LCA of agricultural biogas production – the effects of plant size

Martina Alig, ART

47th LCA Discussion Forum, 23 April 2012
Background

- Switzerland: 72 Biogas plants (2010) of very different sizes: 50kW\textsubscript{e} - 1’000 kW\textsubscript{e}

- Augmentation of capacity =
  - Better efficiency in conversion of organic matter
  - better energy efficiency
  - better utilization of infrastructure
  BUT: More substrate is needed $\rightarrow$ more transports

- What is the ideal size of an agricultural biogas plants regarding its environmental impacts?

  $\Rightarrow$ Comparison of centralized and decentralized agricultural biogas plants of different sizes

  $\Rightarrow$ Data collection on real farms with a questionnaire

  $\Rightarrow$ Impacts analyzed: non-renewable energy demand, global warming potential, total environmental impact (UBP)
Project information

- Project title: **Life-cycle assessment of centralized vs. decentralized biogas production in agricultural facilities**

- Partners & Collaborators
  - **ENERS Energy Concept**
  - Agroscope Reckenholz (ART)
  - EREP
  - Ernst Basler + Partner (EBP)
  - Agroscope Changins (ACW)
  - A. Dauriat
  - G. Gaillard, M. Alig, D. Scharfi
  - Y. Membrez, N. Bachmann
  - R. Steiner
  - R. Charles
Key questions and goals

- Evaluation of the ecological balance of agricultural biogas production as a function of output level (size of production facility), based on real biogas production facilities in Switzerland: “centralized vs. decentralized”

- Comparative analysis of the results and identification of the main determinants of environmental performance (non renewable primary energy use, greenhouse gas emissions, global ecological balance according to UBP method) of agricultural biogas production

- Elaboration of practical recommendations addressed to biogas producers, investors and/or political actors regarding the size of agricultural biogas production

- Update of ecoinvent inventories (v3) regarding agricultural biogas production (including cogeneration)
Project structure and organisation

Methodology (ENERS)
Definition of methodological basis
Elaboration of a questionnaire addressed to biogas producers

Life cycle inventory (ENERS)
Implementation of life cycle inventories based on the answers to the questionnaire and on the structure of ecoinvent biogas inventories

Life cycle analysis (ENERS)
Environmental impact of centralized vs. decentralized agricultural biogas production
Identification of the main determinants of environmental performance
Sensitivity analysis

Case studies (ART)
More in-depth analysis of selected biogas production facilities

ecoinvent
Resp.: ART

EREP, EBP: expert knowledge regarding biogas production, contact to biogas producer

ACW: expert knowledge regarding soil fertility and use of digestate
Biogas plants analysed

Production annuelle de biogaz [m3/an]
- Exploitations
  - 1'000
  - 10'000
  - 50'000
  - 100'000
  - 1'000'000

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Analysis of the questionnaires (I)

No relationship between production of biogas, quantity of co-substrates used, transport distance of co-substrates and number of co-substrates providers!
Only weak relationship between transported co-substrates multiplied by mean transport distance and production of biogas / number of co-substrate providers!
Use of co-substrates in agricultural biogas plants depends on proximity of co-substrate providers as well as geographical and economic factors, but not primarily on the size of the installation.
### Definition of reference cases

<table>
<thead>
<tr>
<th>Size of the installation</th>
<th>Share of co-substrates</th>
<th>Transport of co-substrates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>small</strong> (50 kW, 200'000 m³ biogaz/an)</td>
<td>0% co-substrats</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>20% co-substrats</td>
<td>5 km P50-CS0-KM0</td>
</tr>
<tr>
<td></td>
<td>50% co-substrats</td>
<td>5 km P50-CS50-KM5</td>
</tr>
<tr>
<td><strong>middle</strong> (150 kW, 600'000 m³ biogaz/an)</td>
<td>20% co-substrats</td>
<td>20 km P150-CS20-KM20</td>
</tr>
<tr>
<td></td>
<td>50% co-substrats</td>
<td>20 km P150-CS50-KM20</td>
</tr>
<tr>
<td><strong>big</strong> (350 kW, 1'400'000 m³ biogaz/an)</td>
<td>20% co-substrats</td>
<td>35 km P350-CS20-KM35</td>
</tr>
<tr>
<td></td>
<td>50% co-substrats</td>
<td>35 km P350-CS50-KM35</td>
</tr>
</tbody>
</table>
Definition of reference cases

Production of biogas (1'000 m³/year)

Transport distance of co-substrates (km)

Quantity of co-substrates transported (tkm/year)
System boundaries

- Engrais de ferme
- Résidus de l'industrie
- Déchets communaux

- Transport
- Stockage
- Digestion
- Digestat brut
- Stockage
- Transport

- Biogaz
- Digestat brut pour épandage

- Cogénération de chaleur et électricité
  - Chaleur
  - Elect.

Légende:
- Limites des inventaires ecoinvent
- Processus élémentaires de la filière
Energy demand per m³ biogas produced

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GWP per m$^3$ biogas produced

- non-waste substrates
- production of biogas
- transport of substrates
- storage of substrates
- without waste treatment function

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Global environmental impact per m³ biogas produced

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Share of co-substrates vs. size

Energy demand

Global env. impact

transport distance = 20km
Share of co-substrates vs. transport distance

Energy demand

Global env. impact

plant size = 150 kW_e
Size vs. transport distance

Energy demand

Global env. impact

Share of co-substrates = 20%
Main determinants of the environmental impact of agricultural biogas plants

<table>
<thead>
<tr>
<th>Paramètres et principaux déterminants</th>
<th>Consommation d’énergie primaire non-renouvelable</th>
<th>Emissions de GES</th>
<th>Impact environnemental global</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrats « non-déchets »</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Part des co-substrats</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Fonction « traitement des déchets » (allocation)</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Caractérisation du mix de co-substrats</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Temps où le substrat est stocké chez le producteur de biogaz</td>
<td>0</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Transport des digestats</td>
<td>+++</td>
<td>+</td>
<td>+/++</td>
</tr>
<tr>
<td>Approvisionnement en électricité (auto/externe)</td>
<td>+++</td>
<td>+</td>
<td>+/++</td>
</tr>
<tr>
<td>Distance d’approvisionnement des co-substrats</td>
<td>+++</td>
<td>+</td>
<td>+/++</td>
</tr>
<tr>
<td>Rendement(s) de biogaz (par type de substrat)</td>
<td>+</td>
<td>+/++</td>
<td>+/++</td>
</tr>
<tr>
<td>Type de stockage des digestats (couvert/ciel ouvert)</td>
<td>0</td>
<td>0</td>
<td>+++</td>
</tr>
<tr>
<td>Taille de l’installation</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Valeur économique des co-substrats</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Post-fermentation</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Rendement électrique de la cogénération</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Nombre de jours d’arrêt (émissions directes de biogaz)</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Type de stockage des substrats (couvert/ciel ouvert)</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
</tbody>
</table>

+ : peu significatif / ++ : significatif / +++ : très significatif / 0 : pas significatif
Case study I: Farm with small biogas plant (15 kW<sub>e</sub>) without use of co-substrates
Case study II: Farm with small biogas plant (45 kWₑ) with use of co-substrates
Case study III: Farm with big (common) biogas plant (200 kWₑ) with use of co-substrates
Conclusions

- **Use of non-waste substrates** significantly augments energy demand and global environmental impact of biogas production, but reduces GWP.

- Without use of non-waste substrates:
  - Energy demand dominated by **transport distances** (substrates and digestates)
  - GWP and Global environmental impact dominated by **storage of digestates**
  - The more co-substrates are used the **smaller the environmental impacts**

- For the same amount of co-substrates:
  - Augmentation of size compensates augmentation of transport distances for GWP and Global environmental impact, but not for energy demand

- **Farm level**: Installation of biogas plant can significantly reduce energy demand and - to a smaller extent - also GWP on farm level.
Recommendations

- **Treatment function important**, avoid non-waste substrates
- **Augmentation of the share of co-substrates** to the maximum (50%) advantageous
- High **transport distances** worsen energy demand
- **Size** of a biogas installation has no important influence on environmental performance, except for very small installations (between 50 and 150 kW_e installed power)
- Size has to be adapted to the amount of co-substrates available within a reasonable distance

=> **Optimal size of a biogas plant is the one which allows to optimize the share of co-substrates in the allowed radius of 50km around the installation without using non-waste substrates!**
Thank you!

ART – Research for Agriculture and Nature

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