Anaerobic Digestion
First steps in Developing an on farm AD project

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SEI - Renewable Energy Information Office

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SEI REIO - Background

- Created in 1995, based in Clonakilty, West Cork
- Established to promote the use of renewable resources and provide independent information and advice on the financial, social and technical issues relating to renewable energy development.
Outline

• Introduction

• Developing an AD facility
  – First steps to consider, Example plant design
  – My experience operating plants, technique

• SEI’s grant Aid and provided Information
### Biology

- **4 digestion steps by different enzymes and bacteria without oxygen**
- **End product: biogas, digestate**

<table>
<thead>
<tr>
<th>Component</th>
<th>Chemical symbol</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>CH4</td>
<td>50 - 75 % - vol.</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>CO2</td>
<td>25 - 45 % - vol.</td>
</tr>
<tr>
<td>Water vapour</td>
<td>H2O</td>
<td>2 - 7 % - vol.</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O2</td>
<td>&lt; 2 % - vol.</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N2</td>
<td>&lt; 2 % - vol.</td>
</tr>
<tr>
<td>Ammonia</td>
<td>NH3</td>
<td>&lt; 1 % - vol.</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H2</td>
<td>&lt; 1 % - vol.</td>
</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>H2S</td>
<td>20 - 20.000 ppm</td>
</tr>
</tbody>
</table>

[ppm: Parts per million; % - vol.: volumetric percentage]

Source: FNR
Biogas – an Energy all-rounder

Source: IEA
Developing an AD plant

Developing a project is a long process!

Operating the plant:
What is my motivation for installing/operating a plant?
Who is operating the plant (24/7 supervision necessary)?
1. Feedstock

- **Availability and amount:**
  - What do I have, how much can I get?
  - stable amount over next months, year(s)?

- **Gate fee/price**
  - Stable for the next years? Costs calculated realistically

- **Regulations**
  - Waste permission, DAFF (ABP), nutrient management plan of digestate

- **Quality**
  - gas yield/specific gas production, dry matter, organic dry matter
  - operating a plant viably depends highly income/costs

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Sizing CHP unit

Sizing the plant and components/technique
## Input/gas production

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Dry solids</th>
<th>Dry solids (data can vary)</th>
<th>Gas-production per t fresh material</th>
<th>kWh/tonne input material</th>
<th>kW per t input material and Day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% of Fresh material</td>
<td>% of DM</td>
<td>m3/t fresh material</td>
<td>kWh/t</td>
<td>kW/t FM d</td>
</tr>
<tr>
<td>Food waste</td>
<td>20.0</td>
<td>85</td>
<td>110</td>
<td>225</td>
<td>9.4</td>
</tr>
<tr>
<td>Cattle-dung</td>
<td>25.0</td>
<td>80</td>
<td>70</td>
<td>143</td>
<td>6.0</td>
</tr>
<tr>
<td>Cattle-slurry</td>
<td>8.0</td>
<td>80</td>
<td>20</td>
<td>41</td>
<td>1.7</td>
</tr>
<tr>
<td>Cereals/grains</td>
<td>85.0</td>
<td>95</td>
<td>541</td>
<td>1105</td>
<td>46.0</td>
</tr>
<tr>
<td>Chaff</td>
<td>85.0</td>
<td>90</td>
<td>360</td>
<td>547</td>
<td>30.0</td>
</tr>
<tr>
<td>Chicken litter/dung</td>
<td>40.0</td>
<td>75</td>
<td>126</td>
<td>257</td>
<td>10.7</td>
</tr>
<tr>
<td>Fat</td>
<td>95.0</td>
<td>87</td>
<td>827</td>
<td>1687</td>
<td>70.3</td>
</tr>
<tr>
<td>Glycerine*</td>
<td>100.0</td>
<td>95</td>
<td>713</td>
<td>1200</td>
<td>60.6</td>
</tr>
<tr>
<td>Old bread</td>
<td>65.0</td>
<td>95</td>
<td>432</td>
<td>883</td>
<td>36.8</td>
</tr>
<tr>
<td>Pig slurry</td>
<td>4.5</td>
<td>80</td>
<td>12</td>
<td>24</td>
<td>1.0</td>
</tr>
<tr>
<td>Residuals from vegetables</td>
<td>20.0</td>
<td>80</td>
<td>72</td>
<td>147</td>
<td>6.1</td>
</tr>
<tr>
<td>Sewage sludge</td>
<td>12.0</td>
<td>80</td>
<td>47</td>
<td>96</td>
<td>4.0</td>
</tr>
</tbody>
</table>

35 % electrical efficiency CHP, 21 MJ/m3, 55 % Methane content, 3,6 MJ/kWh

This table only intended to provide indicative results. All values are approximate and can vary extremely. Gas yields depend highly on dry matter content, storage feedstock, handling feedstock. For an exact calculation, feedstock testing is definitely necessary.
Indication Sizing an AD plant

• 2 basic main parameters:
  – **Retention Time**: 35 d (slurry) – 100 d (energy crops)
  – feedstock remains in main digester(s)
    • Volume digester divided by input per day
      – 30 t Slurry/day (app. 50 kW), RT 40 days = 1200 m³

  – **Organic Loading Rate**: < 4.0 - 4.5 kg oDM/m³/d
    • How much organic dry matter (oDM) added per m³ per d
    • Overload system/technique/biology

\[
\text{OLR (kg oDM/(m}^3 \text{ d}) = \frac{\text{Organic dry material added daily (kg oDM/d)}}{\text{Net volume digester (m}^3)}
\]

  – 30 t/d x 0.10 oDM/t = 3000 kg/1200 m³ = 2.5 kg/m³ d

– RT and OLR depending on feedstock and plant system!
## Example feedstock

<table>
<thead>
<tr>
<th>Feedstock per day</th>
<th>Power kW per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 t cattle slurry</td>
<td>30 kW</td>
</tr>
<tr>
<td>2 t dung</td>
<td>15 kW</td>
</tr>
<tr>
<td>2 t chaff</td>
<td>60 kW</td>
</tr>
<tr>
<td>2 t food waste</td>
<td>20 kW</td>
</tr>
<tr>
<td>1 t glycerin</td>
<td>50 kW</td>
</tr>
</tbody>
</table>

### Total:

- **27 t/d**
- **10,000 t/a**
- **175 kW**
Example plant design

**Design:**
- 1 x digester 1200 m3net (RT = 45 d; OLR = app. 3 kg oDM/m3d),
- 1 x 185 kWe CHP (6 cylinder gas Otto, 210 kW th, incl. h.ex. and gas cleaning system)
- 2 x agitators (incl. FC)
- 2 - 3 x pump(s)
- 1 x feeding 6 m3 system
- reception area, mixing tank, disinfection unit
- existing storage tank (covered)

**Production at 8200 hr/a:**
- 1.45 Mio kWh el/a
- 1.70 Mio kWh th/a
energy for app. 350 households/a
Developing an AD plant
Location

2. Location of plant
• Plant integration in existing farm-network-infrastructure
• Possible location of plant
  – Heat demand, heat usage
  – what is situated nearby?
• Grid connection, distance

3. Starting Planning (extract)
• Get in contact with local authorities
  – Planners/planning section
  – Environmental section
  – Agricultural office/DAFF
    • Which planning regulations/legislation?
      – Regulated by local authority (planning permission)
    • What is the content of this permission/legislation?

• public consultation
  – neighbours
Developing an AD plant

4. Consultant, Supplier, developer of feasibility study, plant components, plant design

- Experience, track record, reputation (financing!)

- Similar/same reference-plants ... get in contact...
  - how well were these performing during the last years?

- Suitable equipment and design for feedstock (changing!)

- Compare supplier/developer
  - Price, Recommended plant design/dimension
    - OLR, RT, digesters
  - Trainings
  - Warranty, after sales, maintenance
  - Find out Operating costs!

- Feasibility/financial projection
Developing an AD plant

5. Financial projection

- availability of the plant (7500 - 8200 hr/a)
  - If not, oversized or too small

- What is my income?

- What are my costs?
  - Investment (3500 – 6000 Euro/kW)

- Comparing income and cost in ct/kWh
  - Analyzing income/cost
Financial projection

- **Income:**
  - Selling electricity (REFIT) and heat
  - Fertilizer value/selling fertilizer
  - Gate fee (?)
  - Grants

- **Running Cost, extract:**
  - Loan, interest (investment), Insurance
  - Maintenance/repair/spare parts plant components/CHP
  - Management/Administration
  - ...

Analyze scenarios!

What if...?
Developing an AD plant
Summary

1. Feedstock (amount, quality, Gas prod.)
   Sizing plant and CHP, design

2. Location of plant

3. Planning
   Local authorities

4. Plant design, consultant/supplier
   Feasibility study

5. Financial projection
   income/cost analyzing

⇒ Developing steps take place at the same time
⇒ Calculate everything realistically!
⇒ Miscalculation could be fatal!

Checklist on website:
http://www.sei.ie/Renewables/Bioenergy/Anaerobic_Digestion
Technical requirements

• Main Components:
  - Sorting/screening systems (organic waste)
  - Digester
  - Mixer/agitator
  - Pumps
  - Feeding systems for solid biomass
  - Combined Heat and Power (CHP)

• Components must be suitable for feedstock!
Upgrading Biogas

- **Upgrading to Biomethane**
  - CH4 content from 50-60% to > 95% (natural gas)

- **Utilization**
  - Injection gas-grid
  - Using as a vehicle fuel (natural gas engine)

- **According IEA upgrading Biogas in early commercial stage**

- **High amount of feedstock necessary**

Source: Schmack Biogas AG, Haase
Vehicle fuel and production costs

Source: FNR, Meo Consulting

Range of a car with biofuels from 1 hectare arable land

Herstellungskosten Biokraftstoffe | Production costs liquid biofuels
---|---

<table>
<thead>
<tr>
<th></th>
<th>Herstellungskosten (Euro/l)</th>
<th>Kraftstoffäquivalente (Euro/l)</th>
<th>Herstellungskosten (Euro/GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodiesel aus Raps</td>
<td>0,63</td>
<td>0,69</td>
<td>19,03</td>
</tr>
<tr>
<td>Rapsöl</td>
<td>0,49</td>
<td>0,51</td>
<td>14,17</td>
</tr>
<tr>
<td>Bioethanol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Getreide</td>
<td>0,47</td>
<td>0,72</td>
<td>21,97</td>
</tr>
<tr>
<td>Zuckerrüben</td>
<td>0,57</td>
<td>0,88</td>
<td>27,00</td>
</tr>
<tr>
<td>Zuckerrohr (BRA)</td>
<td>0,22</td>
<td>0,34</td>
<td>10,39</td>
</tr>
<tr>
<td>Lignocellulose</td>
<td>0,64</td>
<td>0,98</td>
<td>30,00</td>
</tr>
<tr>
<td>BtL</td>
<td>1,00</td>
<td>1,03</td>
<td>29,90</td>
</tr>
<tr>
<td>Biomethan (Biogas)</td>
<td>1,04*</td>
<td>0,74</td>
<td>20,83</td>
</tr>
</tbody>
</table>

Quelle: meo Consulting Team

* (Euro/kg)
Grant programme
Biomass CHP/AD_CHP

- Launched January 2008, Duration End of 2010

- Indicative Budget of €5-8m, Biomass CHP, AD CHP

- Grant support:
  - Grant support of up to 40% of the Feasibility study (CHP programme)
  - Grant of up to 30% of eligible costs/Investment costs
  - Cost cap on eligible costs defined in programme
  - Indicative grant cap per project → €1.5 million
Eligible projects’ characteristics (extract):

- New biomass CHP/AD_CHP installed in RoI
- Primary energy savings (PES)
  - For <1 MWe $\Rightarrow$ PES $>$0%
  - For $\geq$1MWe $\Rightarrow$ PES $>$10%
- High efficiency CHP complying with EU CHP Directive 2004/8/EC

Eligible costs (extract):

- Equipment (e.g. prime mover, fuel supply, processing and storage)
- Mechanical/electrical connections of plant items
- Specified building and civil engineering work
AD information

• Application guide/form grant
  – Biomass CHP/AD_CHP: [www.sei.ie/bio_chpgrants](http://www.sei.ie/bio_chpgrants)

• Provided AD Information
  – Calculator
    • Input/feedstock, typical gas yields
    • Calculating main operating parameter, gas yields, kWh el. th.
      – Retention time, organic loading rate
  – Literature f. ex. updated English-Handbook
  – Checklist developing a project
  – Guide Connection to the grid
  – Information Animal By products

[http://www.sei.ie/Renewables/Bioenergy/Anaerobic_Digestion](http://www.sei.ie/Renewables/Bioenergy/Anaerobic_Digestion)
Contact

Thank you

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