

Reed as perspective natural energy crop

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Abstract

In this paper to common reed, most perspective natural energy crop in Estonia, are turned attention. Determination of sustainable resources, fundamental characteristic in the point of combustion and estimation of energetic potential of reed available in a given territorial context are presented. In Estonia we have every year harvestable amount of reed is 90.2 million tons with energy content 0.36 TWh/y. Average productivity of reed as received is 8 t/ha in Estonian wetlands. By combustion characteristics reed as suitable fuel for energetic uses can be estimated.

Keywords

Biomass, reed, resources, productivity, combustion characteristics.

Introduction

One of the most important priorities for countries whose energetic consumption is strongly dependent on fossil combustibles is the developing alternative renewable energy sources. Another important aspect is the environmental one: the ratification of the Kyoto Protocol enforces adherent countries to develop an energetic model founded on renewable technologies. In this background, energy from biomasses emerges like one of the most promising solutions, either for energy production from sources alternative to fossil fuels, or for the contribution to the reduction of greenhouse gases emission in the atmosphere. In particular, natural and artificial energy crops constitute a very interesting resource; such cultivations put us in the position to attain targets like the introduction of an integrated vision of the agricultural development capable of diversifying its activities, the valorization of rural assets and the creation of new sources of employment and profit. For these reasons interest in energetic use of herbaceous biomass and wetland plants among them, have enlarged today in Estonia. The produced biomass can be used like CO₂-neutral energy source, as the amount of greenhouse gasses emitted during combustion is equivalent to the one removed from the atmosphere by plants during their growth thanks to photosynthesis. Moreover, these plants guarantee other environmental benefits, like the vegetal filtration for the treatment of waste water (*phytoreclaim*) and the contrasting action to erosive phenomena.

For the best use of biomass resources, we need to know how much is available, what the limitations are and how to make efficient devices which will harness the energy in a practical, cost-effective way.

Physiology and ecology of reed

Phragmites australis the common reed is a large perennial grass native to wetland sites (Figure 1.) throughout temperate and tropical regions of the world: it is found on every continent except Antarctica and may have the widest distribution of any flowering plant. It commonly forms extensive stands, up to a square kilometer or more, known as reed beds; it has stout creeping rhizomes and, where conditions are suitable, it can spread at up to 5 m or more per year by horizontal 'runner' stems (stolons), which put down roots at regular intervals. The erect stems grow to 2–4 m tall, occasionally up to 6 m in areas with hot summers and fertile growing conditions.



Figure 1. Reed in Peipsi Lake

Reed grows in marshes and swamps, along streams, lakes, ponds, ditches and wet wastelands, often weedy and very difficult to eradicate, as the stoloniferous rhizomes may reach 10 m or more in length; rhizomes can reach down almost 2 m below ground, their roots penetrating even deeper, allowing the plant to reach low lying ground water. Grows best in firm mineral clays, and tolerates moderate salinity, where water level fluctuates from 15 cm below soil surface to 15 cm above, burning if water is above soil surface. Ranging from cool temperate steppe to wet through tropical desert to moist forest life zones, reed is reported to tolerate annual precipitation of 3.1 to 24.1 dm, annual temperature of 6.6 to 26.6°C and pH of 4.8 to 8.2 [1].

Phragmites is typically the dominant species on areas that it occupies. It is capable of vigorous vegetative reproduction and often forms dense, virtually monospecific stands. In general researchers classify “sparse stands” as those with densities of less than 100 culms m⁻² and “dense stands” as those with densities of up to about 200 culms m⁻² in wet areas or up to 300 culms m⁻² in dry areas.

Plants generally flower and set seed between July and October and may produce great quantities of seed, which then is dispersed. However, in some cases, most or all of the seed produced is not viable. Seeds are normally dispersed by wind but may be transported by birds such as red-winged blackbirds that nest among reed. Following seed set, nutrients are translocated down into the rhizomes and the above-ground portions of the plant die back for the season. Temperature, salinity and water levels affect seed germination.

Availability and sustainable resources in Estonia

In the Baltic Sea region, biggest reed beds are located in Sweden, about 100 000 ha. Despite its smaller surface, Estonia has a not negligible percentage of its territory covered by wetland, where reed represents the dominating plant. A study carried out in the Department of Thermal Engineering (TED) of Tallinn University of Technology (TUT) locates the main wetlands and quantifies their extensions, as shown in Figure 2. [1] Wetlands are mainly covered by reed beds and, on a smaller scale, by other herbaceous plants.

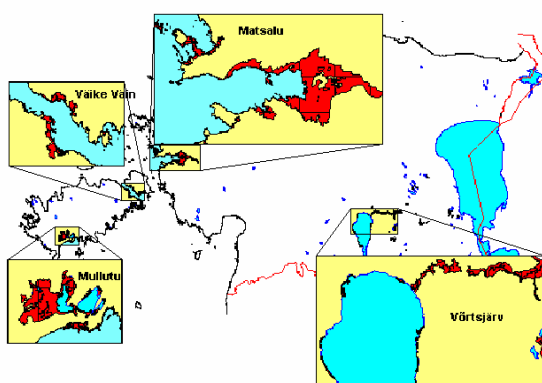


Figure 2. Main Estonia wetland locations

The area of reed beds in Matsalu wetlands is about 2 500 ha (some data refer about 3 000 ha). In Võrtsjärv, the areas of reed beds is approximately 1200 ha, around Peipsi Lake 930 ha [2] and in Käina bay 180 ha. In Saare County, the assessed harvesting potential is about 1 000. Many other reed beds (approximately 11 000 ha) can be harvested, but some limits have to be taken in consideration. Natural preservation limits are in force in Matsalu Natural Reserve, where reed can be harvested only during winter above ice. This location deserves some words more because of its beauty and of its

naturalistic value, which I personally had the opportunity to enjoy in September 2006.

Speaking about productivity, some researches say that about 1-1.5 kg of dry substance per 1 m² grows in natural wetlands, but adding nutrients the productivity can reach 4-5 kg/m² per year. This corresponds to 10-15 t of dry biomass per hectare, or 40-50 t/ha with nutrients. Last kind of yield can be expected from artificial wetlands, where wastewater from settlements or farms is processed (phyto-cleaning). Reed productiveness in Peipsi Lake has continuously increased during last 20 years. Average biomass yield of several testing points is 1.5 kg/m² of dry matter (15 t/ha) [2]. Productivity of above-water biomass in Matsalu reed beds is 11-12 t/ha dry matter per year [3].

But one thing is biomass production, another is the yield we get when we harvest reed: none of the reed cutting entrepreneur has ever obtained values for the yield as those just written (despite they have worked in the 90% of reed bed areas). A values for reed yield closer to reality can be 3 to 5 t/ha at a moisture content of 15%. Anyway, so different values show that we need more reliable data about this topic.

Tables 1 summarize a study carried on at the DET of TUT: it describes the quantity of reed in the Estonian districts and the corresponding energy amounts, supposing an energy yield of 32 MWh ha⁻¹ y⁻¹. Harvesting is thought to be possible in half of the area. In conclusion, reed primary energy resources in Estonia are estimated to be 0.45 TWh per year.

Table 1.
Reed primary energy resources in Estonian wetlands

District	Reed beds area, ha	Harvestable area, ha	Energy content, GWh/y
Harjumaa	265	130	4.16
Hiiumaa	623	300	9.60
Saaremaa	4 937	2 400	76.80
Pärnumaa	1 343	670	21.44
Viljandimaa	577	290	9.28
Valgamaa	491	245	7.84
Võrumaa	497	250	8.00
L.-Virumaa	379	190	6.08
Tartumaa	4 201	2 100	67.20
Läänemaa	10 457	4 700	150.40
Total	23 770	11 275	360.80

Reed productivity tests

Previously presented different values of reed productivity show, that we need more reliable data about this topic. Results of reed productivity measuring tests in Estonian wetlands, coastal sea and lakes are carried out by researches of TED in winter (since February till April 2006) and summer 2006 (in the beginning of August). This research is a part of Finnish-Estonian Interreg IIIA program – project "Reed strategy in Finland and Estonia" bio energy module.

The aim of this investigation is to clarify the energetic potential of reed and with what kind of technologies it could be used as a fuel in small scale to district heating systems.

The district selection was made on the basis of the interest of Estonian municipalities participating in this project (Saare County, Kuressaare Town, Haapsalu Town, Lihula and Noarootsi Parishes), the location of bigger wetlands (Matsalu National Park, Silma Nature Park, Mullutu bay, Väinameri etc), the diversity of districts (shores of open sea like in Häädemeeste Parish, sea bays like Rocca al Mare in Kopli Gulf near debouch of Mustjõe river, lake shores in Peipsi and Võrtsjärv) and on the basis of

the principle that all bigger areas that offer industrial interest would be covered. In numerous abovementioned places have been cut reed for building material. The choice of districts should give a sufficient overview of the biomass productivity of Estonian wetlands.

Overall results of productivity measuring are presented in table 2 and table 3. There are presented productivity as received mater (t/ha), the volume can go directly to the boiler house as energetic fuel, and also as a dry mater. On the basis of dry mater the productivity of biomass of cut reed can be measured in different period (summer, winter) and in different weather conditions (dry, wet).

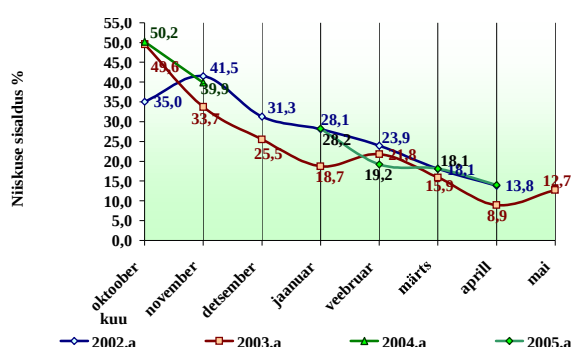
Utmost productivity of dry mater of reed was in Häädemeeste Parish, in Rannametsa Village (cutting area average 9.8 t/ha) and in Kassari, near by Orjaku dam (average 9.25 t/ha). Reed fields of smallest productivity were in Matsalu sedge reedbed (average dry productivity 1.65 t/ha) and in Suurlaht, Kaarma parish (2.5 t/ha). Average productivity of received mater was 8.06 t/ha and dry mater 6.30 t/ha in winter time and respectively 19.98 t/ha and 8.55 t/ha in summer time. In winter time can meet snow, some damages of plants and leaves have fallen down. This may decrease the yield of reed dry matter 20-25%.

Table 2. Reed productivity and moisture content of Estonian reed beds, February-April 2006

<i>No of sample</i>	<i>County, town, parish, time</i>	<i>Accurate location</i>	<i>Average productivity as received mater, t/ha</i>	<i>Average productivity of dry mater, t/ha</i>	<i>Average moisture content of samples, %</i>
1	Põlvamaa, Värskä vald, 10.02.06	Popovitsa küla, Peipsi	10,75	8,45	21,37
2	Põlvamaa, Mikitamäe v., 10.02.06	Lüübnitsa küla, Peipsi	9,25	7,4	20,0
3	Tartumaa, Meeksi vald, 10.02.06	Mehikoorma k., Peipsi	6,33	4,91	22,55
4	Harjumaa, Loksa vald, 15.02.06	Turbuneeme küla	11	8,82	19,8
5	Harjumaa, Kuusalu vald, 15.02.06	Tapurla küla	8,67	6,52	24,8
6	Saaremaa, Muhu vald, 03.03.06	Linnuse küla	6,21	4,94	20,42
7	Saaremaa, Põide vald, 03.03.06	Before Väinatamm,	7,75	6,12	21,02
8	Saaremaa, Laimjala, 03.03.06	Ruhve küla	7,75	5,89	24,05
9	Hiiumaa, Käina vald, 10.03.06	Vaemla (Laisna) küla	11,21	9,25	17,47
10	Hiiumaa, Orjaku õpperada, 10.03.	At lighthouse,	8,83	7,25	17,96
11	Viljandimaa, Vaibla, 13.02.2006	Vaibla, Võrtsjärv	6,17	4,78	22,42
12	Viljandimaa, Jõesuu, 13.02.2006	Jõesuu, Võrtsjärv	5,0	3,77	24,55
13	Saaremaa, Kaarma vald, 10.03. 06	Mullutu laht	6,65	5,48	17,58
14	Saaremaa, Kaarma vald, 10.03. 06	Suurlaht	3,0	2,49	17,13
15	Saaremaa, Kaarma vald, 10.03. 06	Kasti laht	4,33	3,59	17,17
16	Läänemaa, Matsalu RP , 18.03.06	Kirikuküla	7,07	5,99	15,3
17	Läänemaa, Matsalu RP, 18.03.06	Mouth of TuudiRiver	8,53	7,27	14,75
18	Läänemaa, Matsalu RP, 18.03.07	Kirikuküla	1,93	1,65	14,9
19	Pärnumaa, Häädemeeste 24.03.06	Rannametsa küla	12,6	9,79	22,27
20	Pärnumaa, Tahkuranna v. 24.03.06	Tahku küla	7,1	5,79	18,43
21	Pärnu linn, 24.03.06	Papiniidu street	6,33	5,16	18,46
22	Läänemaa, Noarootsi v., 17.03. 06	Sutlepa meri	3,9	3,25	16,78
23	Läänemaa, Oru vald, 17.03.2006	Saunja laht	4,53	3,79	16,42
24	Tallinn, Rocca al Mare, 28.03.2006	Kopli laht	13,83	7,4	46,5
25	Haapsalu linn, 8.04.2006	Tagalaht	15,95	12,35	20,58
26	Läänemaa, Virtsu, 8.04.2006	Puhtu-Laelatu LKA	14,8	11,70	20,88
27	Average productivity of Estonian reed beds, winter-spring 2006		8,06	6,30	20,52

Table 3. Reed productivity and moisture content of Estonian reed beds, August 2006

No of sample	County, town, parish, time	Accurate location	Average productivity as received mater, t/ha	Average productivity of dry mater, t/ha	Average moisture content of samples, %
1	Põlva mk, Värskla vald, 07.08.06	Pihkva Lake, Värskla Bay,	23,50	10,32	56,10
2	Põlva mk, Mikitamäe vald, 07.08.06	Pihkva Lake, Lüübnitsa	25,35	10,76	57,55
3	Harju mk, Loksa vald, 07.08.06	Turbuneeme küla	47,30	17,22	63,60
4	Viljandi mk, Kolga-Jaani vald, 07.08.	Vaibla küla	14,60	6,48	55,60
5	Viljandi mk, Emajõe, 07.08.06	Jõesuu	11,35	5,27	53,55
6	Mahu, Viru-Nigula vald, 07.08.06	Mahu küla	7,23	3,04	57,95
7	Pärnu mk, Pärnu linn, 10.08.06	Papiniidu street	37,30	16,62	55,45
8	Lääne mk, Hanila vald, 10.08.06	Puhtu-Laelatu LKA	21,50	9,52	55,70
9	Lääne maakond, Lihula vald, 10.08.06	Matsalu RP, Kirikuküla	13,00	5,90	54,65
10	Hiiu mk, Käina vald, 12.08.06	Orjaku küla	18,60	7,58	59,25
11	Saare mk, Kaarma vald, 12.08.06	Mullutu küla	21,60	8,91	58,75
12	Saare mk, Põide vald, 13.08.06	Väike Väin	14,50	5,84	59,75
13	Saare mk, Muhu vald, 12.08.06	Väike Väin	21,50	8,89	58,65
14	Lääne mk, Oru vald, 15.08.06	Sutlepa küla	12,10	5,09	57,90
15	Harju mk, Tallinna linn, 09.08.06	Rocca Al Mare, Kopli Bay	26,30	10,95	58,35
16	Lääne mk, Haapsalu linn, 08.04.06	Aiavilja street	22,45	9,41	58,10
17	Saare mk, Kuressaare linn, 12.08.06	Loode tammik	8,70	3,52	59,50
Average productivity of Estonian reed beds, summer 2006			19,98	8,55	57,67

**Figure 3.** Dynamics of monthly moisture content of reed in 2002-2005

Combustion characteristics of reed

Average calorific value of the winter reed at moisture content 20% was 14.6 MJ/kg or 4.06 MWh/t. In calculations of energy resources we use round value of energy content 4.0 MWh/t. Changes in moisture content of reed through the month are measured during the three years (Fig. 2). Intensive drying of plants starts in October and minimal moisture content attain in March-April, which is the best time for harvest the reed, if we have a wish to use it in unchanged form as fuel for the boilers.

Ultimate analyses of reed from different growing places disaccord a few (Table 4).

Table 4. Content of elements in dry matter of different samples of reed

Sample no	County and place	C	H	N	S	O	Cl
I 06 01	Põlva maakond, Peipsi	47,34	5,545	0,237	0,068	43,61	0,17
I 06 02	Harju maakond, Turboneeme	47,06	5,578	0,261	0,054	43,747	0,16
I 06 03	Saare maakond, Väike Väin	47,55	5,50	0,233	0,041	43,176	0,11
I 06 04	Hiiu maakond, Käina	47,37	5,61	0,275	0,029	43,816	0,05
I 06 05	Viljandi maakond, Võrtsjärv	47,63	5,562	0,95	0,033	42,925	0,14
I 06 06	Saare maakond, Mullutu	47,62	5,598	0,308	0,033	42,841	0,05
I 06 07	Saare maakond, Kasti	47,47	5,587	0,29	0,092	43,561	0,18
I 06 08	Lääne maakond, Lihula	47,92	5,54	0,272	0,025	43,743	0,07
I 06 09	Pärnu maakond	47,64	5,592	0,246	0,041	43,181	0,12
I 06 10	Lääne maakond, Silma	47,45	5,517	0,234	0,026	43,373	0,06
I 06 11	Harju maakond, Rocca al Mare	46,96	5,508	0,34	0,042	42,75	0,16
I 06 12	Lääne maakond, Haapsalu	47,44	5,524	0,253	0,04	43,043	0,09
I 06 13	Lääne maakond, Virtsu	48,34	5,563	0,262	0,047	43,688	0,06

Necessary to mention that the nitrogen content in Võrtsjärve reed is differs from average value 3.5 times. The minimum and maximum content of sulfur and chlorine as the most well-known corrosion promoters can differ depending from growing places approximately four times (compare sulfur content in samples 1 06 07 and 1 06 08 and chlorine in samples 1 06 06 and 1 06 07).

Average ash content of reed samples is 3.2 %, but the differences between maximum and minimum values approximately two times (Rocca al Mare and Virtsu samples, Fig 5).

Research has shown that the main chemical component of reed ash is SiO_2 , which average content is 77.8% (difference between the minimum and maximum value $\sim 20\%$, Fig. 4).

Quantities of the other ash chemical components are staying lower than 10%. Essential reed ash chemical components affects to ash-fusibility temperatures are CaO , K_2O and Na_2O (Fig 3). Table 5 gives the winter and summer reed ash-fusibility temperatures. Important to mark that the summer reed ash has fused down at temperature lower 1200°C , initial deformation take place at temperatures lower 800°C (Table 5). On the other hand ash of the winter reed has not fused down even 1350°C ; only one sample shows evidence the deformation temperature only $\sim 800^\circ\text{C}$. We able to state that average ash-fusibility temperatures for summer and winter reed ashes differ 200 K. This point out that reed as fuel for boilers is necessary to harvest certainly in winter, when the nutrients and minerals are leaved to the roots and leaves are fallen town.

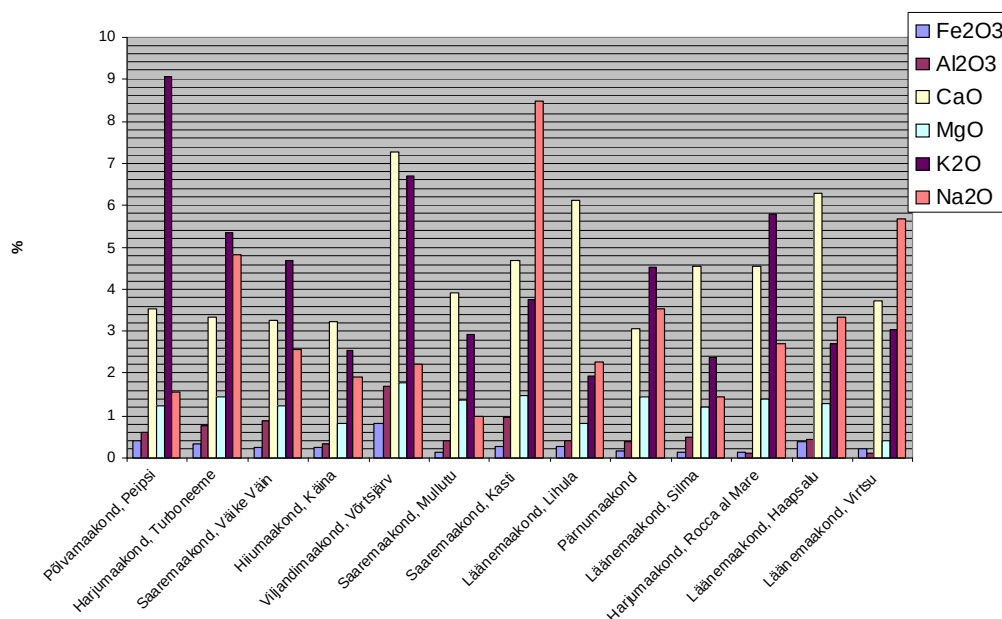


Figure 4. Results of silicate analysis of reed ash

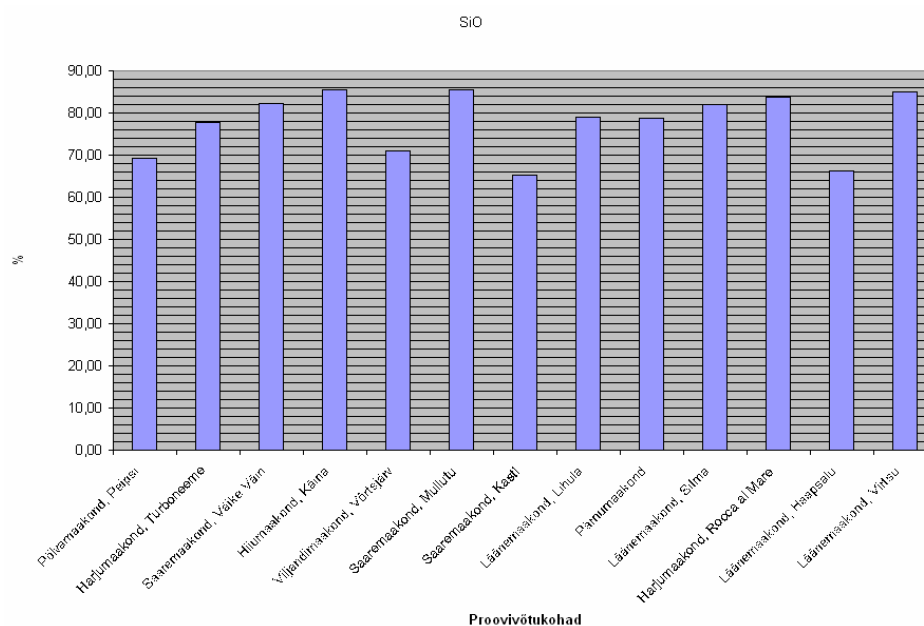


Figure 5. SiO_2 content in different samples of reed ash

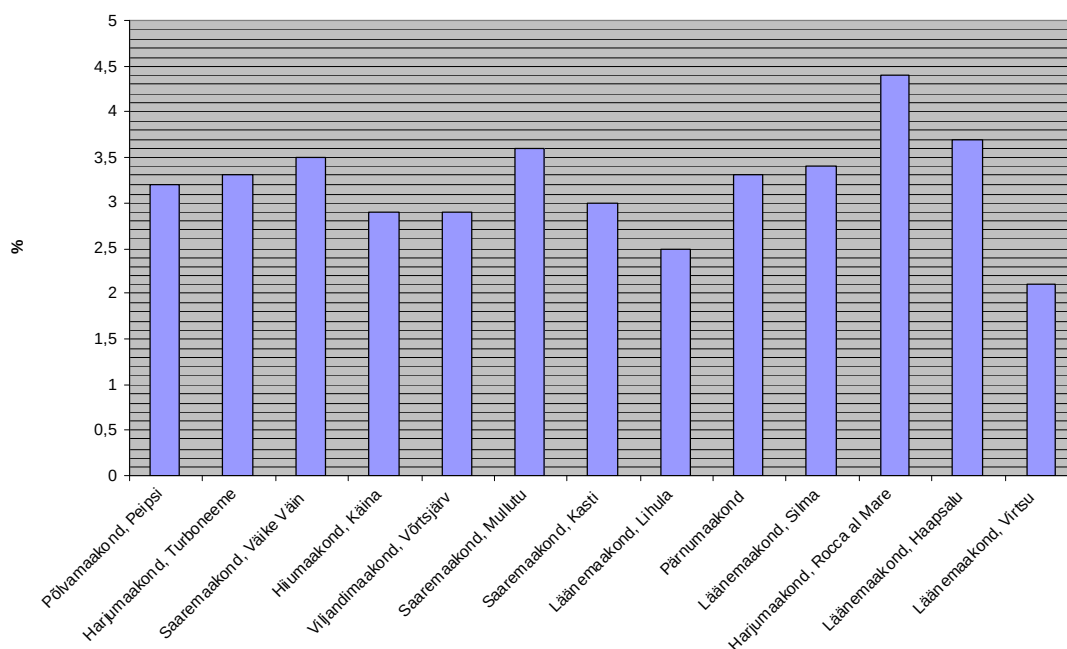


Figure 6. Ash content in different samples of reed dry matter (winter), at 550 °C

Table 5. Fusibility characteristics of reed

Fusibility characteristics of summer reed							
Samples from different places	I 06 01	I 06 02	I 06 03	I 06 04	I 06 05	I 06 06	I 06 07
Point of deformation (IT) °C,	700	650	670	640	730	690	580
Softening temperature (ST) °C	990	1000	1040	960	1030	910	760
Formation of hemisphere (HT) °C	1130	1110	1120	1060	1150	1080	910
Flow temperature (FT) °C	1170	1130	1160	1090	1170	1120	990
Fusibility characteristics of winter reed							
Point of deformation (IT) °C,	800	1040	1220	up to 1350 don't melt	790		1050
Softening temperature (ST) °C	1240	up to 1330 don't melt	up to 1330 don't melt		1040		1200
Formation of hemisphere (HT) °C	1290				1230	up to 1375 don't melt	1270
Flow temperature (FT) °C	up to 1340 don't melt				1270		1290

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