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ONE SOLUTION FOR VINEYARDS IN ACTUAL ENERGY CRISIS

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Abstract: *In vineyard residual biomass is obtained that can be used locally to produce electricity, heat and biochar, when and as much as necessary, so necessary in this state of actual energy crisis. In RO 2021, 160000 ha were cultivated with vines and a minimum of 0.274 Tg.br.db dry vine ropes with an energy potential of 1.45 TWh/year would be collected. In farms from vine prunings, chopped and dried, with CHP equipment is produced electricity for own use with an efficiency of 19% and a thermal energy with efficiency of 52%. With CHAB systems heat and biocar is produced, biocar is used as an agricultural amendment or is gasified to produce gas.bc that can locally replace natural gas, or electricity production with a CHP. The vineyard activity is seasonal, the collection and storage of biomass for energy use is an investment and lock-up of capital, recoverable through lower costs and the supply of energy* ***when and as much as needed****. Ecological variants with energy and economic efficiency are analyzed. Chopped and dried vine prunings as well as biochar represent an energy stock that can be used when and as much as needed in wine growing units to ensure safe and economical operation.*

Keywords: *Vine prunings, power, heat, biochar, carbon footprint*

1. Introduction

In the current energy crisis, the utilization of local resources is essential to ensure operation **when and as much as necessary.**

One problem with systems that harness the solar and wind resource is that they cannot deliver energy immediately and as needed, that is, they are not dispatcable.

In Romania, in august 2022 there were 23,400 prosumers with a power of 200 MWe produced by photovoltaics and wind with a share of biomass below 2%. Energy is produced during the day and when there is wind, which loads the distribution network heavily because it is above the actual consumption, which has imposed restrictions.

A storable energy source is residual vegetable biomass from which, when and as much as needed, thermal energy, electricity and biochar are produced locally that can be used as an energy stock or as an agricultural amendment that sequesters carbon for long periods of time.

Romania has an annual reserve of residual vegetal agricultural biomass of at least 20 Tg.br/y to which viticulture contributes with 3% quality residual woody biomass.

From biomass local energy is produced by direct burning, pyrolysis or gasification **when and as needed.** Cogeneration is the most energy-efficient and economical option to produce electric and thermal energy.

For farms and small communities, the intelligent energetic network type **Smart Grid** concept represents the trend of decentralizing power supply from various sources of energy through the organization of energy network. The Smart Grid system identifies the status and charging of all network elements, it can provide basic loading and can prevent real-time overhead from managing network-connected power sources.

Locally, the most complete utilization of the residual biomass from vineyard represents a major contribution to sustainable development that also involves increasing the level of energy independence of farms, which is desirable that correlates with the current ecological requirements of reducing CO2 emissions and economic sequestration of atmospheric carbon in agricultural soils.

2. Materials and methods

The chemical composition and heat of combustion of cut vine ropes is relatively uniform regardless of the vine variety grown. [1, 2, 4]
Table 1 shows the estimate potential of residual biomass from viticulture for Romania in 2021.

Table 1: Rezidual mass vine prunings in RO 2021

Feature	U.M.	Value
Cultivated area in RO 2021	Mha/an	**0.1656**
Vine prunings dry	Mg.br/ha	**1.828**
Collection rate	%	**90**
Usable collected dry vine prunings	Mg.br/ha	**1.645**
Annual dry vine prunings mass collected	Tg.br.db/an	**0.272**
Vine prunings average HHV	TWh/Tg.br.db	**5.320**
Energy potential at mass annual collected	TWh/an	**1.449**
Energy consumption for biomass chopping	MWh/MWh.br	**0.030**
Annual energy consumption for chopped mass	TWh/y	**0.008**
Annual usable energy from chopped mass	TWh/y	**1.441**

It is found that at 90% annual collection rate, **272 Gg.br/**y biomass would be obtained with an energy potential of **1.45 TWh/y**. Collection, transport, chopping and storage consume energy and produce CO_2 emissions. Energy consumption was found to be no more than 0.8–1% of string energy, for drying with waste heat and chopping with electricity produced from biomass.
For the production of energy from biomass, excluding direct combustion with a lot of PM2.5 and positive CFP, thermo-chemical conversion processes such as autothermal pyrolysis and gasification are currently used, which produce fuel gas, called gas.bm, as well as vegetable charcoal sterile and porous called biochar (BCH).
The current concept used called CHAB - Combined Heat and Biochar production - ensures a very good utilization of a large variety of plant biomass. [6, 7]. They are systems with batch operation to produce water or hot air, or hot gases for technological processes, **when and as much as needed**, reducing the need for heat storage. They are usable with powers from 20 to 200 kWth.
The installations named SEB.HW, systems for hot water and biochar production, gasify biomass and produce thermal energy with an efficiency of 45-50%, as well as high quality biochar with molar ratios O/C <0.2 and H/C < 0.4 with very few volatiles. [6, 7, 9]. In [8] are presented the performance of a SEB.HW.100 system for vine prunings.
For the production of electricity, the vine prunings (BVR) is gasified in the CHP with an energy efficiency of 20% and a thermal efficiency of 60%. [10, 13].
In [8, 13] are presented the performance of a CHP type HK45 Spanner that produces electricity with an energy efficiency of 19% and thermal energy with an efficiency of 52%.
Figure 1 shows the block diagram of a SEB.HW system and Figure 2 shows the block diagram of a CHP with vegetable biomass. [7, 8].
The biochar produced by SEB.HW can be used for energy production through gasification with a positive CFP, or as an agricultural amendment or filter material with a negative CFP. Typical is an electrical energy efficiency of 30% and thermal efficiency of 56%. Figure 3 shows the block diagram of the ways of using the biochar produced by systems with the CHAB concept, the production of gas.bc, electricity, heat or agricultural amendment and as filter material.

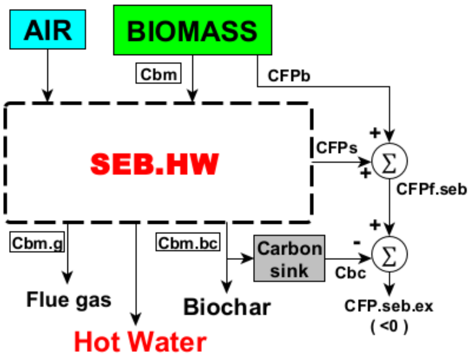

Fig. 1. Block diagram for a SEB.HW

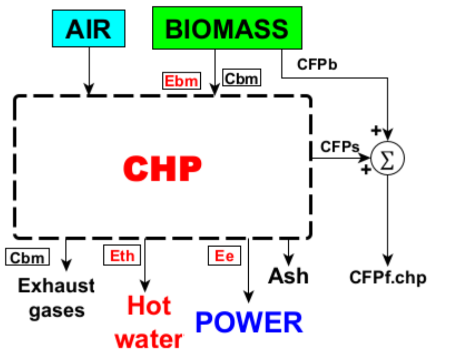

Fig. 2. Block diagram for a biomass CHP

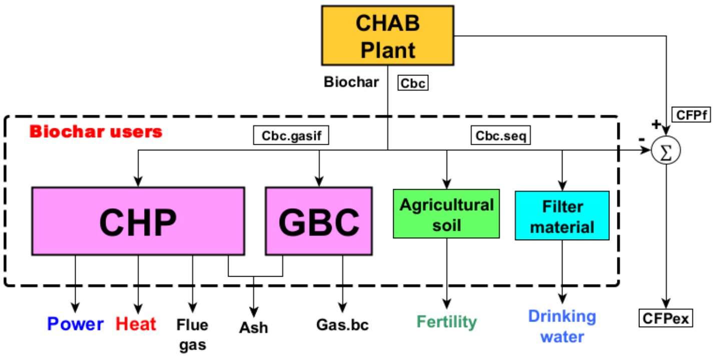

Fig. 3. Block diagram of biochar utilization for energy and amendment

The biochar obtained from the gasification of vineyard prunings has very few volatiles, it gasified with CO2, H2O and air produces a gas.bc with very little tar and high HHV, usable instead of methane gas in local Smart recipes.

Table 2 shows the results of the gas.bc production estimation in different versions by the share of gasified biochar, 100 % or zero. From the 100 % potential of **458 GWh/y**, gas can be obtained, which would replace about **34.3 million m^3** of natural gas.

If less than 75% of the biochar produced is gasified, the energy conversion operation is done with a negative CFP, the biochar used as an amendment sequesters the carbon taken from the biomass for long periods of time.

Gas.bc can be used to power generators, similar to CHP, with an electrical efficiency of 30% and a thermal efficiency of 56%. If less than 70% of the biochar produced is gasified the CFP is zero or negative.

Gasification of biochar with CO2, H2O and air produces a combustible gas with CO, H2 and CH4, similar in use to natural gas, which can be a substitute when and as needed in areas without a gas network where PLG is used.

Table 3 shows the functional performances of using biochar for the production of electricity and heat with CHP systems.

Modern electrical energy production systems with internal combustion engines use gas engines that operate in single mode, constructively optimized and with extremal autocontrol to operate around the economic pole. Real yields reach 50%, but for the case studied, 42% is a value confirmed by functional hybrid systems.

The functional advantage of the CHP with biochar is that it can operate at idle at 20% of the load, from gas.bc produced by producing usable heat. The system produces electricity when needed locally or in the grid where it is connected.

Table 2: Gas.bc from GBC WITH biochar for NG replacement

Feature	U.M.	Value				
Biochar relative mass gasified	%	**100**	**75**	**50**	**25**	**0**
Annual biochar input energy	TWh/y	**0.458**	**0.343**	**0.229**	**0.114**	**0.000**
Biochar Mass not gasified	Tg.bc/y	**0.000**	**0.014**	**0.027**	**0.041**	**0.054**
Carbon mass sequestered in soil	TgC/y	**0.000**	**0.011**	**0.022**	**0.033**	**0.044**
Mass of CO2 sequestered in soil	TgCO2/y	**0.000**	**0.040**	**0.081**	**0.121**	**0.162**
Energy efficiency of gas.bc cooled	%	**75**	**75**	**75**	**75**	**75**
Gas.bc specific HHV	MWh.gbc/Mg.bc	***6.300***	***6.300***	***6.300***	***6.300***	***6.300***
Annual energy gas.bc cooled	TWh/y	**0.343**	**0.257**	**0.172**	**0.086**	**0.000**
HHV of natural gas	kWh/m3	10.000	10.000	10.000	10.000	10.000
Volume of NG with equal energy	Mm3.ng/y	**34.328**	**25.746**	**17.164**	**8.852**	**0.000**

Table 3: CHP with biochar from vine prunings

Feature	U.M.	Value				
Biochar relative mass gasified	%	**100**	**75**	**50**	**25**	**0**
Biochar mass gasified	Tg.bc/an	**0.054**	**0.041**	**0.027**	**0.014**	**0.000**
Annual biochar energy for CHP	TWh/an	**0.458**	**0.343**	**0.229**	**0.114**	**0.000**
Energy efficiency cooled gas.bc	%	**75**	**75**	**75**	**75**	**75**
Gas.bc engine yield	%	42	42	42	42	42
Electric generator yield	%	95	95	95	95	95
Electrogenerator yield	%	**39.9**	**39.9**	**39.9**	**39.9**	**39.9**
Electricity production efficiency	%	**29.9**	**29.9**	**29.9**	**29.9**	**29.9**
Electricity annual production	TWhe/y	***0.137***	***0.103***	***0.068***	***0.034***	***0.000***
Yield heat recovery gas.bc cooling	%	**21.3**	**21.3**	**21.3**	**21.3**	**21.3**
Yield heat recovery from gas engine	%	34.8	34.8	34.8	34.8	34.8
Heat recovery yield	%	31.4	31.4	31.4	31.4	31.4
Recovered heat from cooling gas.bc	MWhth/Mg.bc	1.785	1.785	1.785	1.785	1.785
Recovered heat from gas engine	MWhth/Mg.bc	2.923	2.923	2.923	2.923	2.923
Heat production in CHP	MWhth/Mg.bc	4.708	4.708	4.708	4.708	4.708
CHP heat production efficiency	%	**56.1**	**56.1**	**56.1**	**56.1**	**56.1**
Heat annual production	TWh.th/y	**0.257**	**0.192**	**0.128**	**0.064**	**0.000**
Cogeneration efficiency	%	**86.0**	**86.0**	**86.0**	**86.0**	**86.0**
Cogeneration index		**0.534**	**0.534**	**0.534**	**0.534**	**0.534**
Annual energy production	TWh/y	0.394	0.295	0.197	0.098	0.000
CFP emitted from CHP operation	kg.CO2/Mg.bc	**35.000**	**35.000**	**35.000**	**35.000**	**35.000**
Annual CFP emitted from CHP operation	Mg.CO2/y	1.907	1.430	0.954	0.477	0.000

If all the 100 % of biochar produced annually is gasified, **137 GWh.e** of electric energy can be obtained, as well as **257 GWh.th** of thermal energy. For a zero or negative emission, a maximum of 70% of the biochar produced must be gasified.

3. Results

Table 4 shows the products obtained from gasification in SEB.HW systems from vine prunings. The calculations were made for the entire mass of BVR collectable at RO level, **650 GWh.th/y** thermal energy and **54 Gg.bc/y** quality biochar with positive CFP can be produced annually.
If more than 30% of the produced biochar is used as an agricultural amendment, a negative CFP is obtained for the entire energy conversion operation.

Table 4: Energy and biochar from SEB.HW systems

Feature	U.M.	Value
Energy efficiency heat production	%	**0.450**
Annual heat production	TWh/an	**0.652**
Average biochar production	g.bc/g.br.db	***0.200***
Biochar mass annually produced	Tg.bc/y	**0.054**
Average Carbon content of biochar	g.Cbc/g.bc	**0.810**
Annual Carbon mass from biochar	Tg.Cbc/y	**0.044**
Biochar HHV	kWh/kg.bc	**8.400**
Annual biochar energy potential	TWh/y	**0.458**
CFP emitted from CHAB plant operation	kgCO2/Mg.br	**135.000**
CFP emitted from CHAB plant operation	kgC/Mg.br	**36.818**
BCH incorporated into soil for CFP=0	kg.bc/Mg.br	**45.455**
Relative mass BCH gasified for CFP=0	%	***77.3***

The economic analysis of the use of an HK45 CHP manufactured by Spanner is presented in table 5. The usage period for the LCA study was chosen to be only 5 years to investigate whether extensive operation at full production capacity can be economic.
At maximum load, 285 tons of dry biomass are consumed annually, which would be harvested from 160 ha, so it would be feasible for a farm with at least 200 ha cultivated, or for a similar association.
Production costs below 150 €//MWhe depend a lot on the value of the collection, transport, chopping, drying and storage operations. The value of 120 €//Mg.bcr.db is relatively covering for a modern technology use, which requires investments recoverable in 5-8 years.
The important advantage of the HK45 type systems is that they can work with woody chips from different origins, forestry, energy crops, etc. [13]
For lower electrical powers, it is recommended to use ECO20X type CHP aggregates produced in Italy. It produces 20 kWe and 40 KWth with an average hourly consumption of 25 kg.br/h.

Table 5: Economic evaluation of HK45 with chopped vine prunings

Feature	U.M.	Value 1	Value 2
Live Cycle operating time	y/LC	5	7
Average load level	%	100	71
Annual operating time	h/y	7000	5000
Electricity produced annually	MWhe/y	315	225
Heat produced annually	MWh.th/y	700	500
Annual consumption of biomass	Mg.bm/y	283.5	202.5
Price chopped vine prunings	€/Mg/bm	120	120
CHP specific investment	€/kWe	2500	2500

Installation and start-up	%	10	10
Total investment for CHP	€	123750	123750
Biomass storage	€	6000	6000
Distribution electric block	€	4500	4500
Total investment	€	134250	134250
Feature	**U.M.**	**Value 1**	**Value 2**
Annual maintenance rate costs	%	10	10
Maintenance costs for live cycle	€/LC	13425	13425
Operator cost for live cycle	€/LC	60000	84000
Prices ratio MWh.th / MWh.e		0.376	0.376
Equivalent electricity production	MWhe.ech/y	578.038	412.923
Total operating costs	€/LC	207675	231675
Annual operating costs	€/y	41535.00	33096.43
Annual biomass expenses	€/y	34020.00	24300.00
Annual operating costs	€/y	75555.00	57396.43
Share of biomass expenses	%	45.03	42.34
Cost electricity production	€//MWhe	130.71	139.00
Cost heat production	€//MWhth	49.12	52.24
ENEL network tariff	lei /kWhe	1.230	1.230
ENEL network tariff	€//MWhe	246.000	246.000
Electricity tariff difference	€//MWhe	115.291	107.000
Heat tariff	€//MWh.th	64.000	64.000
Heat tariff difference	€//MWh.th	14.884	11.757
Investment recovery time	operating day	811.512	909.030
Investment recovery time	year	2.782	6.109
Annual saving electricity production	€/y	36316.52	24074.95
Annual saving heat production	€/y	10418.48	5878.62
Annual saving operating CHP	€/y	46735.00	29953.57
Saving from operating costs	%	61.86	52.19

It is worth noting that the cost of electricity production is similar to that of 2021, which made the use of CHP with biomass economical in terms of ensuring energy independence. In 2022, in the midst of the energy crisis, the production cost is below 60% of that practiced on the networks, which ensures real economic efficiency.
Since the production costs depend on the cost of using the residual biomass, it is economical to process and store it for larger quantities, corresponding to about 100 ha of cultivation, so for growers' associations.
For higher powers, systems with 150 kWe or 600 kWe can be used, which, however, are debited to the network and require large amounts of biomass.

Table 6: Economic evaluation for using gas.bc to replace natural gas

Feature	U.M.	Value			
Biochar relative mass gasified	%	**100**	**75**	**50**	**25**
Conversion rate euro/leu	lei/€	4.95	4.95	4.95	4.95

Energy price for 2022 natural gas	lei/MWh	472	472	472	472
Energy price for 2022 natural gas	€/MWh	95.35	95.35	95.35	95.35
Energy price for 2022 PLG	lei/MWh	1792	1792	1792	1792
Energy price from PLG	€/MWh	398.22	398.22	398.22	398.22
Production price gas.bc	€/Mg.bc	850	850	850	850
Price energy from gas.bc	€/MWh	134.92	134.92	134.92	134.92
Price energy between PLG and gas.bc	€/MWh	-263.30	-263.30	-263.30	-263.30
Additional annual income from gas.bc	M€/y	**90.386**	**67.790**	**45.193**	**22.597**

Table 7 shows the evaluations of carbon emissions produced by the energy recovery of BVR according to the share of BCH used for gasification in GBC or CHP.
For 100 % of biochar gasification the CFP is positive, but much lower than those produced by the use of fossil fuels. CFP ≈ 0 can be obtained for 25% BCH used as an agricultural amendment. The use as an agricultural amendment produces a long-term sequestration with the value of **-0.46 Tg.CO2/Tg.br**, which annually for viticulture would represent - 25 Gg.CO2/y equivalent for a consumption of **4100 tons of diesel**.

Table 7: Carbon footprints from energetic uses of vine prunings

Feature	U.M.	Value				
Annual biochar mass gasified	%	**100**	**75**	**50**	**25**	**0**
CFP from SEB.HW	Mg.C/Mg.br	0.037	0.037	0.037	0.037	0.037
Annual CFP from SEB.HW	Tg.C/y	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**
Annual CFP from CHP operation	Tg.C/y	5.2E-04	3.9E-04	2.6E-04	1.3E-04	0
Annual CFP from energy production	Tg.C/y	0.011	0.010	0.010	0.010	0.010
Sequestered carbon from amendment	Tg.Cbc/y	0	**0.011**	**0.022**	**0.033**	**0.044**
Annual CFP for energy	TgC/y	**0.010**	**-0.001**	**-0.012**	**-0.023**	**-0.034**
Annual CFP for energy production	Tg.CO2/y	**0.037**	**-0.004**	**-0.044**	**-0.085**	**-0.125**
Specific CFP energy production	Tg.CO2/Tg.br	**0.135**	**-0.014**	**-0.162**	**-0.311**	**-0.459**

4. Conclusions

In the current energy crisis, the use of renewable, storable local energy resources is even more urgent, with which energy can be produced for productive or domestic use **when and as much as necessary**, preferably with a negative carbon footprint.
In RO viticulture, it is produced annually on 160,000 ha from which a minimum of **272 Gg.bvr.db/y** dry vine prunings with an energy potential of **1.45 TWh/**y would be collected, an energy resource from which through pyrolysis and gasification produces heat, electricity and biochar.
By gasifying BVR in systems with the CHAB concept, **650 GWh.th/**y of heat and **54 Gg.bc/y** of quality biochar can be obtained with the energy potential of **458 GWh/y**, without residues and with very low CFP.
From the biochar gasification, a gas.bc is obtained that could annually replace **34.3 million m of natural gas**, or about 137 GWh.e/y and 257 GWh.th/y of heat would be produced with CHP.
The economic estimate indicates that the use of gas.bc instead of PLG is economically efficient, reducing annual expenses by up to 90 million euros in wine farms.
At a use of 50% of biochar as an agricultural amendment the energetic and ecological use of BVR is made with a negative carbon footprint of **-44 Gg.CO2/y**.

A wine farm with **100 ha** can annually collect a BVR mass of 165 Mg.bvr.db/y from which a CHP produces 180 MWhe/y and 400 MWh.th/y. Gasified in SEB.HW systems, 390 MWh.th/y and 33 Mg.bc.y biochar are obtained.
It is economically feasible to use CHP with biomass for the production of electricity and heat, with lower energy costs than the current ones, with a maximum investment payback time of 4 years.
The paper highlights the current usefulness of harnessing the energy potential of the residual viticultural biomass, being the basis for the development of optimal variants, adapted to the real conditions of the viticultural farms.

References

[1] Cavalaglio, G., and S. Cotana. *Recovery of vineyards pruning residues in an agro-energetic chain*. University of Perugia – Biomass Research Centre, 2008.
[2] Giorio, Chiara, Sarah Pizzini, Enrico Marchiori, Rossano Piazza, Stefano Grigolato, Michela Zanetti, Raffaele Cavalli, Marco Simoncin, Lidia Soldà, Denis Badocco, and Andrea Tapparo. "Sustainability of using vineyard pruning residues as an energy source: Combustion performances and environmental impact." *Fuel* 243 (May 2019): 371-380.
[3] Genesio, Lorenzo, Franco Miglietta, Silvia Baronti, and Francesco P. Vaccari. "Biochar increases vineyard productivity without affecting grape quality: Results from a four years field experiment in Tuscany." *Agriculture, Ecosystems and Environment* 201 (March 2015): 20–25.
[4] Murad, Erol, M. Seiculescu, C. Sima, and G. Haraga. "Using the energy potential of vine ropes" / Utilizarea potenţialului energetic al corzilor de viţă." Paper presented at the Scientific communications session ICDVV Valea Călugărescă, Romania, June 10, 2010.
[5] Murad, Erol, and Florian Dragomir. "Heat generators with TLUD gasifier for generating energy from biomass with a negative balance of CO_2." Paper presented at the International Conference on Hydraulics and Pneumatics HERVEX 2012, Călimăneşti-Căciulata, Romania, November 7-9, 2012.
[6] Murad, E., C. Dumitrescu, F. Dragomir, and M. Popescu. "CHAB concept in sustainable development of agriculture." Paper presented at the International Symposium ISB-INMA TEH' 2016, Bucharest, Romania, October 27 – 29, 2016.
[7] Murad, Erol. "Production of energy and agribiochar without residues and with negative carbon footprint with CHAB and CHBAP concepts from the Romanian residual vegetable agricultural biomass." Paper presented at the International Symposium ISB-INMA TEH' 2021, Bucharest, Romania, October 29, 2021.
[8] Murad, Erol, Manuela Drăghicescu, Perino-Constantin Baraga, and Adrian-Ioan Drăghicescu. "Energy and Biochar production with a ZERO carbon foot print." Paper presented at the National Conference of New and Renewable Energy Sources, CNSNRE 2022, Valahia University, Târgoviște, Romania, June 2 - 3, 2022.
[9] Schmidt, Hans-Peter, Claudia Kammann, Claudio Niggli, Michael W.H. Evangelou, Kathleen A. Mackie, and Samuel Abiven. "Biochar and biochar-compost as soil amendments to a vineyard soil: Influences on plant growth, nutrient uptake, plant health and grape quality." *Agriculture, Ecosystems and Environment* 191 (June 2014): 117-123.
[10] Pröll, Tobias, and Florian Zerobin. "Biomass-based negative emission technology options with combined heat and power generation." *Mitigation and Adaptation Strategies for Global Change* 24, no. 7 (2019): 1307–1324.
[11] Bioenergy Europe. *Bioenergy Europe factsheet: Biomass for energy - Agricultural residues & energy crops*. October 15, 2019. Accessed October 10, 2022. https://bioenergyeurope.org/component/attachments/attachments.html?id=561&task=download.
[12] European Biochar Industry Consortium e.V. (EBI). *EBI Whitepaper. Biochar-based carbon sinks to mitigate climate change*. October 2020. Accessed October 10, 2022. http://www.biochar-industry.com/wp-content/uploads/2020/10/Whitepaper_Biochar2020.pdf.
[13] Spanner Re² GmbH. "Biomass power plant from Spanner Re²." Accessed October 19, 2022. https://www.holz-kraft.com/en/products/biomass-chp.html.