Animal wastes and energy production: manure, biogas, compost

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Content

• Estonian agriculture in figures
• 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
- Abandoned agricultural land 283,485 ha

Source: P. Muiste jt. Eestis olemasoleva, praeguse või juba kavandatud tootmise-tarbimise juures tekkiva biomassi ressursi hindamine, EMÜ 2007
<table>
<thead>
<tr>
<th>Maakond</th>
<th>Veisesõnnik</th>
<th>Seasõnnik</th>
<th>Lambasõnnik</th>
<th>Hobusesõnnik</th>
<th>Kokku</th>
<th>%</th>
<th>t/ha</th>
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<td>3,9</td>
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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

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

Source: [http://www.anaerobic-digestion.com](http://www.anaerobic-digestion.com)
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.

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$_2$)
  – Methanogenesis
    • 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 processes

Source: Instrumentation, Control and Automation in Wastewater Systems, G. Olsson et al. IWA Publishing 2005
Dry digestion

Allikas: [www.anaerobic-digestion.com](http://www.anaerobic-digestion.com), [www.dranco.be](http://www.dranco.be)
Domestic reactors

Figure 1: Fixed dome plant Nicaraq 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 Development. 1999 ISAT
## Characteristics of most important agricultural feedstock

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Total Solids TS [%]</th>
<th>Volatile Solids [% of TS]</th>
<th>C:N Ratio</th>
<th>Biogas Yield $^b$ [m$^3$ . kg$^{-1}$ VS]</th>
<th>Retention Time [d]</th>
<th>CH$_4$ Content [%]</th>
<th>Unwanted substances</th>
<th>Inhibiting substances</th>
<th>Frequent problems</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig slurry</td>
<td>3-8 $^4$</td>
<td>70-80</td>
<td>3-10</td>
<td>0.25-0.50</td>
<td>20-40</td>
<td>70-80</td>
<td>Wood shavings, bristles, H$_2$O, sand, cords, straw</td>
<td>Antibiotics, disinfectants</td>
<td>Scum layers, sediments.</td>
<td>(3), (4), (22), (24)</td>
</tr>
<tr>
<td>Cow slurry</td>
<td>5-12 $^4$</td>
<td>75-85</td>
<td>6-20 $^1$</td>
<td>0.20-0.30</td>
<td>20-30</td>
<td>55-75</td>
<td>Bristles, soil, H$_2$O, NH$_4^+$, straw, wood</td>
<td>Antibiotics, disinfectants</td>
<td>Scum layers, poor biogas yield</td>
<td>(3), (4), (22), (24)</td>
</tr>
<tr>
<td>Chicken slurry</td>
<td>10-30 $^4$</td>
<td>70-80</td>
<td>3-10</td>
<td>0.35-0.60</td>
<td>$&gt;$30</td>
<td>60-80</td>
<td>NH$_4^+$, grit, sand, feathers</td>
<td>Antibiotics, disinfectants</td>
<td>NH$_4^+$-inhibition, scum layers.</td>
<td>(3), (15)</td>
</tr>
<tr>
<td>Whey</td>
<td>1-5</td>
<td>80-95</td>
<td>n.a.</td>
<td>0.80-0.95</td>
<td>3-10</td>
<td>60-80</td>
<td>transportation impurities</td>
<td>soil</td>
<td>pH-reduction</td>
<td>(3), (22)</td>
</tr>
<tr>
<td>Ferment. slops</td>
<td>1-5</td>
<td>80-95</td>
<td>4-10</td>
<td>0.35-0.55</td>
<td>3-10</td>
<td>55-75</td>
<td>undegradable fruit remains</td>
<td>Pesticides</td>
<td>high acid conc., VFA-inhibition</td>
<td>(3), (22)</td>
</tr>
<tr>
<td>Leaves</td>
<td>80</td>
<td>90</td>
<td>30-80</td>
<td>0.10-0.30</td>
<td>8-20</td>
<td>n.a.</td>
<td>soil</td>
<td>Pesticides</td>
<td>(3), (22)</td>
<td></td>
</tr>
<tr>
<td>Wood shavings</td>
<td>80</td>
<td>95</td>
<td>511</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>Unwanted material</td>
<td>Mechanical problems</td>
<td>(3), (22)</td>
<td></td>
</tr>
<tr>
<td>Straw</td>
<td>70</td>
<td>90</td>
<td>90</td>
<td>0.35-0.45</td>
<td>10-50 $^5$</td>
<td>n.a.</td>
<td>Sand, grit</td>
<td>Scum layers, poor digestion</td>
<td>(3), (22)</td>
<td></td>
</tr>
<tr>
<td>Wood wastes</td>
<td>60-70</td>
<td>99.6</td>
<td>723</td>
<td>n.a.</td>
<td>$\infty$</td>
<td>n.a.</td>
<td>Unwanted material</td>
<td>Poor anaerobic biodegradation</td>
<td>(3), (22)</td>
<td></td>
</tr>
<tr>
<td>Garden wastes</td>
<td>60-70</td>
<td>90</td>
<td>100-150</td>
<td>0.20-0.50</td>
<td>8-30</td>
<td>n.a.</td>
<td>Soil, cellulosic components</td>
<td>Pesticides</td>
<td>Poor degrad. of cellulosic comp.</td>
<td>(3), (22)</td>
</tr>
<tr>
<td>Grass</td>
<td>20-25</td>
<td>90</td>
<td>12-25</td>
<td>0.55</td>
<td>10</td>
<td>n.a.</td>
<td>Grit</td>
<td>Pesticides</td>
<td>pH-reduction</td>
<td>(3), (22)</td>
</tr>
<tr>
<td>Grass silage</td>
<td>15-25</td>
<td>90</td>
<td>10-25</td>
<td>0.56</td>
<td>10</td>
<td>n.a.</td>
<td>Grit</td>
<td>pH-reduction</td>
<td>(3), (22)</td>
<td></td>
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<tr>
<td>Fruit wastes</td>
<td>15-20</td>
<td>75</td>
<td>35</td>
<td>0.25-0.50</td>
<td>8-20</td>
<td>n.a.</td>
<td>Undegradable fruit remains, grit</td>
<td>Pesticides</td>
<td>pH-reduction</td>
<td>(3)</td>
</tr>
<tr>
<td>Food remains</td>
<td>10</td>
<td>80</td>
<td>n.a.</td>
<td>0.50-0.60</td>
<td>10-20</td>
<td>70-80</td>
<td>Bones, plastic material</td>
<td>Disinfectants</td>
<td>Sediments, mechanical problems</td>
<td>(18)</td>
</tr>
</tbody>
</table>

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 consists of:

- Cellulose degradeable (hexoses)
- Hemicellulose degradeable (hexoses and pentoses)
- Lignin not degradeable
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 enzymes
- **Combinations**
Pretreatment of lignocellulosic materials prior to bioethanol and biogas production

Lignocellulosic materials

Pretreatment

1) Hydrolysis
2) Fermentation
3) Distillation

Bioethanol

1) Hydrolysis
2) Acidogenesis
3) Acetogenesis
4) Methanogenesis

Biogas
Energy from Grassland

- Silage
  - Hydro-thermal pretreatment
    - Mechanical dewatering
      - Liquids
        - Press cake
      - Solid fuel
    - Biogas production
      - Digestate
        - CHP
        - Electricity
        - Heat
      - Thermal drying
        - Heat
        - Solid fuel
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.

• Energy demand for milling about size of 600 μm is approx. 30 kWh/t
Land

Haritava maa boniteet, hp
- 46 - 50.4 (18)
- 41 - 46 (45)
- 36 - 41 (66)
- 31 - 36 (53)
- 22.5 - 31 (17)

Source: P. Muiste jt. Maaressurss, EMÜ 2007
Abandoned agricultural land (ha)

Täielikult kasutamata põllumassiviide pind (ha)
ja nende osatüütsus (%), 2007. a.

Source: P. Muiste jt. Maaresturss, EMÜ 2007
Abandoned land in Võrumaa

Source: P. Muiste jt. Maaressurss, EMU 2007
Abandoned land in Võrumaa (2)

Source: P. Muiste jt. Maressurss, 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
Jööri Biogas Plant in Saaremaa

- 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)

Photo: A.Normak
Full scale biogas plants in WWTP in Estonia

Photo 1. Tallinn Wastewater Treatment Plant

Photo 2. Narva Wastewater Treatment Plant

Figure 1. Comparison of aerobic and anaerobic treatment of carbon

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
Centre of Renewable Energy of EMU

– Renewable energy related information and consulting
– Initiating and leading renewable energy projects
– Participating in cooperation networks

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www.emu/TEKENG/
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The project partners are
- University of Helsinki, department of Agricultural Sciences – Agrotechnology
- MTT Agrifood Research Finland - Agricultural Engineering
- Estonian University of Life Sciences

Project home page is at [http://enpos.weebly.com/](http://enpos.weebly.com/)

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