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ESSENTIAL PROPERTIES OF REED AND THEIR INFLUENCE ON COMBUSTION EQUIPMENT

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Topics

- Why are the properties so essential?
- The characteristics under observation
- Field works – gathering the samples
- Productivity of reed beds
- Moisture, elemental composition, calorific value, ash content and composition
- Conclusions

Why are the properties so essential?

- To examine the properties of reed as a potential bio fuel are important, because
  - - the way of handling of reed for burning,
  - - lifetime of combustion equipment (due to fouling, erosion and corrosion),
  - - combustion regimes
  - - and environmental impacts like pollutants, ash handling etc,

  depend on these properties.

- This presentation presents the results of tests carried out in Thermal Engineering Department of Tallinn University of Technology during 2006 – 2011.

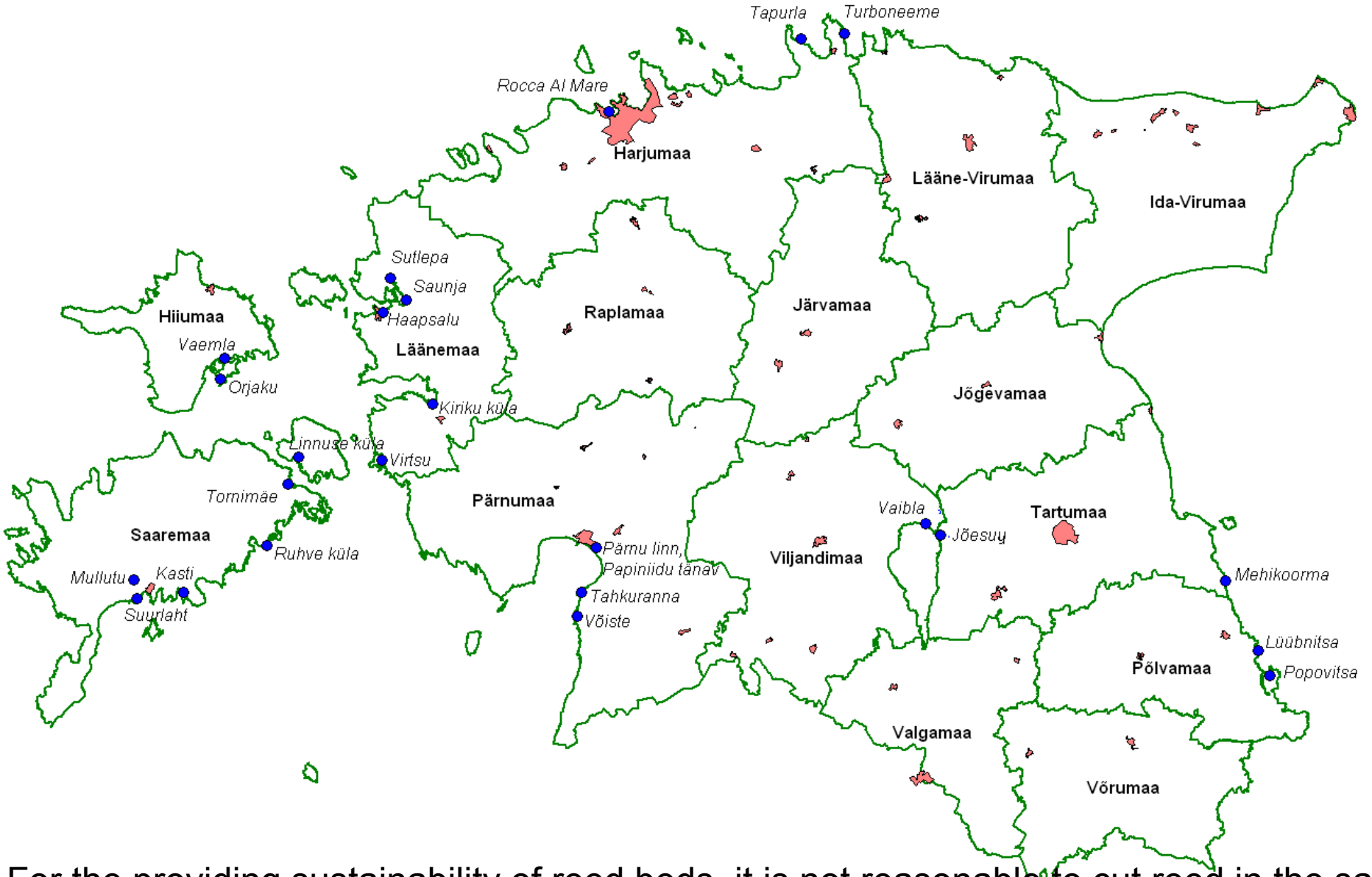
The characteristics under observation

- Chemical composition of summer and winter harvested reed
- Moisture and ash content,
- Ash fusibility temperatures,
- Physical properties like bulk density,
- Calorific value and energy content.

Field works – gathering the samples

- TUT, Department of Thermal Engineering has arranged measurements of reed yield and gathering the samples for laboratory tests in 27 different growing sites total of 9 Estonian counties, both in the spring-winter and summer period in 2006-2007.

Places in Estonia where samples of reed were taken, 2006-2007



For the providing sustainability of reed beds, it is not reasonable to cut reed in the same areas each year and harvesting in all the areas is also not realistic due to unfavourable environmental conditions and ownership relations.

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

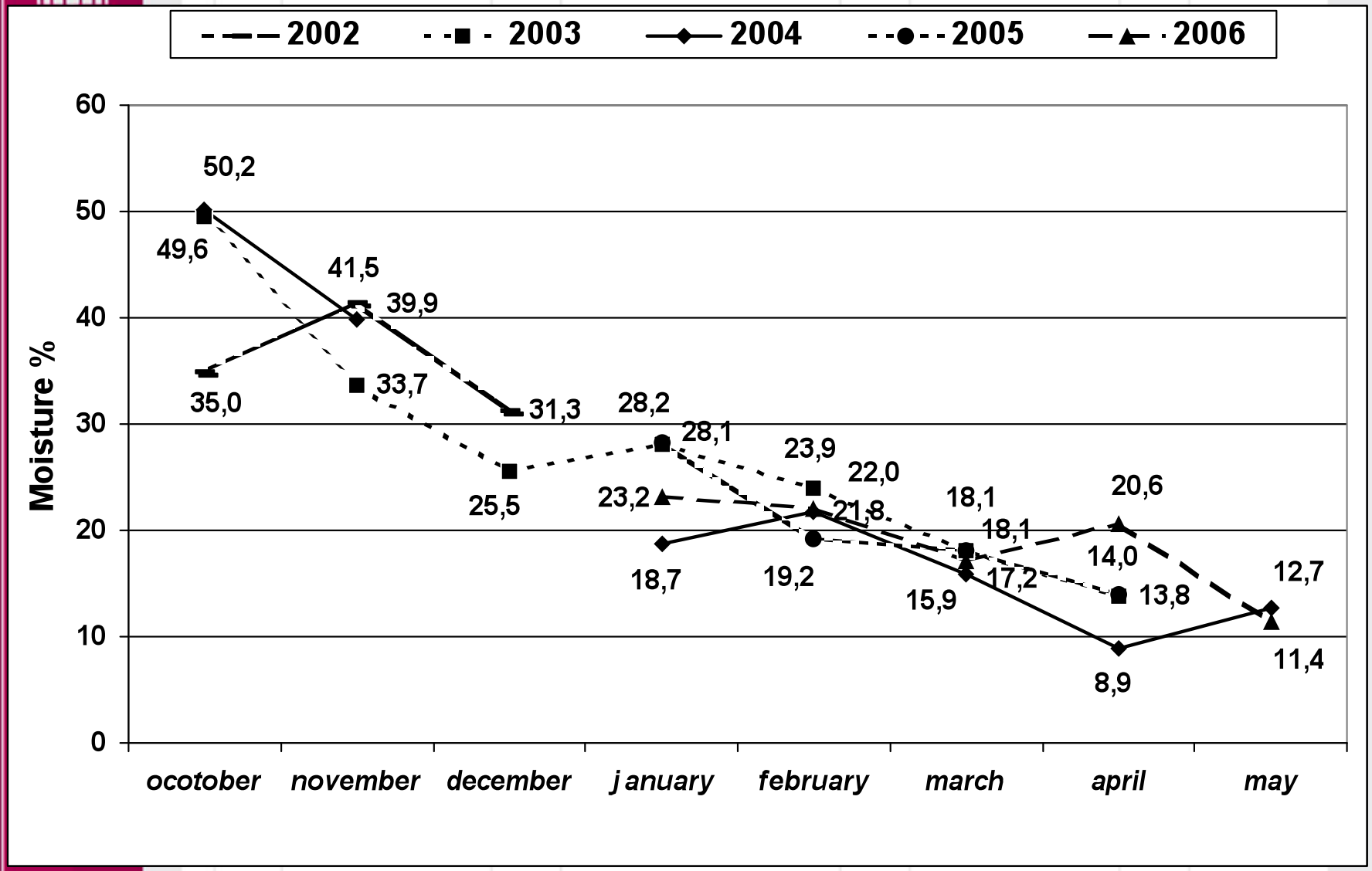
No	County, town, parish, time	Accurate location	Average productivity as received mater, t/ha	Average productivity of dry mater, t/ha	Average moisture content of samples, %
1	Põlvamaa, Värska vald, 10.02.06	Popovitsa küla, Peipsi	10,75	8,45	21,37
2	Põlvamaa, Mikitamäe v., 10.02.06	Lüübnitsa küla, Peipsi	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, Pöide 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
…					
27	**Average productivity of Estonian reed beds, winter-spring 2006**		**8,06**	**6,30**	20,52

Productivity of Estonian reed beds

No	County, town, parish	Average product. as received mater, t/ha				Average productivity of dry mater, t/ha			
	Years	2006		2007		2006		2007	
		Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
1	Põlva maakond, Värska vald	10,75	23,50	9,75	19,10	8,45	10,32	7,75	6,50
2	Põlva maakond, Mikitamäe vald	9,25	25,35	19,33	17,02	7,40	10,76	15,33	6,33
3	Harju maakond, Loksa vald	11,00	47,30	12,57	47,43	8,82	17,22	10,43	14,63
4	L-Viru maakond, V-Nigula vald		7,23	10,17	31,17		3,04	8,45	10,11
5	Saare maakond, Muhu vald	6,21	21,50	7,13	9,70	4,94	8,89	5,79	3,78
6	Saare maakond, Kuressaare L	6,20	8,70	5,10	9,70	4,98	3,52	4,19	4,30
7	Saare mk, Pöide vald	7,75	14,50	7,17		6,12	5,84	5,92	
8	Saare maakond, Kaarma vald	6,65	21,60	4,20	10,23	5,48	8,91	3,46	3,81
9	Saare mk, Kaarma vald	3,00		3,30		2,49		2,75	
10	Saare maakond, Kaarma vald	4,33		4,57	10,00	3,59		3,73	4,05
11	Lääne maakond, Lihula vald			15,60	32,90			8,69	12,38
12	Lääne maakond, Lihula vald	8,53	13,00	9,90	14,13	7,27	5,90	5,68	5,50
13	Pärnu maakond, Häädemeeste v.			8,87	22,87			4,73	8,28
14	Pärnu maakond, Pärnu linn	6,33		9,87	31,37	5,16	16,62	5,47	12,17
15	Lääne maakond, Noarootsi vald	3,90	12,10	5,20	10,40	3,25	5,09	4,4	4,72
16	Lääne mk, Oru vald	6,33		5,05		3,79		4,16	
17	Harju maakond, Tallinna linn	13,83	26,30	14,23	17,93	7,40	10,95	11,46	6,09
18	Lääne maakond, Haapsalu linn	15,95	22,45	9,30	15,65	12,35	9,41	6,19	5,89
19	Lääne maakond, Hanila vald	14,80	21,50	6,40	18,70	11,71	9,52	2,89	7,52
20	Hiiu maakond, Käina vald	8,83	18,60	12,65	18,50	7,25	7,58	8,46	7,58
21	Viljandi maakond, K-Jaani vald	6,17	14,60	10,57	20,25	4,78	6,48	8,41	7,09
Average productivity,		**8,32**	**19,88**	**9,09**	**19,33**	**6,00**	**9,34**	**6,59**	**7,09**

Weight loss in winter - 2,25 t/ha or 26,3%

Moisture content dynamics of reed from October till May in 2002–2006



emental composition of dry reed fuel, %

Element	Ranges		Average	
	Winter	Summer	Winter	Summer
Carbon, C	46,96−48,34	46,13−47,11	47,5	46,5
Hydrogen, H	5,50−5,60	5,93−6,42	5,6	6,2
Oxygen, O	42,75−43,84	39,7−42,2	43,3	40,7
Nitrogen, N	0,23−0,34	0,57−1,17	0,3	1,0
Sulphur, S	0,03−0,09	0,12−0,45	0,04	0,2
Chlorine, Cl	0,05−0,18	0,28−0,48	0,1	0,4

Comparison of the elemental composition of solid biomass

Fuel source	Elements, %				
	C^p	H^p	S^p	N^p	O^p
Lake reed	46-48	6-8	0,02-0,2	0,24-1,32	37-47
Coastal reed	46-48	6-8	0,01-0,3	0,23-1,81	37-47
Peat	55-60	6-7	0,4-0,6	2-3	30-35
Wood	50-55	6-7	0,05	0,5	40-45

Heating value of dry matter of reed fuel

Parameters: Calorific value, MJ/kg Energy content, MWh/t	Ranges		Average	
	Winter	Summer	Winter	Summer
Q_p/q_b,	18,62−19,16	18,33−18,77	18,92	18,51
$Q_ü^k/q_{gr,\,d}$	18,62−19,16	18,31−18,75	18,91	18,49
$Q_a^k/q_{net,\,d}$	17,48−18,01	17,02−17,44	17,77	17,21
$Q_a^{20}/q_{net,\,20}$ *	**13,68−14,86**	**13,16−13,49**	**14,17**	**13,31**
E^{20}/E_{20}, MWh/t*	**3,80−4,13**	**3,65−3,75**	**3,94**	**3,70**

*at moisture content 20 %

Ash content

- The ash content of reed harvested in winter is 2.1– 4.4 %, in average 3.2 %, but for summer harvested reed it is significantly higher being 4.1– 6.2 %, in average 5.4 %.

- The ash as a solid residue formed by combustion plays an important role in the selection and running of combustion equipment and its auxiliary devices.

Chemical composition of reed ash at (550 °C), %

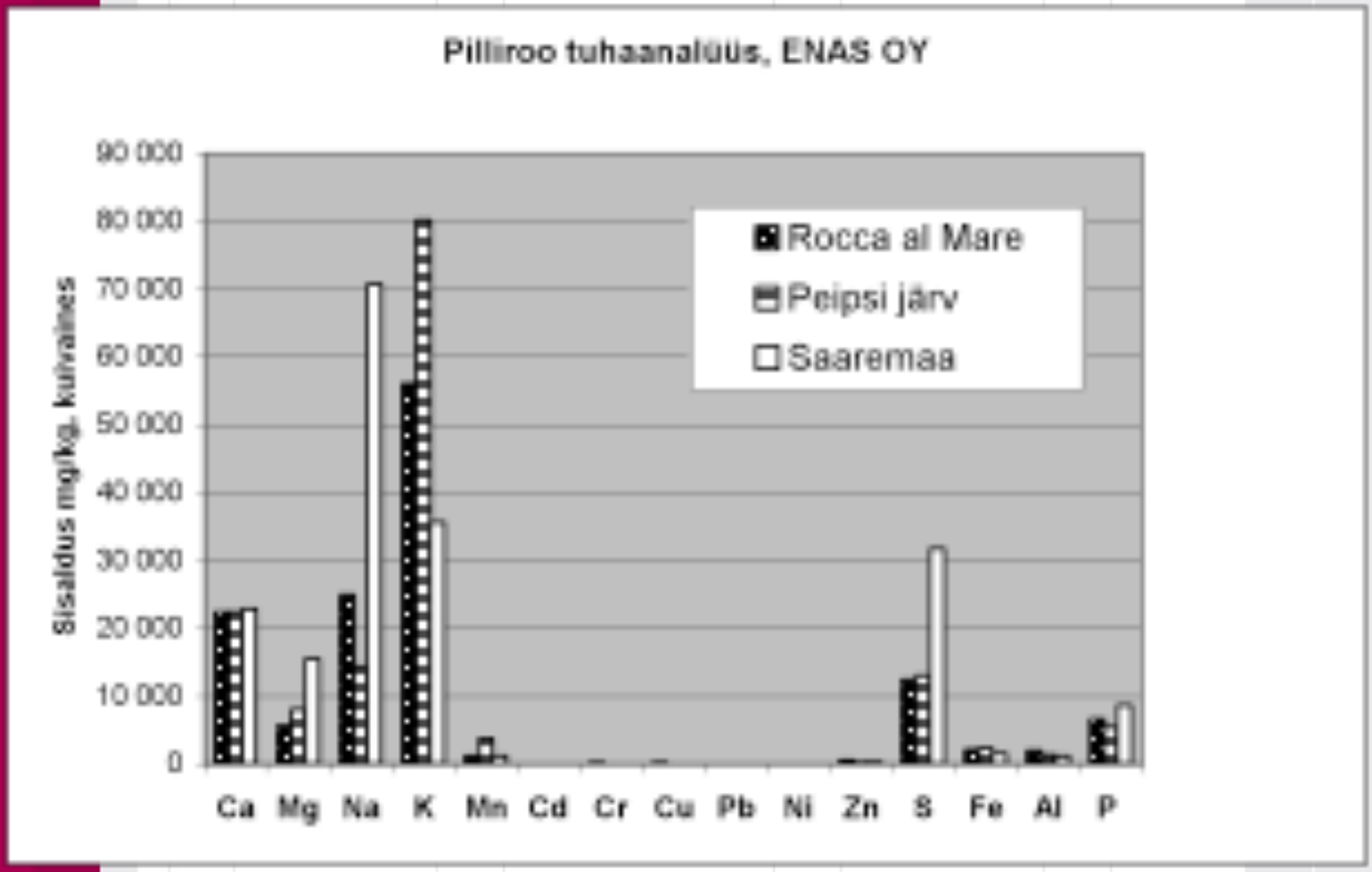
Component	Ranges		Average	
	Winter	Summer	Winter	Summer
SiO_2	65,34−85,50	25,90−48,33	77,77	37,10
Fe_2O_3	0,13−0,84	0,17−1,69	0,29	0,70
Al_2O_3	0,1−1,69	0,11−1,12	0,57	0,61
CaO	3,07−7,27	4,02−11,53	4,42	6,84
MgO	0,4−1,45	1,87−4,88	1,22	3,33
Na_2O	1,96−9,05	0,87−10,98	3,19	3,61
K_2O	0,99−5,69	14,89−31,33	4,26	24,77
Other	1,57 − 19,4	17,28 − 33,5	8,28	23,04

Reed ash

- The chemical composition of reed ash for summer and winter harvests differs essentially for the content of SiO_2 and K_2O.
- The reed harvested in winter would be a much better fuel to burn in the combustion equipment from the point of view of ash amount and composition.
- The ash of reed harvested and dried in summer contains in significant amounts alkali metals that influence both ash fusibility, formation of ash deposits on the heating surfaces and corrosion.

Reed ash is loose (light) and not collapsing after burning (like wood ash)

Content of some elements in winter reed ash, mg/kg. (By ENAS Oy, Finland)



Fusibility characteristics of reed (summer and winter reed 2006)

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

Reed bottom ash structure

Reed ash properties

- It is important to note that the summer reed ash cone fused down at the temperature lower than 1200°C, initial deformation took place at temperatures below 800°C (Table, see slide before).
- On the other hand ash of the winter reed has not fused down even at 1350°C; only one sample shows evidence the deformation temperature only ~ 800°C.
- We are able to state that average ash-fusibility temperatures for summer and winter reed ashes differ 200 K.

Appearance of fusion of reed ash

Suitable forms of burning reed

- The choice of burning equipment for herbaceous solid biomass (incl. reed) is relatively large, but to find suitable we have to know what are the form and type of fuel and fuel characteristics.

- These are:
  - Pellets (granulated fuel, mechanically processed)
  - Bales (or bundles)
  - Chips (crushed or chopped)

- One suitable way to handle reed as fuel is to make silage and digest it anaerobically for biogas. Biogas as a engine fuel for CHP and transport vehicles.

Reed solid fuels

Conclusions

- The winter times shows more successful for reed as a fuel comparing with summer time, because the burning characteristics of reed are better (moisture content, fusibility of ash, energy content, etc.) when the nutrients and minerals are leaved to the roots and leaves have fallen down.

- The winter harvested reed shows low moisture and ash content compare with summer reed.

- The summer reed ash more melting occurred in the lower temperature range (<1200°C) and for winter reed more melting occurred in the higher temperature range (>1300°C). The most dominating ash forming elements in reeds are SiO2, K2O and CaO.

Conclusions II

- The most well-known components that accelerate corrosion are the compounds of alkali metals, chlorine and sulphur, for example pyrosulfates formed of the named compounds.

- This is why the corrosive impact of alkali metals and low content of sulphur on the boiler heating surfaces must be considered and an appropriate furnace and convective surface metal of boiler will chosen.

Conclusions III

- The reed combustion characteristics vary to some extent depending both on the site of growth (on the shore of sea or lake, river deltas, wetland treatment systems) and seasonally (harvested either in summer or winter).
- In order to gain further experience, tests should be carried out to find suitable fuel handling technologies and combustion equipment and develop combustion regimes for different types of reed.
- It must be considered that reed fuels can be added to other biomass-based fuels, however the peculiarities of their co-combustion should be studied.

Other harnessings of reed

Thank you for your attention!

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