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ENERGETIC UTILIZATION OF BIOMASS FROM REWETTED PEATLANDS

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The global biomass demand for food and fodder as well as for energy production will continuously increase in the near future, leading to increasing pressure on land use. For example, agriculture and forestry on drained peatlands will substantially change the physical, biological and chemical soil properties and results in peat degradation, accompanied by huge emissions of greenhouse gases. Peatlands cover an estimated area of ca. 400 million ha, equivalent to 3 % of the Earth's land surface [23]. According FAO only 15 % percent of peatlands are drained and used for agriculture, grazing,

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peat mining and forestry, especially for bioenergy plantations, but causing almost 6 percent of total anthropogenic CO_2 emissions and almost 25 percent of the GHG emissions from the entire land use [10]. Since November 2018, HTW in collaboration with Greifswald University started a new and innovative research project, studying the production of biomass on wet peatland sites and the optimization of the thermal utilization of such biomass sources in small and medium scale applications, e.g. household systems and centralized heating plants for communities. The project is therefore focused on an alternative opportunity of using peatlands for bioenergy production, avoiding soil degradation and reducing fossil fuel based GHG emissions by replacing such fuels. Several peat forming plant species such as Common Reed, Reed Canary Grass Sedge species can be produced on rewetted peatlands. Common Reed (Phragmites australis) e.g. grows rapidly and the annual yields will reach under Central European conditions between 3.6 up to 43 t dry matter per ha and year (depending on water level, nutrient availability and pH values) [31]. The heating value of reed (17.7 MJ/kg) e.g. is remarkable and comparable with Miscanthus. Modified conventional agricultural technologies are suitable to harvest, compact, transport and store the reed and well established conversion technologies as e. g. boiler technologies for straw can be used for the utilization of the reed biomass. The presentation and the respective publication of the related paper will introduce the first results of this research project, including the results of measuring campaigns, carried out at a 800 kW heating plant for community heating in Malchin (Mecklenburg Western Pomerania) during February/March 2019.

Key words: bioenergy; common reed; reed canary grass, sedges; combustion; bioenergy; peatlands; climate change mitigation.

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ЭНЕРГЕТИЧЕСКОЕ ИСПОЛЬЗОВАНИЕ БИОМАССЫ ИЗ ЗАБОЛОЧЕННЫХ ТОРФЯНИКОВ

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В ближайшем будущем мировой спрос на биомассу для призводства продуктов питания и корма, а также энергии будет непрерывно расти, что приведет к увеличению нагрузки на землепользование. Например, сельское и лесное хозяйство на осушенных торфяниках существенно изменит физические, биологические и химические свойства почвы и приведет к деградации торфа, сопровождаемой огромными выбросами парниковых газов. Торфяные угодья занимают около 400 млн га, что эквивалентно 3 % поверхности Земли [23]. По данным ФАО, только 15 % торфяников осушаются и используются для сельского и лесного хозяйства, выпаса скота, добычи торфа и особенно в качестве биоэнергетических плантаций. В результате этой деятельности количество выбросов составляет 6 % от общих антропогенных (CO_2) и почти 25 % выбросов ПГ от землепользования [10]. С ноября 2018 г. HTW в сотрудничестве с Университетом Грайфсвальда начал новый инновационный исследовательский проект, посвященный изучению производства биомассы на заболоченных торфяниках и оптимизации термического использования источников биомассы в малых и средних проектах: бытовых системах и централизованных отопительных установках. Проект сфокусирован на альтернативной возможности использования торфяников для производства биоэнергии, предотвращения деградации почвы и сокращения выбросов парниковых газов на основе замены ископаемого топлива. На повторно заболоченных торфяниках можно выращивать несколько видов таких торфообразующих растений, как обыкновенный тростник, канареечник тростниковидный или осока. Тростник обыкновенный (Phragmites australis) быстро растет, а ежегодный урожай в среднеевропейских условиях может достигать от 3,6 до 43 т сухого вещества на гектар в год (в зависимости от уровня воды, наличия питательных веществ и значений pH) [31]. Теплотворная способность тростника (17,7 МДж/кг), например, сопоставима с мискантусом. Модифицированные традиционные сельскохозяйственные технологии подходят для сбора, уплотнения, транспортировки и хранения тростника. Хорошо зарекомендовавших себя технологии переработки, например, теплотехнику для соломы можно использовать для утилизации тростниковой биомассы. В отчете и соответствующих актах представлены итоги исследовательского проекта, включая результаты замеров, проведенных на теплоцентрали мощностью 800 кВт коммунального отопления в Мальхин (Мекленбург, Западная Померания), в феврале и марте 2019 г.

Ключевые слова: биоэнергетика; тростник обыкновенный; канареечник тростниковидный; осоки; горение; биоэнергия; торфяники; смягчения влияния изменения климата.

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General background Information

The global estimated peatland area covers approximately 4 Mio km² and it is estimated that approx. 550 Gt carbon, representing 30 % of the total carbon in soils is stored globally in peat soils [17; 31]. Northern Europe, especially the regions around the Baltic Sea, such as e.g. Finland, Sweden, Russia, Estonia, Latvia, Lithuania, Poland and Germany originally enclose large natural wetland areas [16] but huge shares (almost 45 %) of the peatland area in the Nordic region have been drained and emit almost 80 Mt of CO_2 annually, i. e. 25 % of the total CO_2 emissions of these countries [11]. Rewetting of such areas and the production of energy biomass from peat forming plant species on the rewetted areas can result in a substantial reduction of the CO_2 emissions and contribute to climate protection [3]. After rewetting, an increase of CH_4 emissions may occur effecting the reduction of GHG emissions because CH_4 has a 23 times stronger climate effect compared to CO_2, but the overall result of rewetting is likely to be a reduction in global warming potential [5].
According [11] the net greenhouse gas emissions from rewetted peatlands are significantly lower compared to the previous drained situation (table 1) resulting in the climate benefits from rewetting peatlands in terms of potential for GHG emissions reduction and in the return of the carbon sequestration function of natural peatlands [19; 32]. Additional benefits are water and nutrient retention as well as local climate cooling and habitat provision for rare species [31].

Table 1

Emission reduction after rewetting of former drained peatlands [11]

Initial land use of drained peatlands	Emission reduction after rewetting in t CO_{2equiv}/(ha *year)	
	Temperate zone	Boreal zone
Forest land	6	2
Cropland	28	34
Grassland	20	25
Peat extraction	9	11

An additional benefit arises when biomass is produced on these areas and their energetic use replaces fossil fuels. A typical yield of wetland biomass of 12.5 t dry matter per ha and year (average common reed yield measured in field tests in Northern Germany [28]) can replace 7,5 tons of coal equivalent (1 TCE = 8.142 MWh) and thus reduce fossil fuel based GHG emissions.

Biomass utilization pathways and productivity of rewetted peatlands

During recent years the combination of rewetting of former drained peatlands and the production of biomass (paludiculture) has gained interest as a possible land use option for obtaining benefits in terms of climate protection without losing agricultural land and producing valuable biomass sources for different utilization pathways (table 2).

Table 2

Utilization pathways for biomass from wet peatlands

Utilization pathway		Harvesting period
Animal husbandry	Fodder (Hey, Silage)	Early summer
	Animal bedding	Summer, Autumn
Industrial Material	Paper & pulp industry	Winter
	Thatching	Winter
	Walls, panels, mats, insulation materials	Winter
Energy	Combustion, Gasification	Autumn, Winter
	Biogas	Summer

The productivity of rewetted peatlands varies depending on the plant species dominating the vegetation (Reed, Reed Canary Grass or Sedges), climate conditions of the respective site, weather conditions during the year of sampling, harvesting time and other specific site conditions such as medium water levels and nutrient conditions [30]. Depending on water regime, trophy level, seed potential and other factors, the development of the vegetation first leads to reed beds of Reed Canary Grass (Phalaris arundinacea), Sweet Reedgrass (Glyceria maxima), Common Reed (Phragmites australis), or Cattail (Thypha spec.), more rarely to sedge (Carex spec.) reed-beds, but also to Grey Willow (Salix cinerea). After rewetting the plant communities develop spontaneously, and the biomass can be harvested according to the intended use (table 2). Because of the productivity of such a site and the possible yield of biomass (table 3), the site adapted and sustainable use of rewetted peatlands for the production of biomass is an innovative and cost effective chance for agriculture. It's assumed that high productivity yields of about 10−15 t dry biomass per hectare and year are possible and 2 Million t dry biomass for the Energy production could be harvested from this peatlands e. g. in Northern Germany [1].

Table 3

Productivity of selected wetland biomass sources [3; 6]

Dominant species	Productivity in t_{DM}/(ha*year)	Average yield in t_{DM}/(ha*year)	Energy yield [*1] in MWh/ha*a	Cal. equivalent[*2] in toe
Common Reed	3.6–43.5	12.5	53	4.55
Cattail	4.8–22.1	14	66.1	5.68
Reed Canary Grass	3.5–22.5	10	43.9	3.77
Sedge	3.3–12,0	6,5	27.7	2.38

[*1] Energy yield calculated for 15 % water content, [*2] 1 toe = 11.63 MWh

As shown in table 3 especially Common Reed, Cattail and Reed Canary Grass show a high potential for biomass production. Average yields of about 12.5 t of dry Reed biomass per hectare and year were found for sites surveyed in eastern Germany during the research project ENIM [28]. For Cattail average yields of about 15 t_{DM}/(ha*year) are reported in pilot trials in Donaumoos (Germany) [12] and similar results with average yields of 13 t_{DM}/(ha*year) are reported for other sites e.g. in Canada [8]. Yields can rise up to 30 t_{DM}/(ha*year) as reported e. g. from studies in the US [20]. Reed Canary Grass (RCG) and a wide variety of Sedges species are further possible biomass sources growing on wetlands. Reported RCG yields for northern Germany range between 3.5–22.5 t_{DM}/(ha*year) [24] and 3.9–9.6 t_{DM}/(ha*year) for sites studied in Belarus [30]. Yields for Sedges are reported for selected sites in Belarus in the range between 7.0–31.1 t_{DM}/(ha*year) [30] and 7.9–22.3 t_{DM}/(ha*year) for North- and Central US [20]. It can be summarized that typical yields for all above mentioned perennial peat forming biomass sources in natural stands the productivity will range between 3.5–22.5 t_{DM}/(ha*year). Some sites show even higher productivities, as mentioned before caused by factors such water levels and nutrient conditions. According Kask et al. the productivity can be substantially increased by adding nutrients and yields between 40–50 t_{DM}/(ha*year) might be possible [14].

Main fuel properties

The combustion process of solid biomass fuels is significantly affected by the chemical and the physical-mechanical properties of the feedstocks. Biomass feedstocks distinguish between each other in a wide range and show significant differences towards solid fossil fuels. The essential difference is expressed by the caloric value and the elementary compositions of the fuels. The elementary (chemical) composition is divided into the

- main elements: carbon (C), hydrogen (H) and oxygen (O);
- secondary elements: nitrogen (N), potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), silicon (Si), sodium (Na), phosphorus (P), chlorine (Cl) and
- trace elements.

The main elements (carbon, oxygen, hydrogen) are essentially responsible for the energy content (calorific value), expressed by the exothermal reaction of the carbon and the hydrogen with oxygen. The secondary elements (nitrogen, potassium, magnesium, sodium, calcium, phosphorus, sulfur, silicon and chlorine) with the exception of silicon and sodium, are the main nutrients consumed during growing and accumulated in the plants [13]. Nitrogen, sulfur and chlorine are so called "critical" components since they are involved in pollutant formation and corrosion processes. High concentrations of nitrogen and sulfur lead to NO_X and SO_2 emissions which can be further transferred into acid components. High chlorine concentrations can cause corrosion damage to the combustion plants components or further react to harmful components such as dioxins and furans as well as HCl emissions [6].

Potassium, magnesium, sodium, calcium will have an effect on the ash melting behavior and can cause slag formation problems in combustion chambers. Trace elements, which are mostly heavy metals (iron, manganese, zinc, copper, molybdenum, cobalt, lead, aluminum, chromium, cadmium, nickel, mercury, arsenic) are considered partly as essential micronutrients for plant growth, but in some cases high concentrations of trace elements can have a plant-damaging or contaminating effect. Further important properties are the content of water, ash, volatile components, fixed carbon and the caloric value of the biomass fuels. An overview of the effects of fuel properties on combustion behavior is shown in table 4.

Table 4

Impact of fuel characteristics on the combustion process

	Impact on the combustion process
Chemical composition	
C, H, O	Caloric value, equivalent air ratio, energy output
S, N, Cl	Emission of pollutants, corrosion, material cost
Mg, K, Ca …..	Ash content, ash melting behavior, ash utilization opportunities
Fuel quality parameters	
Heating value	Energy content, fuel demand and design of the boiler
Water content	Energy content, combustion temperature, fuel storage risks
Volatile matter and fixed carbon content	Reaction rate, combustion temperature and combustion burnout times, design of the boiler
Ash content	PM emission, ash quantity and utilization opportunities
Physical/mechanical properties	
Particle size	Reaction rate, combustion temperature and combustion burnout times, design of the boiler
Bulk density	Fuel transportation and storage

Some selected results of the proximate- and ultimate-analysis of wetland biomasses from different regions are shown in table 5 and compared with other potential biomass fuels and coal as typical solid fossil fuels. As shown in the table, the caloric value of common reed and reed canary grass is significant lower than the heating value for fossil fuels and requires higher fuel inputs for the same energetic output (which is generally valid for all solid biomass fuels). However, compared to other biomass fuels the relative high value of 17.5–18.9 MJ/kg indicates that biomass produced on peatlands can be used as a promising energy source. The nitrogen content is low, so that no problems concerning nitrogen oxide emissions are expected (for biomass combustion processes only the formation of NOx from fuel nitrogen is important, the formation of thermal NO occurs only at high temperatures to a great extent and plays a minor role during biomass combustion) [2]. Compared to pine wood (the traditional fuel in biomass heating and CHP plants in Germany) the higher contents of chloride, sulfur and ash might cause problems regarding emissions and process management if the reed is used in conventional combustion technologies. Sulfur and chlorine are air-polluting elements. During combustion these elements mainly convert to SOx and HCl. Especially the chloride content could increase the risk of Cl-corrosion [26].

The values for ash content of the different reed samples vary in a wide range (e.g. for reed canary grass between 3 % in Belarus and 10 % in Northern Germany) which might be caused by different harvesting dates and methods. Samples in Germany were taken from reed bales, harvested and compacted by conventional agricultural machinery, whereas samples in Belarus were collected manually.

To provide a standardized fuel and to reduce storage and transport costs the fuels can be compressed into densified fuel products such as pellets or briquettes. Pellets, produced from common reed, reed canary grass and sedges were used for initial combustion experiments in a commercial biomass heating plants in Malchin, Northern Germany (fig. 1). These pellets have uniform size and shape (Ø 8 mm, L 10–20 mm) and are characterized by a low water content and a high energy density. However, the production of pellets is associated with high technical, energetic and economic costs.

Table 5

Comparison of fuel analysis for wetland biomass sources from different regions with other biomass samples and fossil fuels (*[1] from Barz et. al., (2007), *[2] Kask, et. al., (2007), *[3] Wichtmann et al., (2011), *[4] Komulainen, et al., (2008), *[5] TLL (2009)

Fuel species	Cv (wf) [MJ/kg]	Volatile [%]	Ash [%]	Ultimate analysis (wf) in %					
				C	H	N	O	S	Cl

Solid fossil fuels									
hard coal	31.8	38.8	6.3	79.4	5.1	1.5	6.6	1.0	<0.2
brown coal	27.0	55.0	7.6	68.4	5.5	1.8	15.4	1.3	-
Reed samples from different regions									
Northern Germany[*1]	17.7	66.8	8.8	46.5	5.9	0.3	42.5	0.14	0.16
Estonia[*2]	17.76	n. a.	3.2	47.5	5.56	0.31	43.34	0.04	0.11
Belarus[*3]	n. a.	n. a.	5.7	45.52	n. a	0.7	n. a.	0.11	0.05
Finland [*4]	18.92	81.8	2.1 – 4.4	47.5	5.6	0.3	43.3	0.04	0.11
Reed canary grass (RCG) samples from different regions									
Northern Germany[*5]	17.5	n. a.	10	43.29	5.79	1.17	38.17	0.19	1.39
Belarus[*3]	n. a.	n. a.	3.0 – 4.3	46.7	n. a.	0.75	n. a.	0.12	0.013
Finland [*4]	17.6	74.0	5.5	46.0	5.5	0.9	n. a.	0.1	0.09
Sedges									
Germany [*5]	17,45	n. a.	n. a.	47,6	5,95	1,81	38,07	0,24	0,4
Other Biomass Fuels									
Miscanthus	17.8	81.0	2.7	47.2	6.5	0.7	41.7	0.13	0.23
Pine wood	18.7	84.0	0.3	50.9	6.6	0.2	42.0	0.02	0.01
Wheat straw	17.1	79.6	5.3	46.7	6.3	0.4	41.2	0.1	0.4

Fig. 1. Sedge pellets used for combustion experiments in Malchin [6]

Table 6

Energy content and bulk density of different wetland biomass pellets used for combustion experiments in Malchin

Sample	Reed	RCG	Sedges	RCG + Reed
Caloric value (wf) in MJ/kg	18.65	18.5	18.19	17.83
Bulk density in kg/m³	613	604	616	539
Energy density in MJ/m³	11,432.5	11,174	11,205	9,610.4

Table 7

Composition of different wetland biomass pellets used for combustion experiments in Malchin (elementary composition obtained from Dahms, et al., 2017)

	TGA Analysis results in %				Elementary composition in %					
	Water	Volatiles	C fix	Ash	C	H	N	O	S	Cl
Sedges	6.92	76.76	9.37	6.97	47.8	5.8	1.0	37.7	0.2	0.5
RCG	6.07	78.42	10.36	5.51	46.7	6.0	0.9	40.2	0.2	0.8
Reed	5.16	82.41	7.88	4.54	47.2	5.8	0.7	41.6	0.1	0.04

Suitable conversion technologies

Different conversion pathways for wetland biomass can be considered regarding the harvesting time and the resulting biomass qualities. Winter harvest or late autumn harvest (table 2) will lead to lower water content (combined with higher heating values) because first frosts will dry the stand so that it can be harvested and directly stored and used for thermochemical conversion like conventional combustion [23]. Harvest during the vegetation period (e. g. during flowering) will provide high yields too, but the water content (60–80 %) will lead to a significant reduction of the heating value and it must be dried on the fields before stored or used in a combustion plant. Especially since grass silages are increasingly being used in biogas plants, the use of early harvested wetland biomass for biogas plants is a more promising opportunity. In this case plants like reed canary grass or sedges can be harvested 2–3 times during the vegetation period for the generation of substrates for biogas plants and an additional late autumn or winter harvest can provide biomass for a combustion plant.

In recent years, many projects studied the opportunity to use wetland biomass sources such as common reed, reed canary grass, sedges and cattail for energy purposes. Anaerobic digestion to produce biogas from grasses is today an interesting opportunity to provide alternative substrates for many existing biogas plants. Technologies include so called dry fermentation processes and classical wet fermentation processes where grass is used as co-substrate together with animal manure to improve the stability of the biogas process. High biogas yields of e.g. up to 0.78 m^3/kg dry matter are reported for dry fermentation experiments using silage from reed canary grass in Germany by Vogel et al. 2009. In general, the investigated biogas yields from different grass species using different harvest periods and methods varies in a very wide range (from 0.08 to 0.86 m^3/kg dry matter) [18].

For combustion two main technologies, a) fixed bed combustion and b) fluidized bed combustion systems are suitable to use such biomass as fuel for heat or heat and power generation. Since fluidized bed systems are more complex and require higher investment costs, an economic operation of the plants is only possible at high capacities (above 10 MW for bubbling fluidized bed systems and above 50 MW for circulating fluidized bed systems). Such technologies are a promising opportunity to use wetland biomass sources e.g. through co-combustion with coal in conventional power plant applications. Since herbaceous biomass sources have (compared to woody biomass fuels) usually higher contents of ash, N, S, K, Cl, etc. (table 5), leading to higher emissions of NOx, particulates, corrosion and deposits, co-combustion seems to be a good choice for the energetic utilization. Coal fired power plants are equipped with efficient flue gas cleaning and air pollution control systems ensuring an efficient and environmental sound combustion. Caused by the low density of the baled biomass long distance transportation is not suitable this option is only suitable if conventional coal fired power plants are located close to the production sites of the biomass sources. For this reason, fixed bed combustion systems are more favorable for decentralized (small scale) projects [12]. The two main types of fixed bed combustion systems are underfeed stokers and grate firing systems. Underfeed stokers are relatively cheap, but only suitable as small-scale systems. Fuel handling is very easy in such systems, but these technologies require a uniform fuel property in size, shape, moisture and energy content (pellets or small briquettes). They have the advantage of being easier to control than other technologies, since load changes can be achieved quickly and with relative simplicity due to the fuel feed method. Fuel is fed into the furnace from below by a screw conveyor and then forced upwards onto the grate where combustion process occurs. Disadvantage of the systems is that underfeed stokers are limited to low ash content fuels such as wood chips due to ash removal problems [12].

Grate firing systems, such as moving grate, traveling grate or vibrating grate boilers can accommodate fuels with high moisture and ash content [29]. They allow a continuous and automatic operation since the fuel is fed on one side of the grate, then disposed on the whole grate and burned completely when the grate has transported the fuel to the ash dumping site of the furnace. Such systems can be used in a wide capacity range, starting with only a few kW up to several MW as e. g. in the power plant sector. Within a research project financed by the German Federal Environmental Foundation (DBU), biomass from rewetted peatlands (especially common reed and reed canary grass) was used as fuel in an ORC (Organic Rankine Cycle) heat and power co-generation plant in Friedland (Germany). The used combustion system was a moving grate firing system with a maximum thermal capacity of 10 MW. Since the plant was usually designed to use wood chips as fuel an operation with 100 % of wetland biomass was not possible. During the project the boiler was fed with a mixture of wood chips and common reed and reed canary grass from the Peene valley peatlands. Since the combustion behavior and the particle size of wood chips is quite different from the reed and reed canary grass, a stable operation was only possible with a mixture of up to 1:5 (weight proportion RCG: wood). Higher portions of reed and/or reed canary grass led to problems in biomass supply of the plant because of volume differences when feeding the fuel into the boiler caused by the bulky structure of the fuel inducing blockages in the stoker. Not only differences in volume, but also in humidity led to difficulties in the burning process [28]. A possibility to solve the problems would be pelletizing or briquetting of the loose and gramineous biomass before feeding the boiler. Experiments to use pellets from reed and reed canary grass in small scale 50 kW fixed grate combustion system did not show any disadvantages compared to other biomass fuels such as wood chips normally used in the test facility. Because of the huge amount of fuel, necessary to operate the power plant in Friedland and the fact that pelletizing would increase the fuel prize significantly the effect of burning such pellets in the commercial scale experiments could not be studied during this project-but it can be assumed that pellets or briquettes produced from reed or reed canary grass could replace the wood chips by 100 % without major problems.

Experimental setup for the Combustion experiments using a 800 kW grate firing system

A promising utilization concept for the energetic utilization biomass from rewetted peatlands was realized in Malchin (north eastern part of Germany) 2014 by the company Agrotherm GmbH. A biomass boiler for straw and other gramineous fuels from the Danish technology provider "Linka" with 800 kW combustion capacity was installed and integrated into the existing district heating network of the city of Malchin. The boiler is equipped with a variable fuel feeding system (shredder for baled graminneous biomass and a feeding screw for the alternative use of wood chips and/or pellets). For the operation mode to use baled biomass the bales are automatically transported from the conveyor to the shredder, where the rotating shredder drums secure an efficient shredding, enabling an exact dosage. Since the feeding system is controlled by the boiler's heat consumption an automatic operation of the system is possible. The biomass is fed to the inclined grate, consisting of fixed and movable grate bars. By alternating forward and backward movements of the movable grate bars the fuel is transported through the combustion chamber. Primary air is used for cooling the grate and secondary air is supplied to the combustion chamber above the grate to ensure the correct amount of air for the complete combustion of the fuel and the required turbulences in the secondary combustion zone. The ash auger is installed in the base of the boiler to transport the ash out to the ash container. To avoid air pollution through dust emissions a combination of a cyclon precleaner and a baghouse filter is installed in the flue gas system.

The biomass used for the heating plant is produced near the town on an area of about 400 ha of rewetted peatlands during short term dry phases, baled and stored to ensure a continuous operation of the plant during the heating season. Each year, around 800−1200 t of fuel are produced and used in this plant, supplying about 490 households and office buildings with heating energy and replacing 290,000 to 380,000 l heating oil [4].

Fig. 2. 800 kW biomass boiler in Malchin for combustion of biomass from rewetted peatlands (Source: Agrotherm GmbH)

During a first measuring campaign in February 2019 pelletized wetland biomass (Sedges, RCG and Reed, see table 6 and 7) was used to operate the boiler. The boiler was operated in the capacity range between 600–700 kW (controlled by the heat demand of the district heating system) with an equivalence air ratio $\lambda = 2$ (divided into 40 % primary air and 60 % secondary air). Caused by the limited available amount of the pellets a mixture of them was used to ensure a continuous supply over a measuring time of 3 hours.

Results of the measuring campaign

Table 8 shows the German emission limit values for the combustion of straw like biomass fuels defined in the first general administrative regulation to the Federal Immission Control Act, Technical Instructions on Air Quality Control (TA-Luft).

The results of the flue gas emissions measurements (evaluated according TA Luft with a reference oxygen content of 11 %) are shown in Figure 3. Fluctuations in emissions characterize the fuel delivery cycles which occur every 7 minutes (emission peaks of CO_2 an and low emissions of NO_x during the fuel feeding periods).

Table 8

Emission limit values for the combustion of straw like biomass fuels according TA-Luft (reference oxygen content 11 %)

Flue gas component	Emission limit value
CO in g/m³	0.25
NOx in g/m³	0.5
TOC in mg/m³	50
PM in mg/m³	50

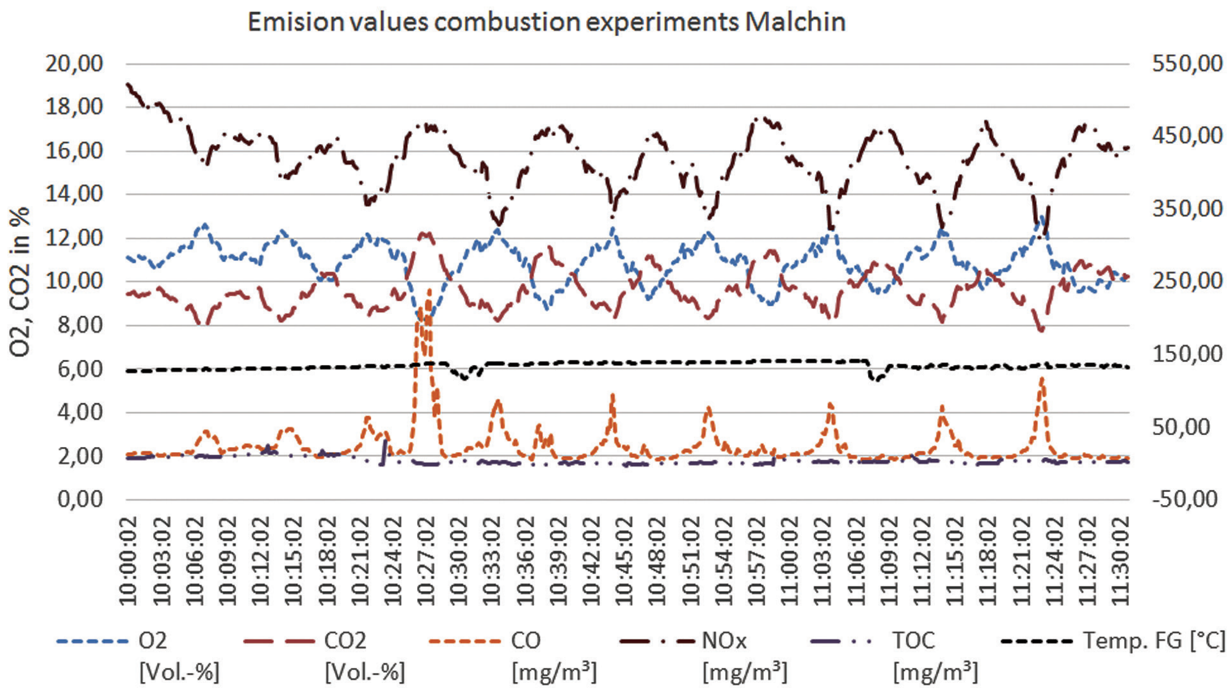

Fig. 3. Concentration of pollutant emissions during the combustion experiments

As shown in Figure 4–7 the concentration of the regulated air polluting components CO, TOC and PM (The measurement values were converted to the reference oxygen content of 11 %) were significant lower than the German emission limits, indicating a clean and stable combustion process.

The concentration of NOx in the exhaust gas was relatively high, but still below the German emission limit. After approx. 3 hours of operation slag formation was detected on the grate and the measurement campaign was stopped to clean the grate and to avoid damage of the grate. Reason was the high temperature of the accumulated burning coke and a blockage of the cooling air supply through the dense coke bed.

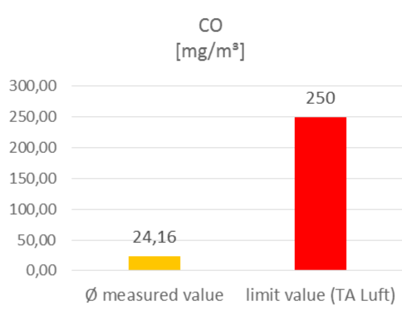

Fig. 4. CO values compared to TA Luft limit value

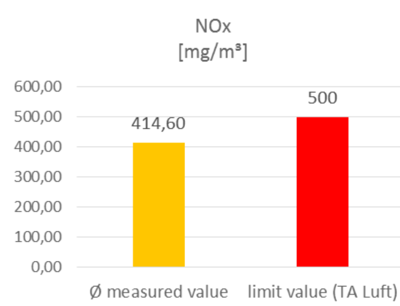

Fig. 5. NO_x value compared to TA Luft limit value

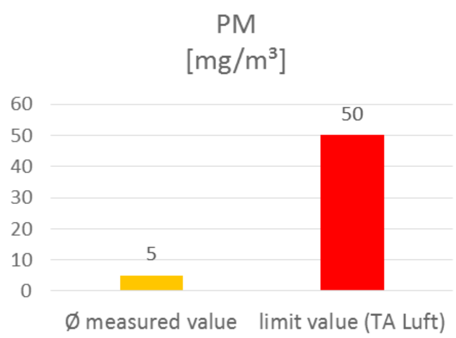

Fig. 6. PM value compared to TA Luft limit value

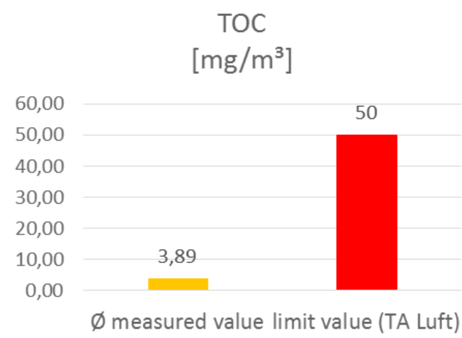

Fig. 7. TOC vaue compared to TA Luft limit value

Conclusion

Peatlands, drained and used for agriculture or forestry are significant sources of anthropogenic GHG emissions, caused by the release of stored carbon in form of CO_2 from peat decomposition. Peatland restoration (rewetting) can reduce this emission and the additional use of the above ground produced biomass as energy source can additionally reduce fossil fuel based GHG emissions by replacing such fuels. In general, many peat forming plant species, such as Common Reed or Sedge species are promising biofuels with yields (range between 3.5–22.5 t_{DM}/(ha*year) in natural stands) comparable to woody biomasses produced e.g. on short rotation plantations. Site productivities can reach even 40–50 t_{DM}/(ha*year) if nutrients are added to the sites. The produced biomass can be used in conventional thermochemical conversion technologies, such as conventional combustion systems or as substrates for biogas production.

Tested wetland biomass pellets made from Reed, RCG and Sedges have similar properties (caloric value, bulk and energy density and elementary composition) in comparison with standard wood pellets. Measurements in a 800 kW grate combustion boiler have indicated a clean and stable combustion process. The measured emissions of CO, NOx, PM and TOC are below the emission limits defined in the German Federal Immission Control Act (TA Luft).

The most negative property of these pellets is the higher ash content and a low ash melting temperature, caused by a high potassium content of the fuel. This property was the reason for the premature termination of the measurement campaign. Further experiments are required to optimize the combustion process by varying parameters, such as temperatures and air supply to the different boiler zones. Reduced temperatures in the primary reaction zone (e. g. by lowering the primary air supply) of the boiler (grate area) will reduce ash slagging problems and lower the NOx values in the exhaust gas. Furthermore, a comprehensive risk assessment and a Life Cycle Assessment (LCA) to asses site specific and general environmental and social factors of the project should be considered and will be carried out during the next project phase.

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