project, address, city, country, description of the project as well as prices of liquid fuels. The price of diesel and gasoline was taken from 1.5 EUR/l each. Conditions suitable for the Republic of Croatia have been set on the DEP. On the right side of the dialogue box, there is information about the resource, its quantity, and price. In the study case, the amount of forest biomass residue was 10,000 tons and its price was 30 EUR/ton for forest residue. This value ranged from 30 to 50 EUR per ton for the chains analyzed in this paper. Changes to the selection of resources and chains can be made with the update buttons. The definition and modification of the chains are shown in Figure 4 and Figure 5, respectively.

Figure 6 displays two special items that can be modified in tab update chain: selling price of output resource and component elements of the chain. Constituents of the chain in this case are: chainsaw, skidder, tractor driven by mobile chipper, and truck for wood chips transport. Parameters of the constituents are also changeable. The selling price of output resource is important for the assumed selling price of fuel, e.g., 80 EUR/ton for wood chips, particularly for the payback period of the project.

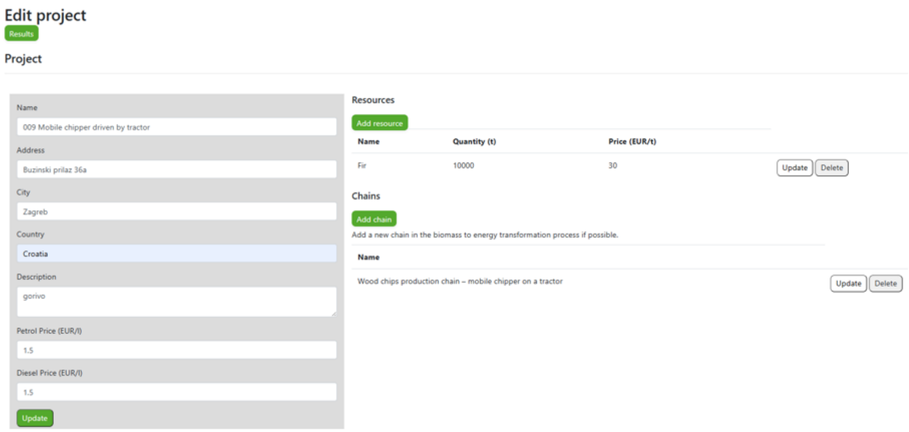

Figure 5. User interface for modifying wood chips projects on the DEP

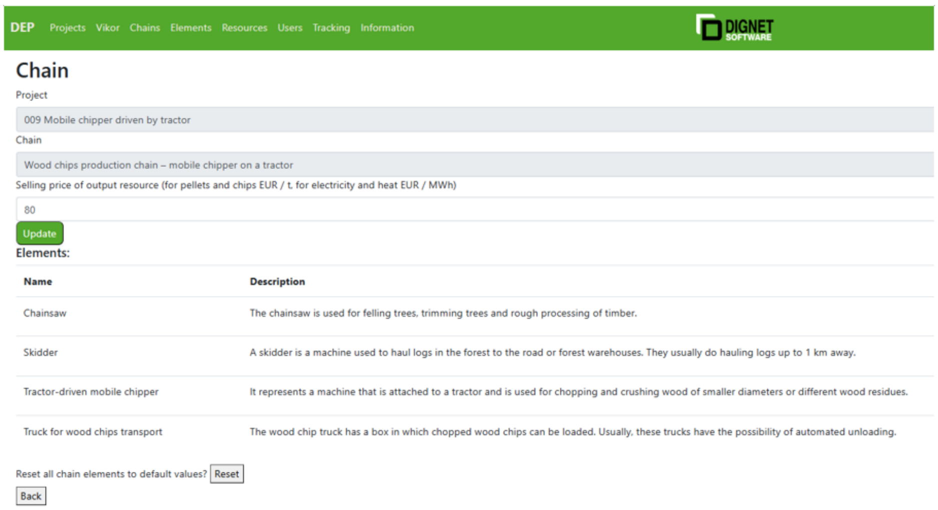

Figure 6. User interface for updating wood chips projects on the DEP

After completing all previously defined steps, it is possible to display the results of the project by clicking the Results button in Figure 5. The way of displaying the project results is shown in Figure 7. Results derived from project calculation can be exported to a PDF file.

Some of the following items related to the project are shown in the project results, including energy efficiency, total investment, total cost of human labour and fuel cost of produced biofuel, total CO_2 emissions for produced biofuel, selling price of output resource, estimated annual sale value of the produced quantity, estimated annual cost of production, estimated annual earnings, estimated return on investment in years. Table 2 provides an overview of the results of five observed biomass projects related to solid fuels: wood chips production chain-mobile chipper on a tractor, production and transport of wood chips from sawmill, wood pellet production, miscanthus chips production, straw bale production chain. All information about chain logistics and their constituent elements is contained in the platform. Table 3 offers an overview of the results of five observed biomass projects related to energy production: CHP-ORC, CHP-Steam engine, CHP-Steam turbine, burner for bales (cigarette burner plant), hot water boiler with a slanted grid (DH-District Heating Plant). The importance of the application of district heating systems as well as their logistics in the future have been emphasized [18].

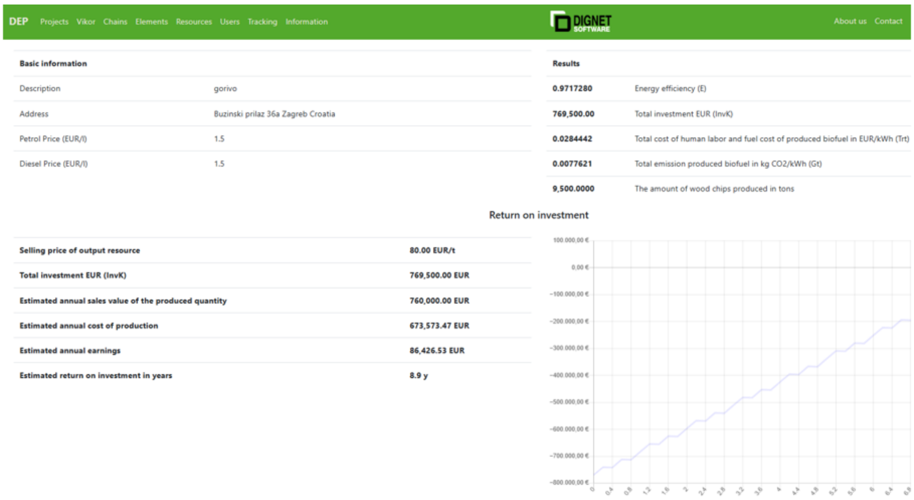

Figure 7. Results of a wood chips project on the DEP

Table 2. Overview of the results of five observed biomass projects related to solid fuel production calculated by the DEP

Parameters of the Projects	Wood Chips Production Chain-Mobile Chipper on a Tractor	Production and Transport of Wood Chips from Sawmill	Wood Pellet Production	Miscanthus Chips Production	Straw Bale Production Chain
Energy efficiency	0.971	0.986	0.691	0.982	0.939
Total investment in Euro (EUR)	769,500.00	700,000.00	1,645,000.00	200,000.00	660,000.00
Total cost of human labor and fuel cost of produced biofuel in EUR/kWh	0.0284442	0.0250892	0.0513398	0.0009424	0.0169833
Total emissions of produced biofuel in kg CO_2/kWh	0.0077621	0.0036913	0.0463511	0.0013561	0.0046540
Selling price of resource output in EUR/ton	80	80	280	100	80
Estimated return on investment in years	8.9	4.2	8.8	9.3	9.1

The data presented in Table 3 are the results of combining at least one fuel production chain and an energy production plant. The prices of produced heat and electricity in Table 3 are regulated by the exergetic factor and are thus given in the unit EUR/MWh for the combined MWh of heat and electricity. It should be emphasized that the system on the DEP for a given amount of biomass performs calculations for all machines and devices as well as energy production plants according to the typically set capacities in the platform. At the same time, the calculation logic itself is integrated within the framework of the platform. In order to form an energy production chain such as a CHP plant, it is necessary to add the resource, its quantity, its price, as well as the logical supply chain of possible fuel from that resource. The user is navigated logically through the platform and drop-down menus exhibited in

Figure 8. Changes in the constituents of the chain are possible and can be adapted to the needs of the user.

Table 3. Overview of the results of five observed biomass projects related to energy production calculated by the DEP

Parameters of the Projects	**Combined Heat and Power (CHP)-Organic Rankine Cycle (ORC)**	**CHP-Steam Engine**	**CHP-Steam Turbine**	**Burner for Bales (Cigarette Burner Plant)**	**Hot Water Boiler with a Slanted Grid (District Heating (DH)-District Heating Plant)**
Energy efficiency	0.789	0.868	0.868	0.798	0.813
Total investment in Euro (EUR)	4,632,649.17	3,273,288.19	3.482.451,92	3,520,576.92	8,345,922.08
Total cost of human labor and fuel cost of produced biofuel in EUR/kWh	0.1051962	0.09908	0,089376295	0.1182496	0.0621092
Total emissions of produced biofuel in kg CO_2/kWh	0.0046141	0.0041946	0.004194613	0.0054753	0.0076218
Exergy factor	0.348	0.331	0.377	0.221	0.313
Selling price of resource output in EUR/MWh	140	125	115	130	105
Estimated return on investment in years	13.8	12.6	10	14.8	14.1

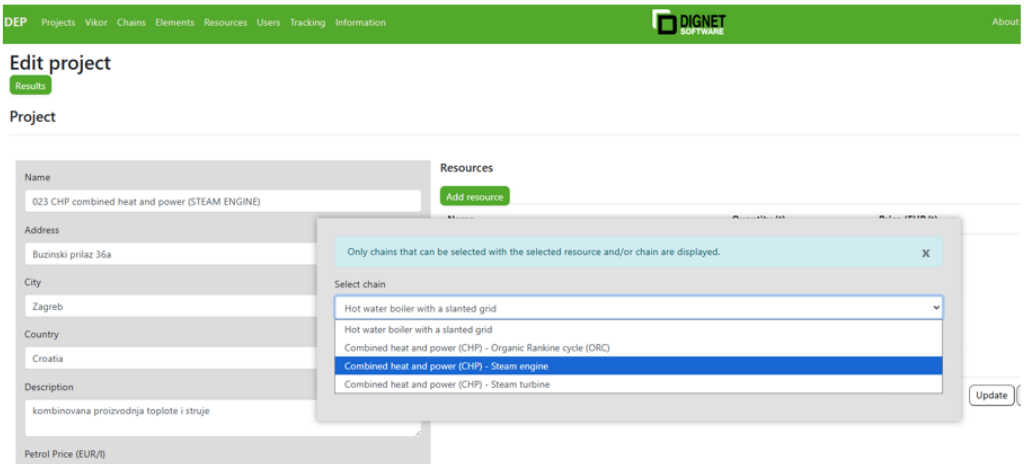

Figure 8. Drop-down menu in the DEP

6 Results from Calculating the Optimal Project by the DEP

Basically, the steps for choosing the optimal project by using the DEP are simple. In the current study, two categories of observed projects were created on the platform. The first category was chains for the production of fuel from biomass and the second category was chains for the production of heat and CHP (combined heat and power) of biomass. A total of five chains from both categories were analyzed in this paper. By selecting created projects and the calculation button, the results of the optimal project were obtained as in Figure 9. All calculations for choosing the optimal project were done by the VIKOR and the Entropy methods.

The optimal fuel supply chain was selected for the miscanthus chips production chain. CHP-Steam turbine was the optimal energy production chain. For the obtained optimal solutions in both categories, checks showed stability and acceptability according to the VIKOR method. The results proposed by the DEP have been verified and proven by the Preference Selection Index (PSI) method [17], also belonged to the objective MCDM methods. Considering the techniques for determining weights, it should be emphasized that the PSI has its own method for determining weights integrated within the method itself. In this way, the PSI method is simpler in application compared to the VIKOR-Entropy optimization method. The entropy method for determining weights has to confront a problem of indeterminacy, when some of the criteria are equal to zero in the initial optimization matrix [19]. On the other hand, in the specific case analyzed in this paper, the PSI method provided more uniform weight values. Of course, this does not reduce the accuracy of the DEP, but it also opens up some new perspectives towards expanding the possibilities of further research in the field of optimizing energy supply chains and fuels from biomass and renewable energy sources in general. Planning the required quantities of fuel for heating systems depends on the outdoor temperatures and the number of cold days. In this regard, the correction of outdoor design for certain climate zones [20] and the application of Artificial Intelligence (AI) models pose a challenge to the integration of such a platform and similar tools into a usable unit.

Since the authors of this paper participated in the development of the DEP, all calculations obtained by the platform were confirmed by independent manual calculations in MS Excel.

Figure 9. Calculation and presentation of the results related to the optimal project by the DEP

7 Conclusions

In this paper, through examples of biomass fuel supply chains and technologies for CHP and heat production, the optimal ranking of chains in both categories was achieved. Biomass fuel supply chains as well as technologies for CHP generation and heat production were taken as examples of chains. Through comparison and calculation, the optimal fuel supply chain was the production of miscanthus chips. The optimal technology and chain for biomass energy production were selected as variants of CHP-steam turbine. All comparison and ranking analyses were performed with the VIKOR-Entropy method, which was integrated into the DEP. The process of modeling chains for the production of energy and solid fuels from biomass was not visible, but it was integrated into the background of the platform to represent a basic aspect of all previous calculations before selecting optimal solutions.

The results of selecting the optimal variant of both the fuel supply chain and the biomass energy supply chain were confirmed independently by the objective PSI method. The numerical data analyzed in this paper and the characteristic values obtained in the calculation by the DEP represent a good guideline for recommendations when it comes to biomass-based projects in terms of fuel and energy production in general.

Further research into the optimization of energy and fuel production from biomass could relate to some new biomass categories such as grass pellets, straw pellets, etc. Platforms such as the DEP and the like should integrate such utilization options. In addition, significant focus should be directed towards the production of biogas and liquid fuels from various resources, taking into account the logistics of raw material supply as well as CHP technologies. In addition, the application of AI and GIS tools would represent a great step forward in terms of prediction of the global aspect of biomass application, especially in respect of the practicality of the DEP.

Biomass certainly has a promising use, but only in the case of good planning and logistics. One of the options is precisely the application of such solutions and research closely related to the locality of biomass application.

Author Contributions

Conceptualization, S.V. and P.G.; Methodology, S.V. and P.G.; Software, N.M. and I.M.; Validation, S.V. and I.M.; Formal analysis, N.M.; Data curation, N.M.; Writing-original draft preparation, S.V. and P.G.; Writing-review and editing, S.V.and P.G.; Visualization, I.M. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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Conflicts of Interest

The authors declare no conflicts of interest.

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