Animal wastes and energy production: manure, biogas, compost

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- Energy production in agriculture- biogas
- Pretreatment of biomass
- Biogas Potential in Estonia
- Biogas plants in Estonia
- Digestate for Compost

Estonian agriculture in figures

Total agricultural land is **1 325 200** ha

By field maps of PRIA 2007:

- Agricultureal land in use **1 126 684** ha
- Abonanded agricultural land **283 485** ha

Source: P. Muiste jt. Eestis olemasoleva, praeguse või juba kavandatud tootmise-tarbimise juures tekkiva biomassi ressursi hindamine, EMÜ 2007

Estonian agriculture in figures (2)

Maakond	Veisesõnnik	Seasõnnik	Lambasõnnik	Hobusesõnnik	Kokku	%	t/ha
Harju	82247	37275	3511	2400	125434	6,0	4,2
Hiiu	16226	8086	1997	480	26788	1,3	8,0
Ida-Viru	33570	4536	895	480	39482	1,9	2,6
Jõgeva	130924	57589	3098	1440	193052	9,2	3,6
Järva	180720	22878	1859	960	206417	9,8	3,6
Lääne	54272	15975	1515	960	72722	3,5	3,7
Lääne-Viru	173447	106303	1652	960	282362	13,5	3,8
Põlva	78331	52658	2341	480	133810	6,4	4,0
Pärnu	137079	10453	2479	2880	152890	7,3	3,7
Rapla	107425	38261	2065	960	148712	7,1	4,9
Saare	85604	49503	7091	2400	144599	6,9	8,2
Tartu	80569	46150	3098	2880	132697	6,3	2,4
Valga	51475	12425	3993	480	68373	3,3	2,9
Viljandi	90640	190320	3167	4320	288447	13,7	4,8
Võru	54272	24456	3718	960	83406	4,0	4,1
KOKKU	**1356802**	**676867**	**42480**	**23040**	**2099189**	**100,0**	**3,9**

Source: P. Muiste jt. Eestis olemasoleva, praeguse või juba kavandatud tootmise-tarbimise juures tekkiva biomassi ressursi hindamine, EMÜ 2007

Biogas yield and Energy of common Agricultural feed stocks

Feedstock	Number of animals to produce 1 tonne/day	Dry Matter Content	Biogas Yield(M3/t)	Energy Value(MJ/m3) Biogas
Cattle Slurry	20-40	12	25	23-25
Pig Slurry	250-300	9	26	21-25
Laying Hen Litter	8,000-9,000	30	90-150	23-27
Broiler Manure	10,000-15,000	60	50-100	21-23
Food Waste	~	15	46	21-25

Source: *http://www.anaerobic-digestion.com*

Biogas

- **Biogas** typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Biogas originates from biogenic material and is a type of biofuel.
- One type of biogas is produced by anaerobic digestion or fermentation of biodegradable materials such as biomass, manure or sewage, municipal waste, green waste and energy crops. This type of biogas comprises primarily methane and carbon dioxide.
- The other principal type of biogas is wood gas which is created by gasification of wood or other biomass. This type of biogas is comprised primarily of nitrogen, hydrogen, and carbon monoxide, with trace amounts of methane

Source: Wikipedia

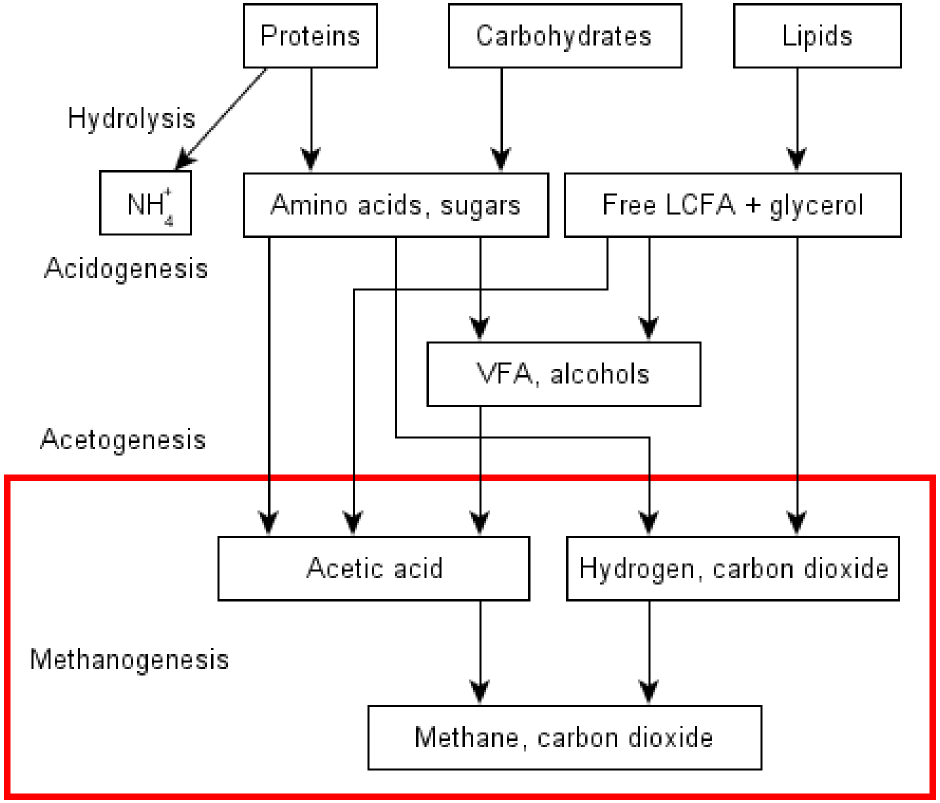
Methanogenesis

- Series of processes in which microorganisms break down biodegradable material in the absence of oxygen.

- Four general stages:
  - Hydrolysis (large polymers into simpler monomers);
  - Acidogenesis (simple monomers into volatile fatty acids);
  - Acetogenesis (volatile fatty acids into acetic acid, CO_2, and H_2)
  - Methagonesis
    - Acetoclastic methanogenesis B.: acetates into CH_4
    - Hydrogenotrophic methanogenesis B.: CO_2 and H_2 into CH_4

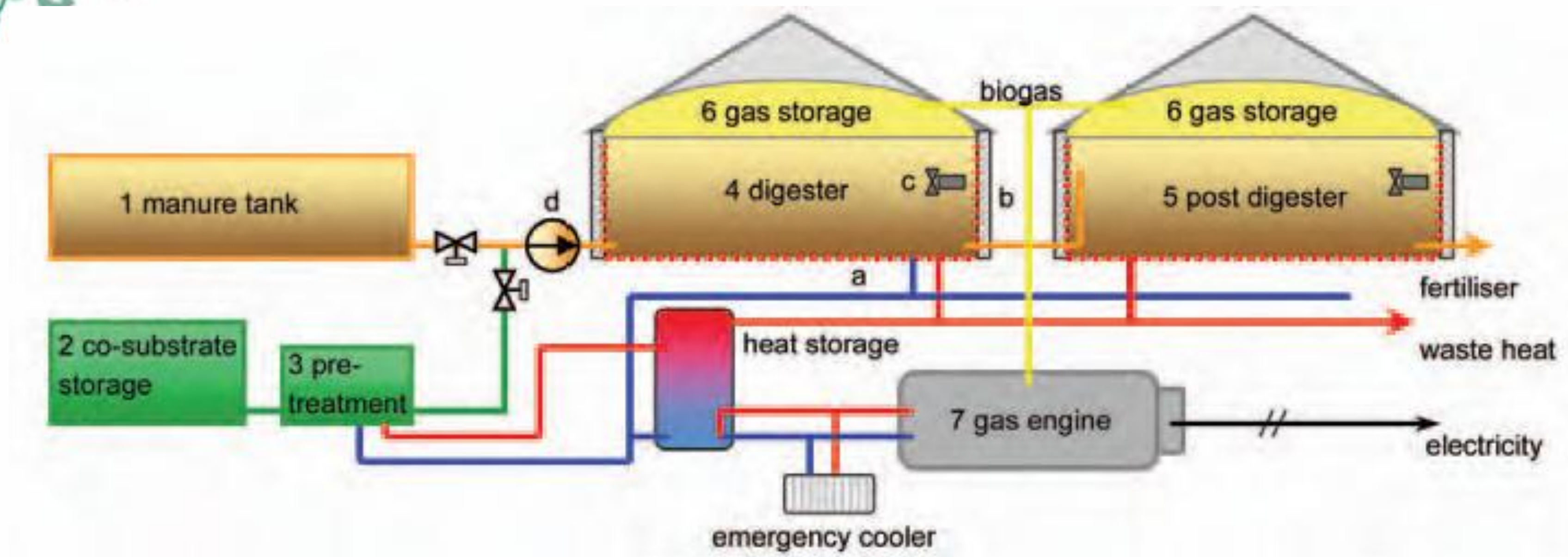
Source: www.wikipedia.org

Methanogenesis (2)



VFA, hydrogen and thermodynamics: significance for ICA.
Prof. H.C. Dubourguier

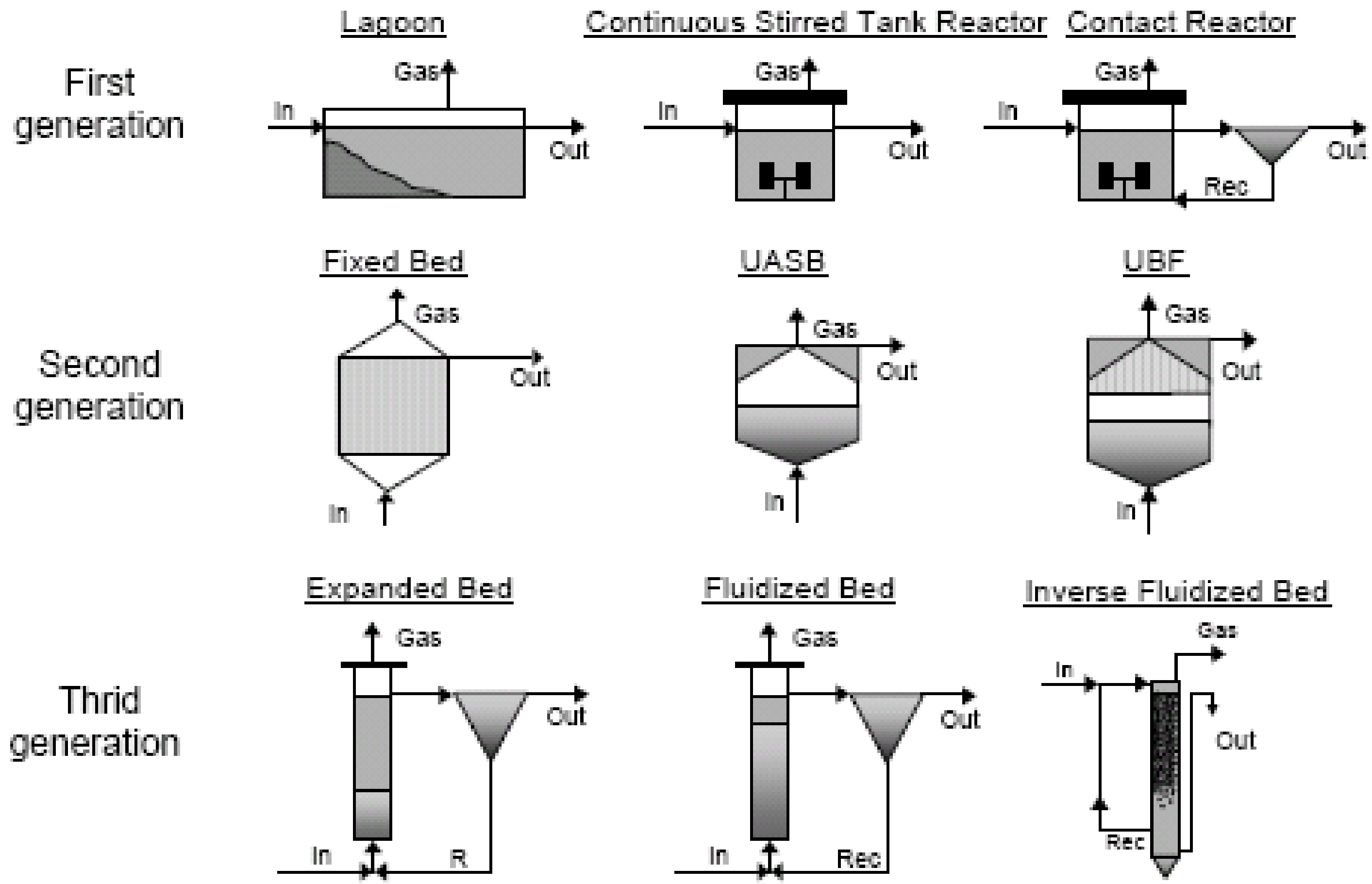
Anaerobic digestion system



Schematic overview of a typical AD system: (a) digester heating; (b) digester insulation; (c) stirring device;(d) substrate pump

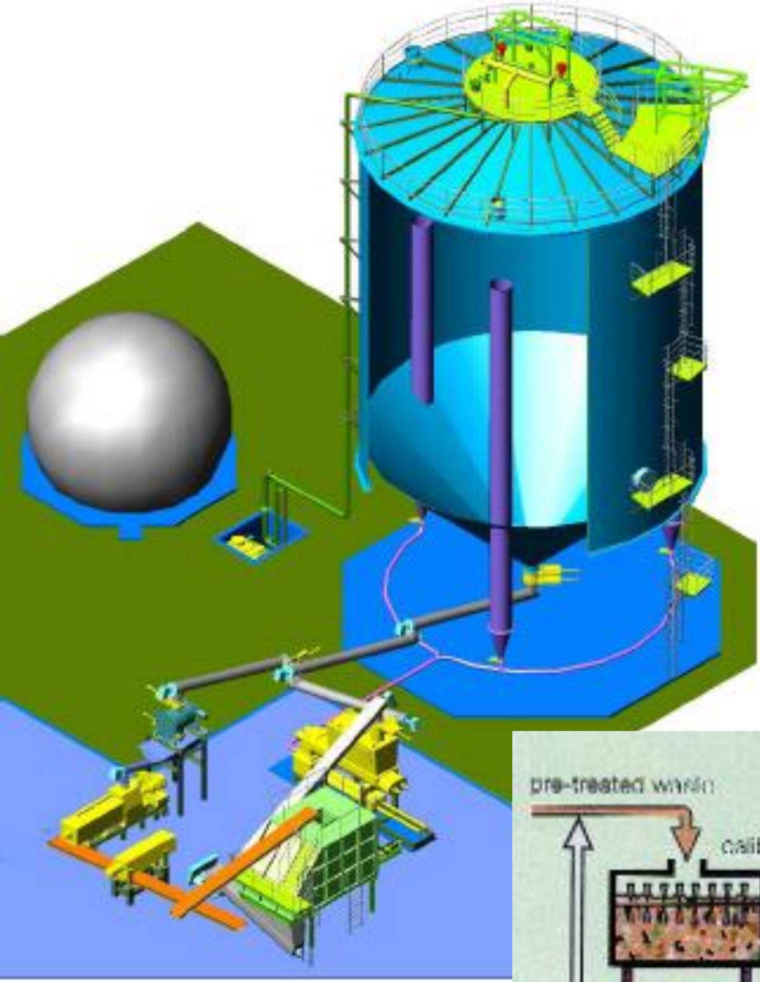
Source: *Planning and Installing Bioenergy Systems James & James Ltd, UK, 2005*

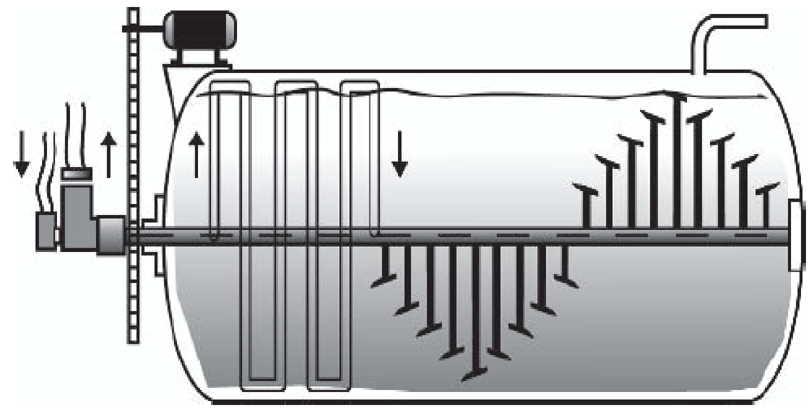
Different generations of AD proccesses

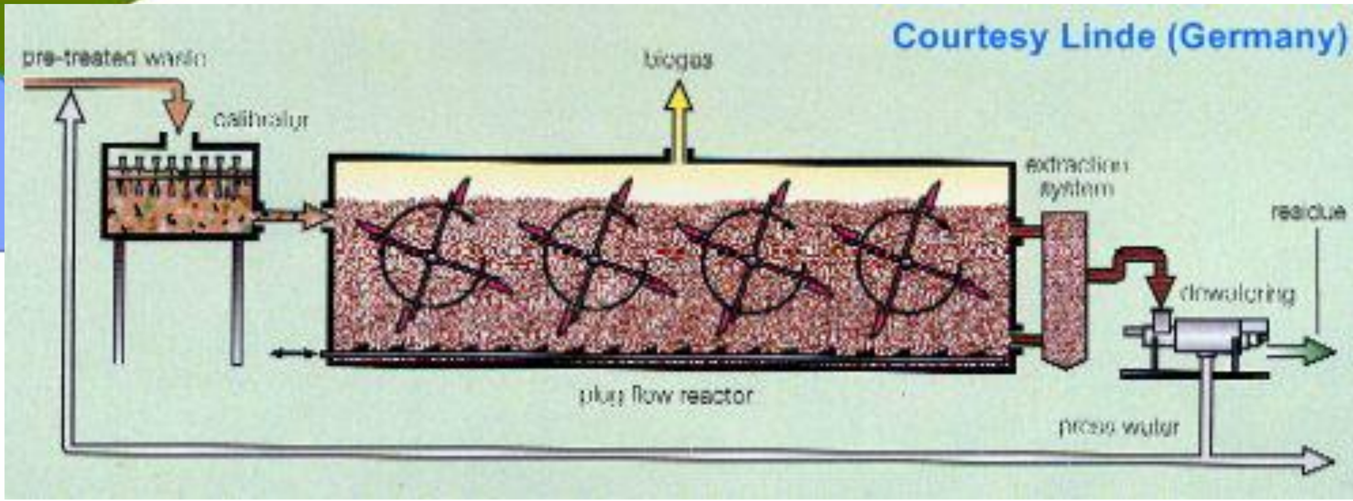


Source: *Instrumentation, Control and Automation in Wastewater sysems, G.Olsson et al. IWA Publishing 2005*

Dry digestion







Allikas: www.anaerobic-digestion.com, www.dranco.be

Domestic reactors

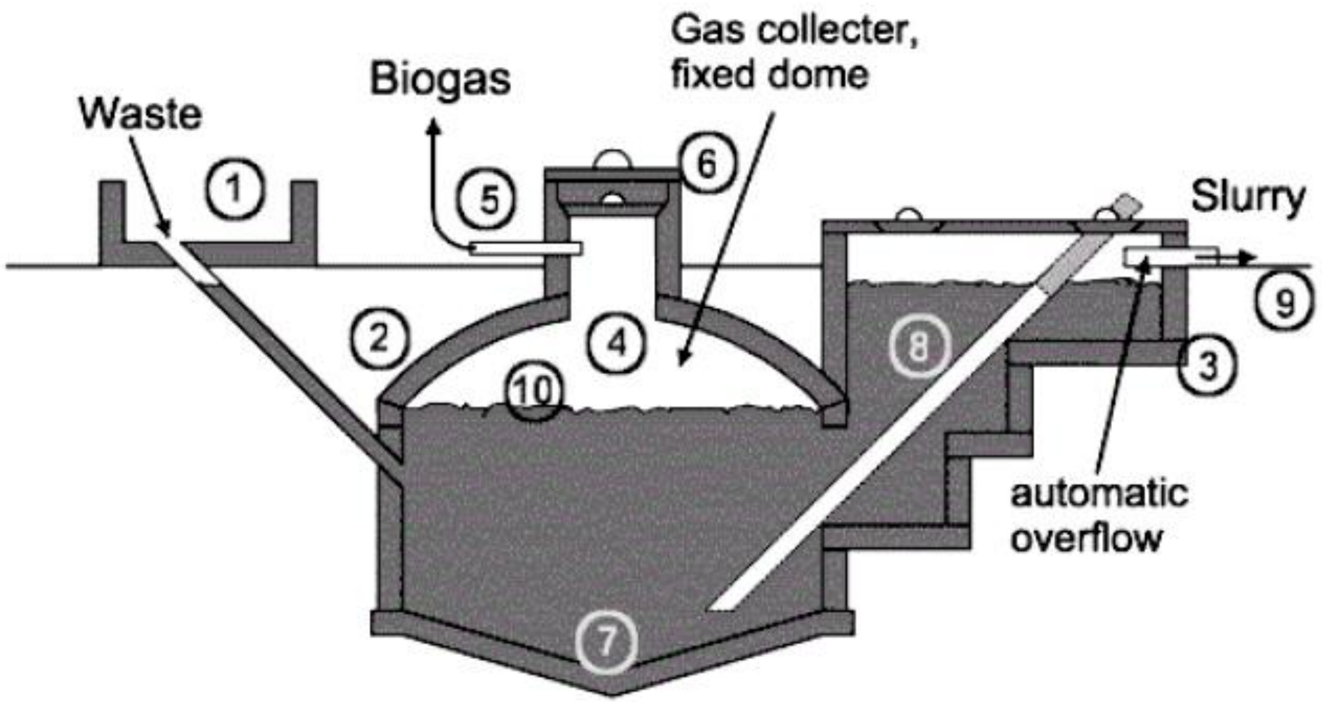


Figure 1: Fixed dome plant Nicarao design: 1. Mixing tank with inlet pipe and sand trap. 2. Digester. 3. Compensation and removal tank. 4. Gasholder. 5. Gaspipe. 6. Entry hatch, with gastight seal. 7. Accumulation of thick sludge. 8. Outlet pipe. 9. Reference level. 10. Supernatant scum, broken up by varying level.

Source: TBW

Allikas: Biogas Digest Volume II Biogas - Application and Product Developmen. 1999 ISAT

Characteristics of most important agricultural feedstock -

Feedstock	Total Solids TS [%]	Volatile Solids [% of TS]	C:N ratio	Biogas Yield [3] [$m^3 \cdot kg^{-1}$ VS]	Retention Time [d]	CH_4 Content [%]	Unwanted substances	Inhibiting substances	Frequent problems	References
Pig slurry	3-8 [4]	70-80	3-10	0.25-0.50	20-40	70-80	Wood shavings, bristles, H_2O, sand, cords, straw	Antibiotics, disinfectants	Scum layers, sediments,	(3), (4), (22), (24)
Cow slurry	5-12 [4]	75-85	6-20 [1]	0.20-0.30	20-30	55-75	Bristles, soil, H_2O, NH_4^+, straw, wood	Antibiotics, disinfectants	Scum layers, poor biogas yield	(3), (4), (22), (24)
Chicken slurry	10-30 [4]	70-80	3-10	0.35-0.60	>30	60-80	NH_4^+, grit, sand, feathers	Antibiotics, disinfectants	NH_4^+-inhibition, scum layers,	(3), (15)
Whey	1-5	80-95	n.a.	0.80-0.95	3-10	60-80	transportation impurities		pH-reduction	(3), (22)
Ferment. slops	1-5	80-95	4-10	0.35-0.55	3-10	55-75	undegradable fruit remains		high acid conc., VFA-inhibition	(3), (22)
Leaves	80	90	30-80	0.10-0.30 [2]	8-20	n.a.	soil	Pesticides		(3), (22)
Wood shavings	80	95	511	n.a.	n.a.	n.a.	Unwanted material		Mechanical problems	(3), (22)
Straw	70	90	90	0.35-0.45 [5]	10-50 [5]	n.a.	Sand, grit		scum layers, poor digestion	(3), (22)
Wood wastes	60-70	99.6	723	n.a.	∞	n.a.	Unwanted material		poor anaerobic biodegradation	(3), (22)
Garden wastes	60-70	90	100-150	0.20-0.50	8-30	n.a.	Soil, cellulosic components	Pesticides	poor degrad. of cellulosic comp.	(3), (22)
Grass	20-25	90	12-25	0.55	10	n.a.	Grit	Pesticides	pH-reduction	(3), (22)
Grass silage	15-25	90	10-25	0.56	10	n.a.	Grit		pH-reduction	(3), (22)
Fruit wastes	15-20	75	35	0.25-0.50	8-20	n.a.	Undegradable fruit remains, grit	Pesticides	pH-reduction	(3)
Food remains	10	80	n.a.	0.50-0.60	10-20	70-80	Bones, plastic material	Disinfectants	Sediments, mechanical problems	(18)

[1] depending on straw addition; [2] depending on drying rate; [3] depending on retention time; [4] depending on dilution; [5] depending on particle size; n.a. = not available

Source: **Feedstocks for Anaerobic Digestion, R. Steffen** et al. Institute for Agrobiotechnology Tulln University of Agricultural Sciences Vienna, 1998

PRETREATMENT OF BIOMASS AND ENERGY CROPS FOR BIOGAS PRODUCTION

Why pre-treatments

Pre-treatment of feedstocks rich in lignocelluloses:

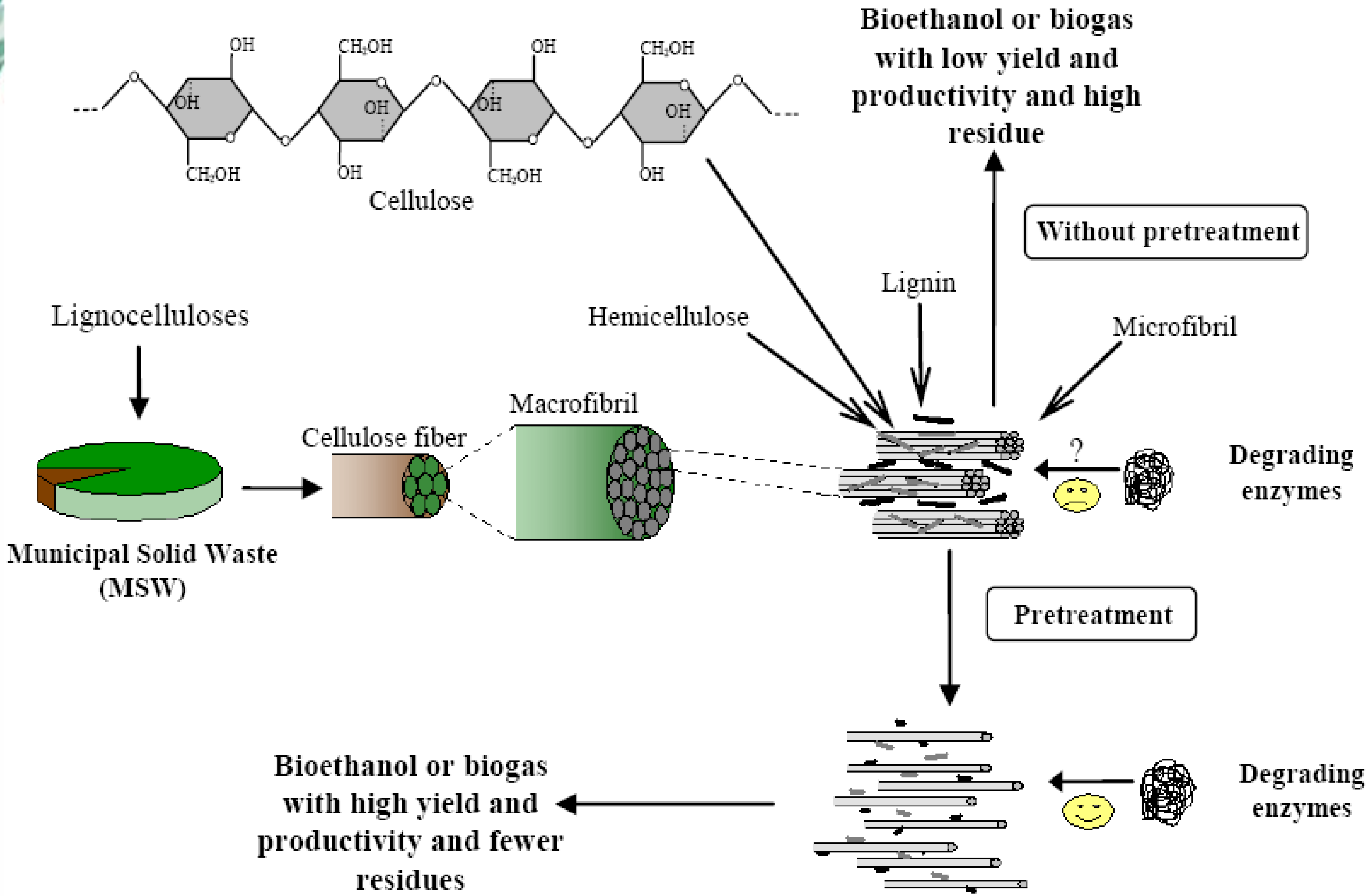
- sizing for technological usability (rheology)
- increases biogas (bioethanol) production
- reduces volatile solids
- increases solubility
- breaks down recalcitrant polymers (biomass feedstocks high in cellulose or lignin)
- enhances the production rate of a reactor
- increases the speed of start up

Lignocellulose degradeability

Lignocellulose consists of:

- Cellulose degradeable (hexoses)
- Hemicellulose degradeable (hexoses and pentoses)
- Lignin not degradeable

Effect of pretreatment on accessibility of degrading enzymes

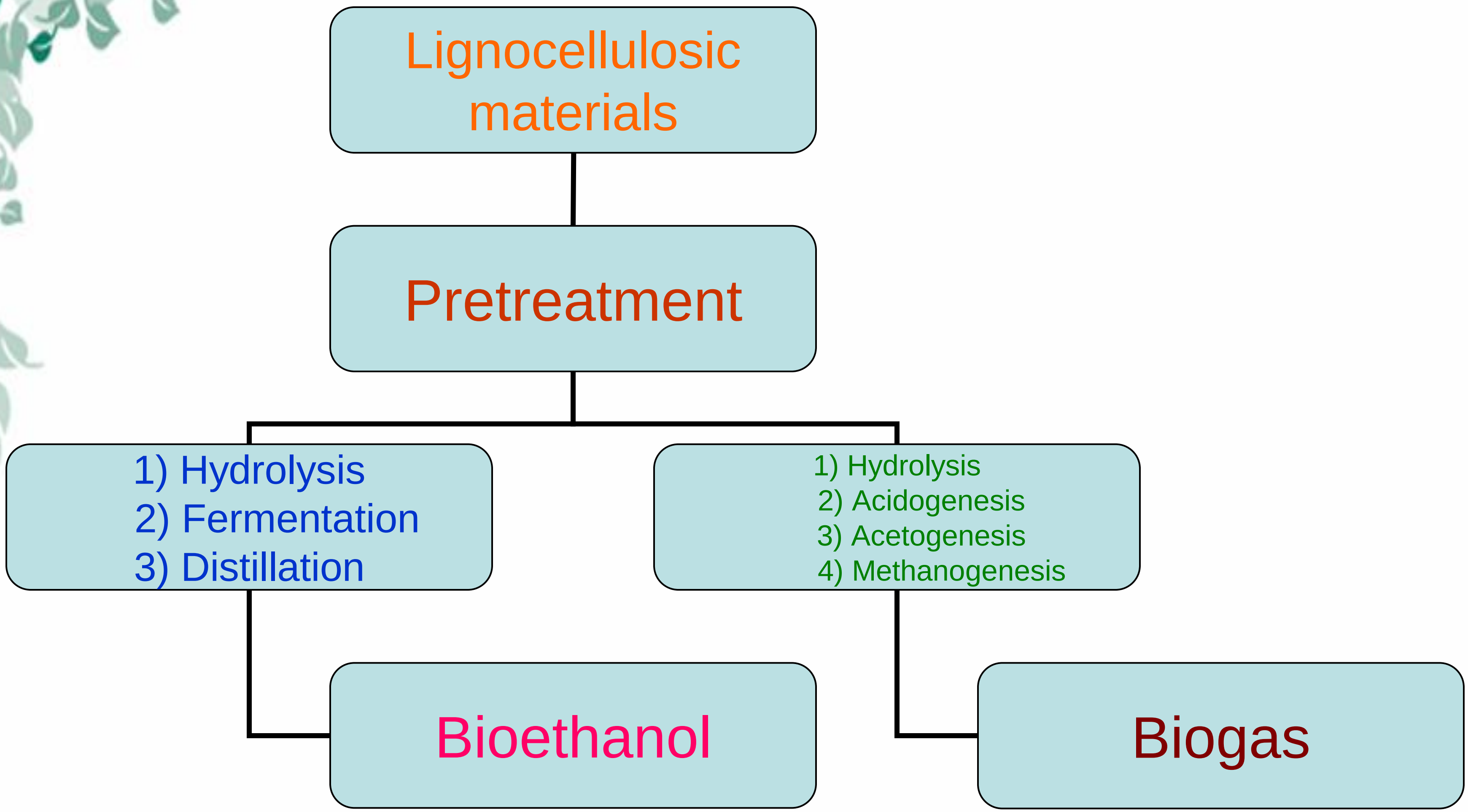


Methods of pre-treatment

Possible pre/ treatment procedures

• Mechanical:	particle size reduction
• Physical:	thermal treatment
	microwave treatment
	ultrasound treatment
• Chemical	addition of chemicals
• Biological	addition of enzumes
• Combinations	

Pretreatment of lignocellulosic materials prior to bioethanol and biogas production



Energy from Grassland

Silage

Hydro- thermal pretreatment

Mechanical dewatering

Liquids

Press cake

Biogas production

Thermal drying

Digestate

CHP

Solid fuel

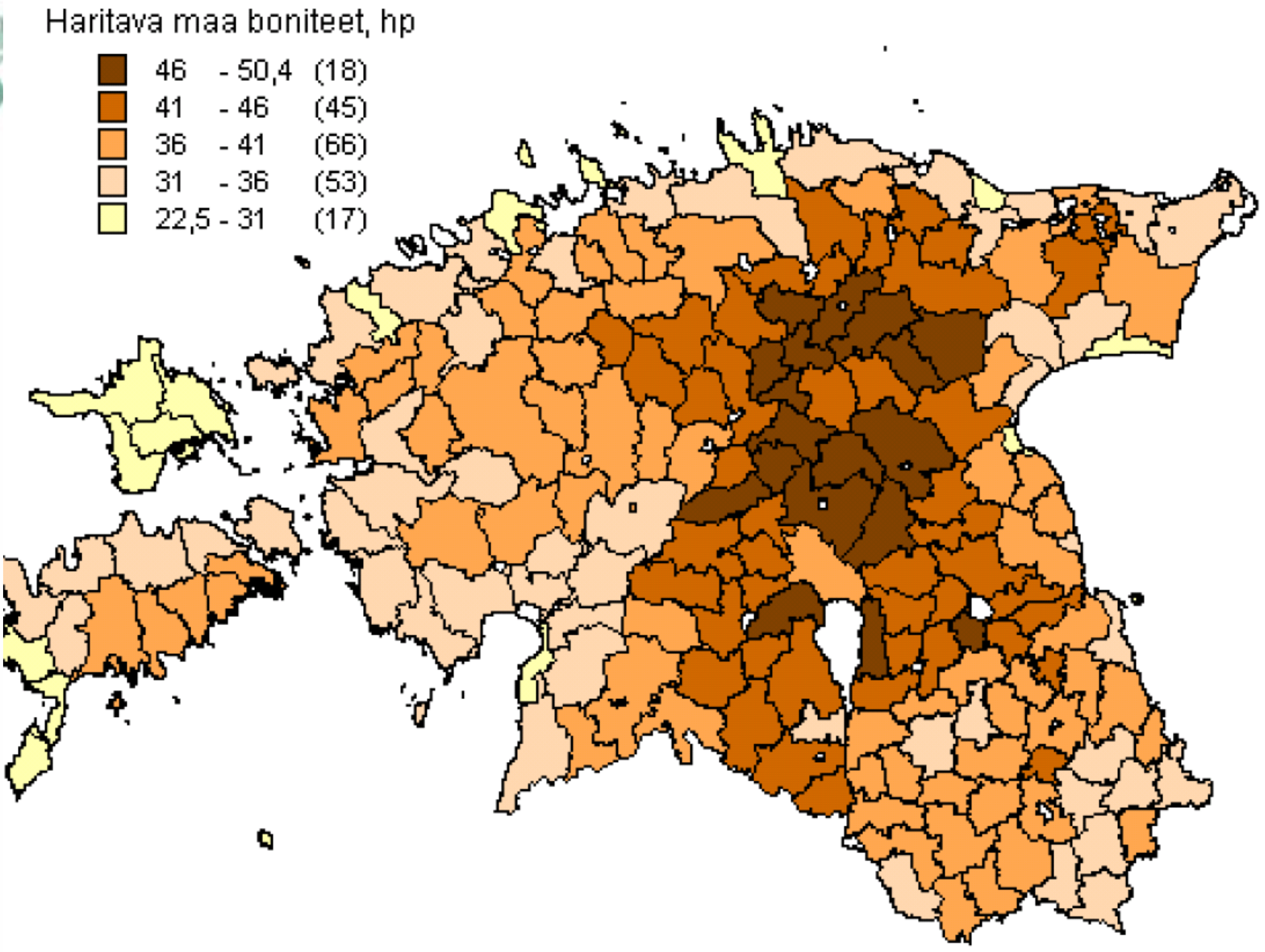
Electricity

Heat

Effect

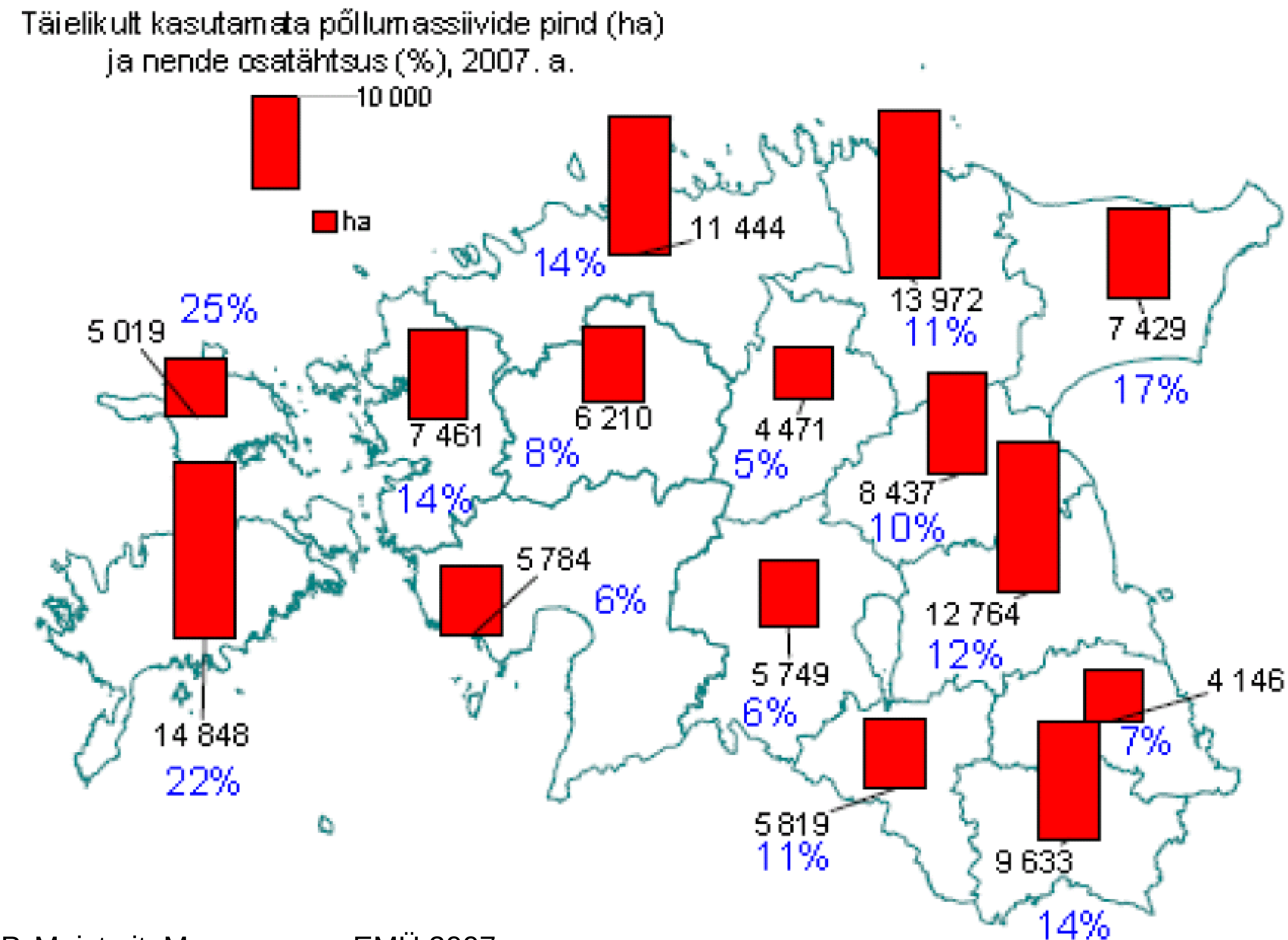
- Total fibre degradation increased from 31% to 70% for the 2 mm fibres, compared to untreated sisal fibres.
- Methane yield increased by 23% when the fibres were cut to 2 mm size and was 0.22 m3 CH4/kg volatile solids, compared to 0.18 m3 CH4/kg volatile solids for untreated fibres. Renewable energy ISSN 0960-1481
- Energy demand for milling about size of 600 µm is approx. 30 kWh/t

Land



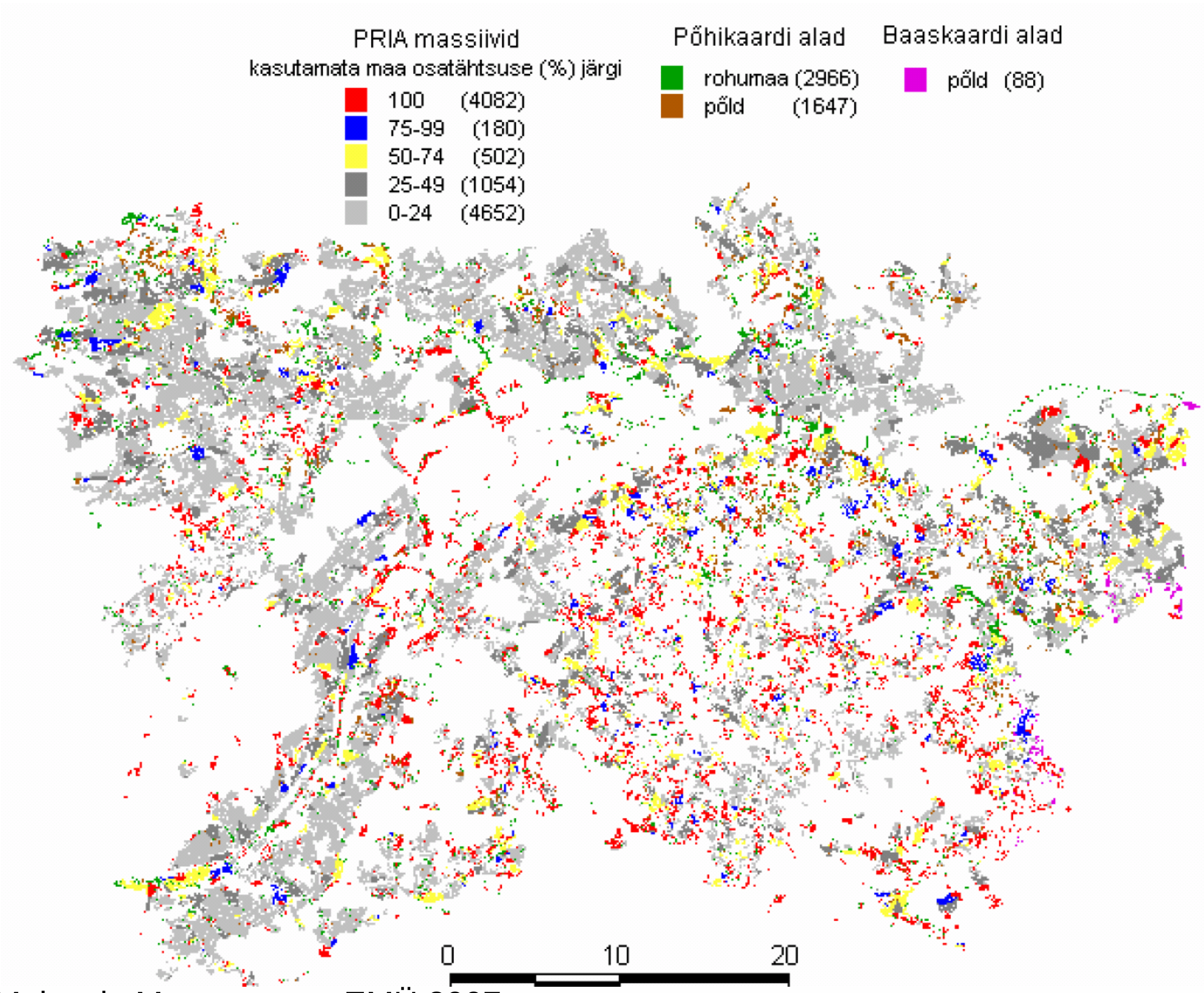
Source: P. Muiste jt. Maaressurss, EMÜ 2007

Abandoned agricultural land (ha)



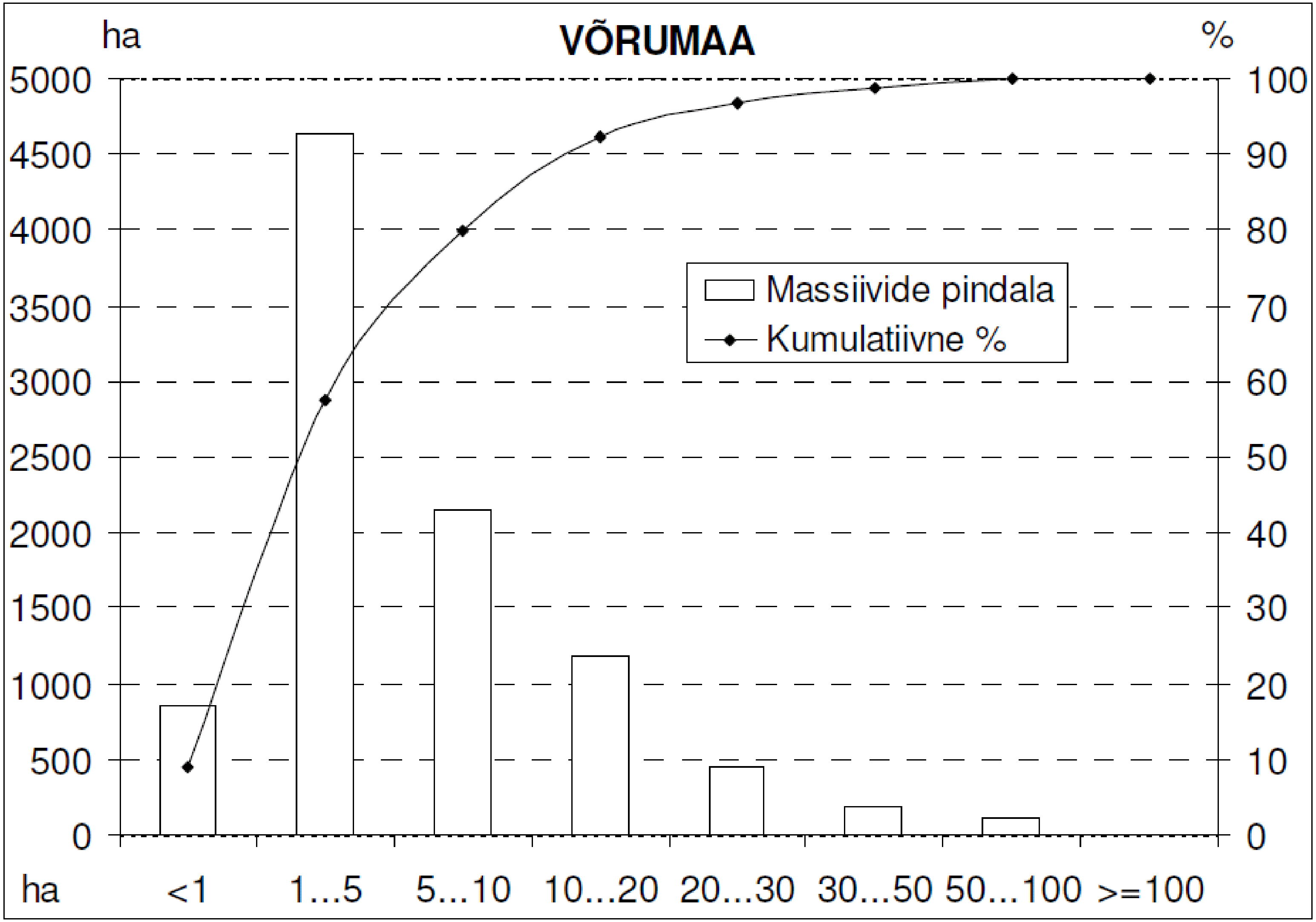
Source: P. Muiste jt. Maaressurss, EMÜ 2007

Abandoned land in Võrumaa



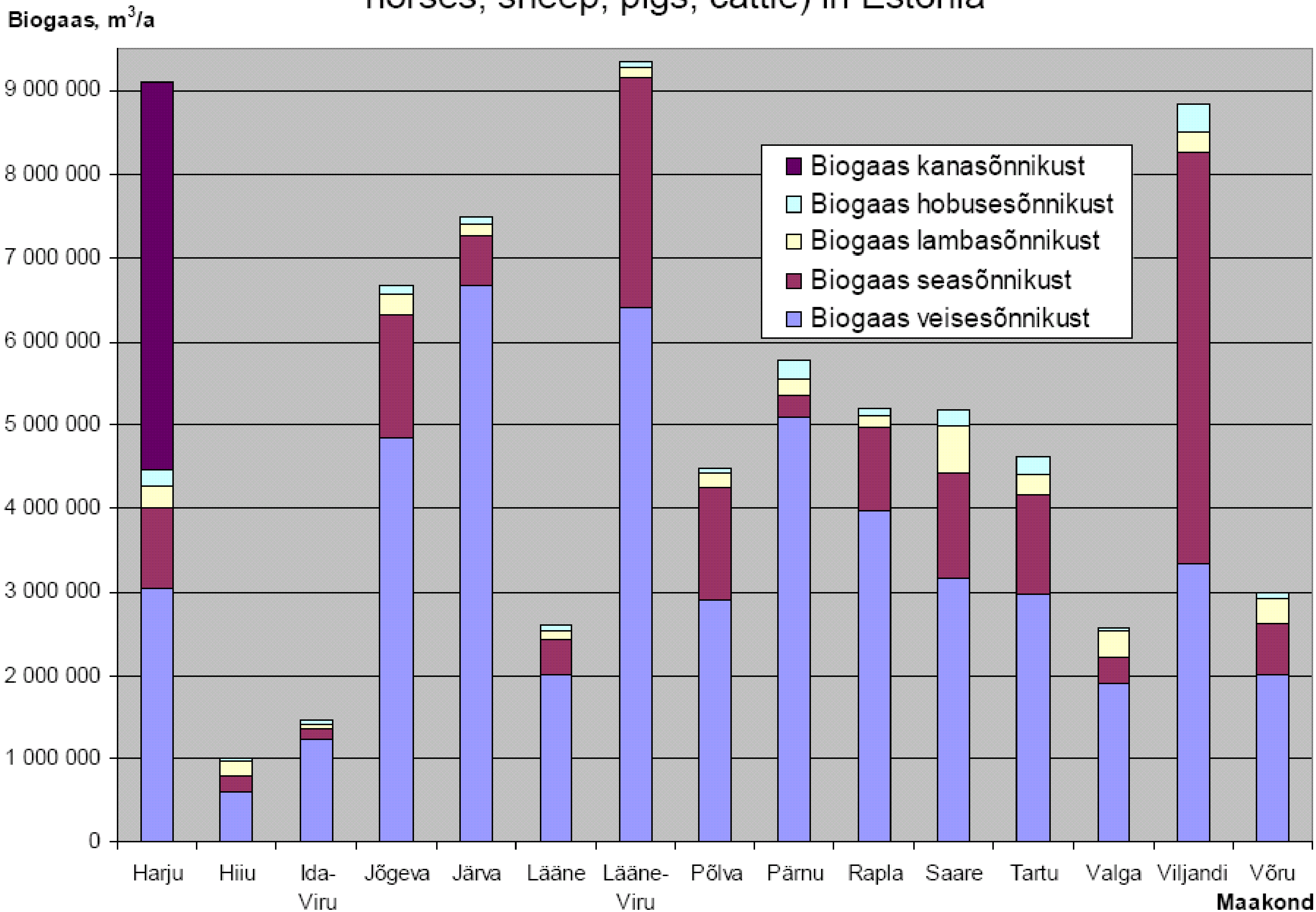
Source: P. Muiste jt. Maaressurss, EMÜ 2007

Abandoned land in Võrumaa (2)



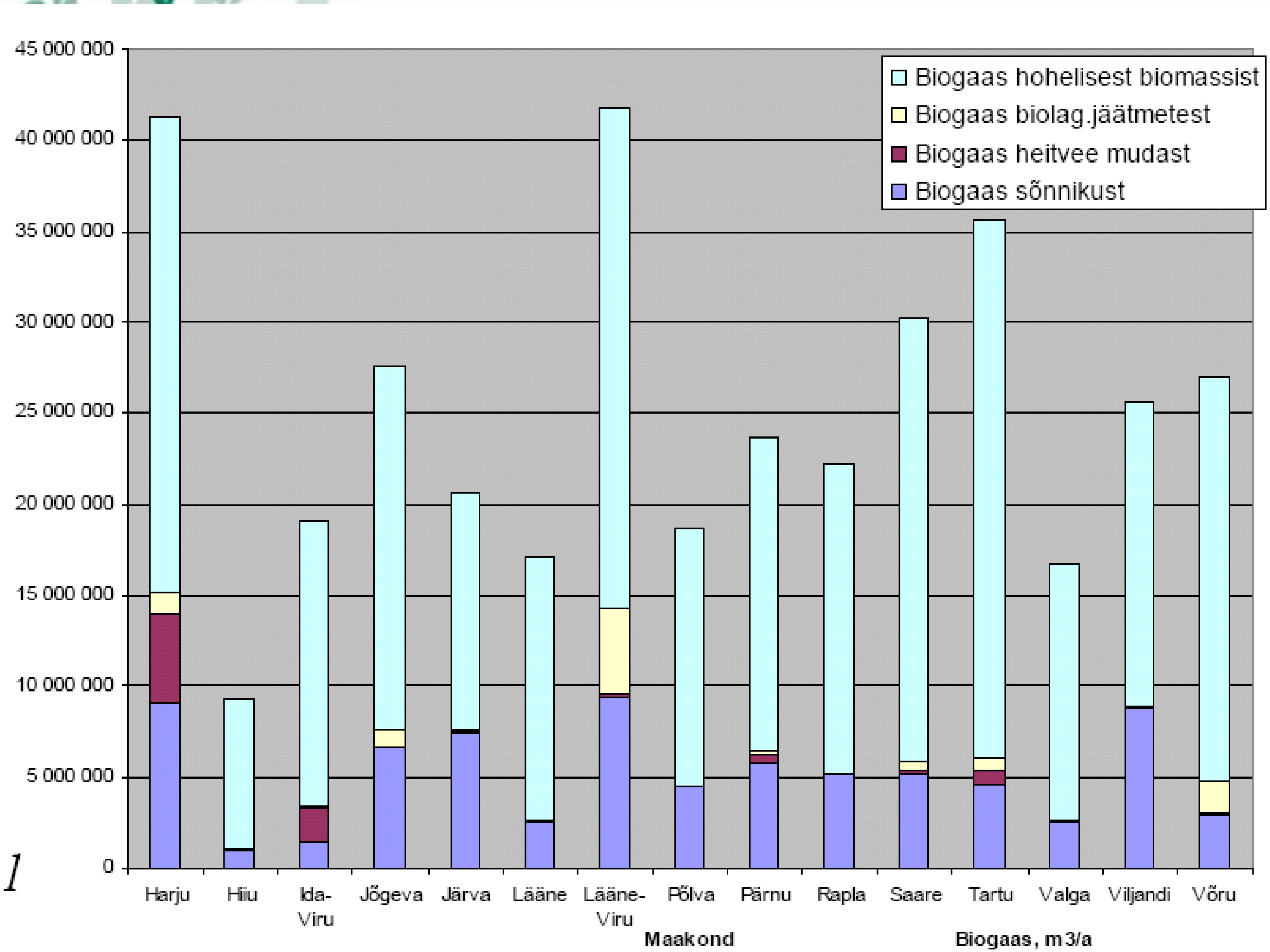
Source: P. Muiste jt. Maaressurss, EMÜ 2007

Theoretical potential of biogas from manure by type of animals (poultry, horses, sheep, pigs, cattle) in Estonia



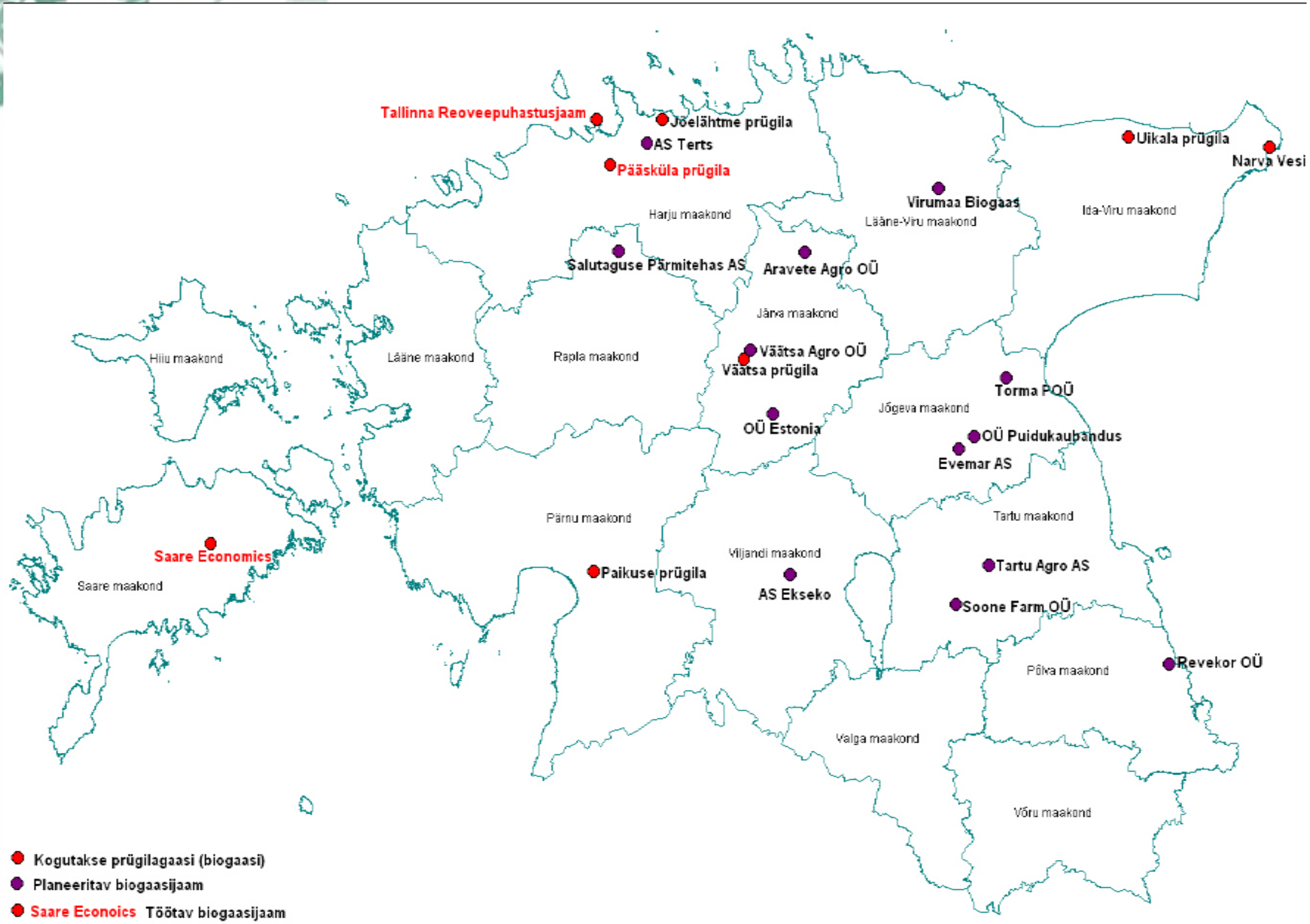
Source: V. Vares jt. Biomassi tehnoloogiauuringud ja tehnoloogiate rakendamine Eestis, TTÜ 2007

Biogas potential in Estonia



Source: V. Vares jt. Biomassi tehnoloogiauuringud ja tehnoloogiate rakendamine Eestis, TTÜ 2007

Biogas installations in Estonia



Source: Production and utilization of biogas in Estonia, Ü.Kask, Tallinn University of Technology 11.06.2008, Riga

Full scale biogas plants in Estonia

<u>Jööri Biogas Plant in Saaremaa</u>

- Manure is collected from 8 pig farms with 27 000 pigs –40 000 t/a
- Estimated biogas production: 2,4 M m3/a
- Total investments: 3,83 M €
- Energy production:
  - 2 200 MWh electricity (75% is own demand)
  - 3500 MWh heat (used for heating the digester and for space heating)

Info: Kask, Ü., 2008. Production and utilization of biogas in Estonia
Photo: A.Normak

Full scale biogas plants in WWTP in Estonia

Photo 1. Tallinn Wastewater Treatment Plant [1]

Photo 2. Narva Wastewater Treatment Plant [2]

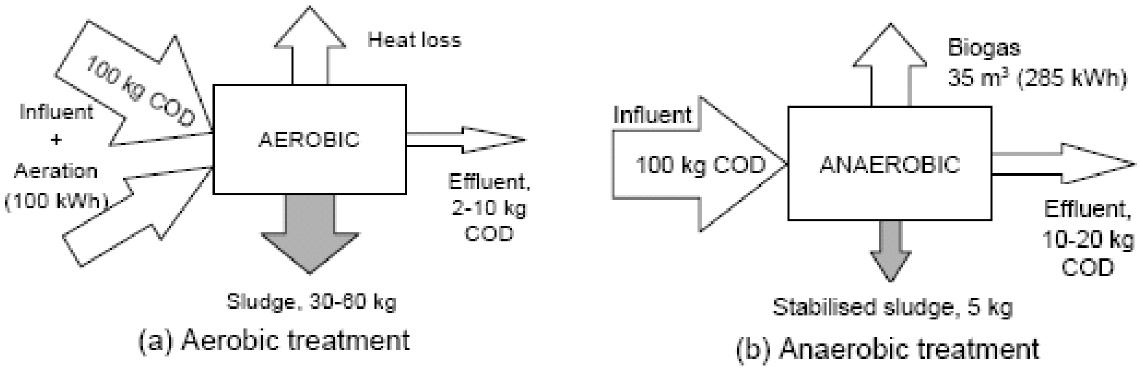


Figure 1. Comparison of aerobic and anaerobic treatment of carbon [3]

Sources:
[1], [2] Photos: [1] A.Normak, [2] H.-C. Dubourguier
[3] Instrumentation, Control and Automation in Wastewater sysems, G.Olsson et al. IWA Publishing 2005

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• MTT Agrifood Research Finland - Agricultural Engineering
• Estonian University of Life Sciences

Project home page is at http://enpos.weebly.com/

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