Technical Aspects and Operating Requirements for Digesters Utilizing co-mingled Waste and Centralized Operation in Cold Climates

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Organizational chart of MOA Renewable energy management system

农业部的可再生能源管理体系

Center for Science and Technology Development
Center for Energy and Environmental Protection
Biogas Research Institute
working areas
主要研究方向

Policy advisory
政策研究

Renewable energy & biomass energy
可再生能源及生物质能研究

Sustainable Development
可持续发展研究

Agricultural waste & Resource management
农业废弃物处理及资源化利用研究

Ecological Sanitation
生态卫生
Embedded in two structures: as IEEP in the Chinese Academy of Agricultural Engineering (CAAE), and as Centre for Energy and Environmental Protection Technology Development (CEEPTD) belonging to the Ministry of Agriculture.


CDM - business plan development expertise.

Carbon emission reduction project team with special expertise for methane emission reduction and energy efficiency.

Public-Private Partnership with Chinese and European companies.
中心职能 CEEP / IEEP is engaged in:

- 宏观政策研究；
  - Macro-policy studies on rural energy and rural environmental protection.
- 重大项目技术指导和管理；
  - Develop and administrate key projects in rural energy and rural environmental protection.
- 农业废弃物处理及资源化利用技术研究与推广；
  - Research and promote technologies of agricultural waste treatment and sustainable resources utilization.
- 农业废弃物处理及资源化利用工程设计与建设；
  - Design and construct projects for agricultural waste treatment and sustainable resource utilization.
- 国际交流与合作、人员培训；
  - International cooperation, information exchange and staff training.
- 农村能源职业技能鉴定站日常管理。
  - Administration of a Vocational Training Centre for Rural Energy Skills.
... is a registered German non-profit association

... was founded in 2001

... promotes sustainable closed-loop approaches as well as sustainable crop rotation systems

... opposes mono-cultures and GMO crops

... supports practioneers with its knowledge and its world-wide network
GERBIO’s focus points

- BIOGAS
- Plant and vegetable oil
- Wood gas
- Manure management
- Ecological sanitation
GERBIO has the knowledge

- long-term experience of its board members (since 1980s)
- knowledge transfer (seminars, study tours and trainings)
- members work with/are farmers and constructors (plant operators, manufacturers)
- active exchange of knowledge within a world-wide network
- extensive international library about biogas, sanitation and agricultural engineering
Content

1) Co-mingled waste
2) Technical aspects
3) Operating requirements
4) Centralized operation
5) Cold climates
Electricity output with co-fermentates

Electricity output (in kWh per M.T.)

- Cattle manure: 55 kWh
- Pig manure: 56 kWh
- Vegetable waste: 144 kWh
- Poultry manure: 148 kWh
- Bush cut: 208 kWh
- Sewage sludge: 320 kWh
- Food waste: 425 kWh
- Bio waste: 426 kWh
- Grassilage: 807 kWh
- Veg oil waste: 816 kWh
### Specific yield of biogas (1/2)

<table>
<thead>
<tr>
<th>Substrat</th>
<th>TS between</th>
<th>TS to</th>
<th>oTS between</th>
<th>oTS to</th>
<th>Biogas between</th>
<th>Biogas to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw glycerine (RME man.)</td>
<td>&gt;98</td>
<td></td>
<td>90</td>
<td>93</td>
<td>0,62</td>
<td>0,67</td>
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<tr>
<td>Potato tops</td>
<td>25</td>
<td></td>
<td>79</td>
<td></td>
<td>0,40</td>
<td>0,47</td>
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<tr>
<td>Beet (turnip) tops</td>
<td>15</td>
<td>18</td>
<td>78</td>
<td>80</td>
<td>0,19</td>
<td>0,40</td>
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<tr>
<td>Diverse cereals</td>
<td>85</td>
<td>90</td>
<td>85</td>
<td>89</td>
<td>0,26</td>
<td>0,53</td>
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<tr>
<td>Clover</td>
<td>20</td>
<td></td>
<td>80</td>
<td></td>
<td>0,32</td>
<td>0,40</td>
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<tr>
<td>Apple slop</td>
<td>2</td>
<td>15</td>
<td>90</td>
<td>95</td>
<td>0,30</td>
<td>0,33</td>
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<tr>
<td>Apple pomace</td>
<td>25</td>
<td></td>
<td>86</td>
<td></td>
<td></td>
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<tr>
<td>Spent grains from beer</td>
<td>20</td>
<td>22</td>
<td>87</td>
<td>90</td>
<td>0,22</td>
<td>0,63</td>
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<tr>
<td>Spent hops (dried)</td>
<td>97</td>
<td>97,5</td>
<td>90</td>
<td></td>
<td>0,45</td>
<td>0,50</td>
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<tr>
<td>Filtration silica gel (beer)</td>
<td>30</td>
<td></td>
<td>6,3</td>
<td></td>
<td>0,02</td>
<td>0,02</td>
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<tr>
<td>Vegetable waste</td>
<td>5</td>
<td>25</td>
<td>76</td>
<td>90</td>
<td>0,18</td>
<td>0,24</td>
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<tr>
<td>Old bread</td>
<td>90</td>
<td></td>
<td>96</td>
<td>98</td>
<td>0,67</td>
<td>0,74</td>
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<tr>
<td>Coco bean shells</td>
<td>95</td>
<td></td>
<td>91</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potato slop</td>
<td>12</td>
<td>15</td>
<td>90</td>
<td></td>
<td>0,22</td>
<td>0,50</td>
</tr>
<tr>
<td>Cereal slop</td>
<td>6</td>
<td>15</td>
<td>87</td>
<td>90</td>
<td>0,52</td>
<td>0,60</td>
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<tr>
<td>Foliage</td>
<td>82</td>
<td></td>
<td></td>
<td></td>
<td>0,33</td>
<td>0,40</td>
</tr>
<tr>
<td>Melasse</td>
<td>80</td>
<td></td>
<td>95</td>
<td></td>
<td>0,29</td>
<td>0,30</td>
</tr>
<tr>
<td>Whey</td>
<td>4</td>
<td>95</td>
<td>80</td>
<td>92</td>
<td>0,48</td>
<td>0,60</td>
</tr>
<tr>
<td>Fruit pomace</td>
<td>45</td>
<td></td>
<td>93</td>
<td></td>
<td>0,25</td>
<td>0,48</td>
</tr>
<tr>
<td>Oil seed residue (pressed)</td>
<td>92</td>
<td></td>
<td>97</td>
<td></td>
<td>0,56</td>
<td>0,60</td>
</tr>
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</table>
## Specific yield of biogas (2/2)

<table>
<thead>
<tr>
<th>Substrate</th>
<th>TS</th>
<th>oTS</th>
<th>Biogas 1</th>
<th>Biogas 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rape extraction residue</td>
<td>88-93</td>
<td>93</td>
<td>0.24</td>
<td>0.59</td>
</tr>
<tr>
<td>Grape pomace</td>
<td>40-50</td>
<td>80-95</td>
<td>0.26</td>
<td>0.63</td>
</tr>
<tr>
<td>Casto extraction residue</td>
<td>90</td>
<td>81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food waste (from large kitchens)</td>
<td>9-40</td>
<td>55-98</td>
<td>0.20</td>
<td>0.64</td>
</tr>
<tr>
<td>Vinaise</td>
<td>63</td>
<td>53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic waste (domestic)</td>
<td>30-75</td>
<td>30-90</td>
<td>0.05</td>
<td>0.54</td>
</tr>
<tr>
<td>Park and garden waste (fresh)</td>
<td>12-42</td>
<td>87-97</td>
<td>0.18</td>
<td>0.49</td>
</tr>
<tr>
<td>Clippings (sedge)</td>
<td>37-93</td>
<td>93</td>
<td>0.47</td>
<td>0.50</td>
</tr>
<tr>
<td>Blood meal</td>
<td>90</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flotation sludge</td>
<td>5-24</td>
<td>93-98</td>
<td>0.56</td>
<td>0.78</td>
</tr>
<tr>
<td>Stomach content (pigs)</td>
<td>12-15</td>
<td>80-84</td>
<td>0.16</td>
<td>0.25</td>
</tr>
<tr>
<td>Rumen contents (untreated)</td>
<td>11-19</td>
<td>80-88</td>
<td>0.21</td>
<td>0.36</td>
</tr>
<tr>
<td>Rumen contents (pressed)</td>
<td>20-45</td>
<td>90</td>
<td>0.54</td>
<td>0.63</td>
</tr>
<tr>
<td>Slaughter house waste</td>
<td></td>
<td></td>
<td>0.20</td>
<td>0.43</td>
</tr>
<tr>
<td>Fisch processing waste</td>
<td></td>
<td></td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>Animal cadaver meal</td>
<td>8-25</td>
<td>90</td>
<td>0.45</td>
<td>0.72</td>
</tr>
<tr>
<td>Separator fat (gelatine prod.)</td>
<td>25-92</td>
<td></td>
<td>0.25</td>
<td>0.70</td>
</tr>
<tr>
<td>Fat (from fat separators)</td>
<td>2-70</td>
<td>70-100</td>
<td>0.29</td>
<td>0.70</td>
</tr>
<tr>
<td>Market waste</td>
<td>5-25</td>
<td>76-90</td>
<td>0.29</td>
<td>0.70</td>
</tr>
<tr>
<td>Residual waste</td>
<td>55-57</td>
<td>46-78</td>
<td>0.06</td>
<td>0.30</td>
</tr>
</tbody>
</table>
Advantages of anaerobic digestion

Very wet waste can be digested – this is not possible by composting

- Slaughter house waste
- Fat – glycerine – flotation fat and grease
- Organically loaded waste water
- Liquid organic waste
- Feecal sludge
The bottleneck of anaerobic digestion

Methane Bacteria

They are

- Sensitive on low temperature < 37°C
- Sensitive on temperature change
- Sensitive on low pH value < 7,0
- Sensitive on high organic load > 3,0 kg/m³/day
Growing of anaerobic bacterias

**Hydrolisis bacteria**
- 1 – 24 h
- 12 – 36 h to 48 h

**Acetogenic bacteria**
- 9 - 12 h
- 12 - 18 h
- 60 – 80 h
- 60 – 120 h
- 2 – 10 d

**Methanogenic bacteria**
- 6 – 18 h
- 18 – 48 h
- 48 – 72 h
- 3 – 5 d
- 240 h

- Carbonhydrates
- Protein
- Fat

- Methanol and acetic acid
- Lactic acid
- Butter acid
- Propion acid
- Fatty acid

- Various bacteria pedigree for producing H₂
- Various bacteria pedigree for producing H₂
- Various bacteria pedigree for producing acetic acid
- Various bacteria pedigree for producing acetic acid

Source: Walter Danner & Alexander Varghese, UNIDO consultants
Closing the nutrient loop

- Nutrient are still in the effluent as fertilizer, mainly the carbon is used for the biogas production.
- Clean fertilizer due to appropriate sorting technology possible.
- Source separated collection produces fertilizer without toxic elements.
- Complete hygienisation possible.
Optimized agricultural nutrient cycle

Source: Silvia Schattner, Bayerische Landesanstalt für Landtechnik
Proces chain for the digestion of biowaste

1. Reception of biowastes
   => closed chamber with odour treatment

2. Preparation
   => Chopping and sorting of disturbing materials

3. Fermentation with post treatment

   - Biogas
   - Hygienising, separation
   - Compost (post composting)
   - Liquid fertilizer
Up to 5 step preparation of co-mingled waste
General design criteria

• Heat and power utilization
• Fertilizer use – nutrient balances
• Effluent preparation
• Type of feedstock and availability
• Affordable investment – additional income generated
• Maintainace – costs, skills, spare parts availability
• Suitable to the climate – stable process
• Available and manageable construction material
• Transportation during construction and for feedstock
• Labour costs
• Size of potential market for fertilizer and technology
Feed-in technology for Energy Crops
Feed-in of solid material
solid
feed-in gear
Liquid Biomass Feeding

Lipp Biogassystem

Getreide / Körnermais
Mühle / Quetsche
Liggamix
Ca. 20% - 30%
Brauchwasser

Lipp
Biomassespeicher
Milchsäureregärung
ph Wert 4
500m³ Inhalt = ca. 350t Getreide
50% TS

Fermenter
Verweilzeit ca. 15 Tage
Vollautomatische, mehrmals tägliche Beschickung mit Schneckenpumpe
Different feed-in systems

- Wash in channel with KG pipe
- Wash in shaft (Hochreiter)
- Throw in shaft (ceiling)
- Throw in shaft (lateral wall)
- Feed in gear horizontal
- Vertical
Mixing

- Homogenization
- Estimulate gas exit
- Avoid sink material
- Avoid floating material, crushing of crust
Mixing
Mixing devices

Mechanical paddle mixing device with heating pipes

Mechanical mixing device (Grindelrührwerk) excentrically placed

Immersion engine propeller mixing device -adjustable

Rod mixing device, swivelling

Hydraulic circulation

Pneumatical injection of
Sorting and preparation for centralized operation

- Receiving
- Digester
- Sorting
- Electricity Production
- Biogas Production
• Minimization of process energy need
• Avoid temperature losses
• Avoid temperature differences

Materials:

Floor and roof (concrete roof): Styropor

Wall and roof (plastic cover): Polystyrol
Insolation
Warming the digesting substrate at optimal temperature.

Compensation of the lost temperature.
Heating
- Risk- and Insurance Management

Risk Identification

Risk Monitoring and Review
Risk Management

Risk Analysis

Risk Control
e.g. Fire protection

Risk Transfer
e.g. Insurance
All Risk Insurance for biogas plants
- No separation in Fire and Machinery Breakdown

- What is insured?
  All components of the plant required for the operations and for maintaining these operations
  - Machines, Installations, Buildings, Pipe Works

  Fermenter Biology

- All Risk Insurance
  - Insured is the unforeseen damage or loss while not being excluded by a specific named peril
Not Insured Perils

- Caused deliberately by or due to gross negligence of the insured or the responsible manager

- For which supplier or the repair workshop are responsible or liable (supplier’s guarantee)

- Which are a direct consequence of permanent influence from operation (e.g. wear and tear)

- War, Riots

- Nuclear Energy
Insured Perils
- Examples (no completed list)

- Fire, Lightning, Explosion
- Machinery Breakdown (e.g. motor loss), failure in material, construction or design
- Natural hazards
  - Storm, Hail, Flood
  - Earthquake, Land subsidence
  - Snow pressure, Avalanche
- Errors in Operating, Faulty Operation
  - Recourse against employees only if damage is caused by deliberate action
  - Wear/Corrosion and secondary damage
- It is possible to extend cover for Fermenter biology if it is damaged from the outside (e.g. poisoned)
Indemnification

- Repair work, replacement of parts (incl. additional cost for overtime, work on Sundays and public holidays, night work, express delivery)

- Loss in Revenues for Electricity Production according to EEG (Erneuerbare-Energien-Gesetz) (Renewable Energy Law)

- Loss in revenues for
  - Acceptance of co-ferments
  - Sale of heat
  - Sale of biogas
  - etc. (according to declaration)
Damages at different plant components
- Payment of Compensation relating to plant components

- CHP: 53%
- Fermenter: 11%
- Stirring Unit: 14%
- Other components: 22%
Engine Breakdowns
- Mostly consequence of poor Biogas Quality

- Fluctuating composition and calorific value of the biogas
- High exposure to aggressive acid substances, especially hydrogen sulfide
- Missing or deficient gas drying / cleaning systems
- Too small dimensioned gas storages
- High strain of particulates in the biogas
- Insufficient quality of oil because of too long oil change intervals
- Deficient control and documentation of the motor performance data, general bad maintenance of the CHP
- Clogging of cooling circuits
Minimum requirement of the operation journal:

<table>
<thead>
<tr>
<th>Datum</th>
<th>Uhrzeit</th>
<th>Gaszählerstand</th>
<th>Stromzählerstand</th>
<th>Motorlagerung</th>
<th>Kühlwäserstemperatur</th>
<th>Schmierölteppelatur</th>
<th>Schmieröldruck</th>
<th>Abgastemperatur</th>
<th>Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

⇒ Measurement at least once a day manual or continuous automatic measure and storage
Recital Clause:

- Desulphurization and drying
- Daily control of the sulfur and methane content
- Online control is advisable

⇒ Avoidance of the most common engine breakdowns

- Permanent control by employees or automatic systems

⇒ Breakdowns have to be reported immediately to limit damages
Consequences - Warranty and Maintenance

Recital Clause:

• At least 6 months warranty of the engine producer
  ⇒ Approved technology can be insured, but no experimental plants

• Maintenance contract with engine producer or a specialist company

• Maintenance and inspection according to the operation journal of the engine producer
  ⇒ A professional maintenance stretches the age of the engine and reduces damage risks
Recital Clause:

- Oil analysis with at least every second oil change
- Evaluation of the result by the service firm
- Result has to be kept in the operating journal

⇒ The state of the engine, e.g. wear and tear, and the gas quality can be estimated by the oil analysis
⇒ The oil changing intervals can be attuned to the oil quality
Advantages of an extensive and coherent Risk and Insurance Management

Only one All Risk Insurance Contract for unexpected happened damages and losses

Entire Biogas Plant – no disqualification, no difference between buildings or equipment

Consequential Damage by wear and tear/corrosion

Amortization/depreciation just for some components of the engine

Late start of operation after material damage during construction

Special extended cover for the biology

Support by independent Engineers and Scientists to achieve acceptance of your claims by the insurer
谢谢各位领导专家

谢谢 Thank you!

• 请多提宝贵意见。

Heinz-Peter Mang

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