# Straw pellets for anaerobic co-digestion with cattle manure in the Netherlands

**W.J. Oosterkamp**

**7-12-2016**


## Summary

The use of straw pellets can increase the specific methane yield per cubic meter of anaerobic reactor volume and day and in this form reduce the production costs of the anaerobic digestion [AD] of cattle manure. This paper reviews the available data on the costs of producing straw pellets and calculates the costs for producing electricity from the co-digestion of straw with cattle manure.

The productions costs are 25 % to high with respect to the subsidy levels in the coming years in the Netherlands. Some possible reductions and increases in revenues are discussed.


## Introduction

There are large amounts of manure available as a source of renewable energy. Mono digestion of cattle manure is only marginally economic [Boekel 2015]. Co-digestion of manure with straw is recommended for small and medium size biogas plants [Reinhold 2012] and  poses a number of problems [Schwartz et al. 2012].

Straw need to be shredded [Slotyuk in Oechsner, 2012] and heated [Raju et al.2010] in order to obtain high methane yields.  The production of pellets or briquettes involves shredding, milling and the compression of the straw into pellets [Nolan et al. 2010]. This compression raises the temperature and is equivalent to heat treatment. Larger distances for the transport for straw are still economic when straw is pelletised. [Hartmann 1997; Nielsen 2015].

## Straw

### Availability of straw

Around 1 000 million kg of straw is being produced in the Netherlands [Koppejan et. al 2009]. Three quarters of this has an economic use. It is assumed that 25 % of the straw is shredded and worked under to keep the humus content of the soil at the optimum level.  More than half of the straw is applied as winter cover of flowering bulbs and carrots [Bosma and Vermeer 2009]. This puts the Netherlands in a special position with regard to the use of straw. Significant amounts of straw are imported from northern France and eastern Germany [Bosma en Vermeer 2009].

### Use of baled straw

Straw to be used in anaerobic digestion plants requires shredding, milling and thermal treatment. These processes require constant supervision and are not suited for dairy farms. Straw can be shredded, during the harvest, and baled   Shredding of straw in the field costs an extra 0.01 - 0.02 €/kg [Troester and Bleisteiner 2012]. Straw bales need to be de-baled, mixed with cattle manure, macerated and pumped into the reactor.  Thermal treatment of the slurry is still required. One option is to operated the primary reactor at 70 $^{o}$ C and the secondary reactor at 55 $^{o}$ C  [ Ward et al. 2010; Nielsen et al. 2004]. There remains however the problem of floating straw layers in the reactor.

**Spent bedding and spoiled straw and fodder**

The amount of straw for bedding varies between 1 and 5 kg/d per cow. This is 10 % to 50 % of what is required for maximum usage of the anaerobic reactor. Spent bedding and spoiled straw and hay can be used when a mixer ( to mix straw with manure), a high solids pump and a macerator are used to prepare the substrates. It is advantageous to use straw pellets for bedding as they absorb much more liquid than long straws. Extra equipment is not necessary when straw pellets are used for bedding and subsequently used as substrate for anaerobic digestion.

**Pelleting of loose straw**

The straw can be collected after the grain harvest, shredded and transported without baling to the pellet factory. This makes sense for transportation distances of about 10 km [Leible et al. 2011, Hering 2012 ]. The straw can then be processed directly into pellets reducing the storage costs [Schindler 2014], but increasing the capital costs [Hartmann,; Nolan 2010] as the pellet installation will be used only during the harvest time ( around 500 h). Costs can be reduced by using large capacity self loading forage wagons ( 50 - 90 $m^3$) [Breen 2009] and temporary storage for loose straw increasing the operating period of the pelleting equipment.

**Mobile pelleting plants**

The German company Krone is developing a tractor pulled pellet plant that picks up straw swaths and produces 13 mm pellets at a rate of 5 000 kg/h [Euwema 2016].

The Danish company CF Nielsen produces containerised briqueting plants that can work at farms [Knudsen No date]. Pelleting costs are around 0.035 to 0.040 €/kg.

A German company [Seip no date] offers a mobile pelleting plant. Costs, exclusive shredded straw, are 0.105 €/kg ( 0.035 depreciation, 0.035 €/kg manpower and 0.035 diesel fuel). Total costs at the field site are 0.15 €/kg.

## Methane yield

There is uncertainty about the methane yield of cattle manure. Xavier et al. [2015] used two types of manure (Three month old manure with a volumetric methane yield of 8 $m^3/m^3$ in the lab scale experiments. Manures were collected each week from a farm for the full scale reactors. Methane yields were higher (13 $m^3/m^3$).

The use of day fresh manures with a high methane yield requires a different manure collection system and modifications to the stables. The company Lely has developed a robot vacuum cleaner for manures [ Stokkermans 2016]. The robot uses clean water for its operation and the manure is somewhat diluted. The collected manure can be pumped directly from the container in the robot 0.34 $m^3$ into the reactor. Estimated VS is similar to that of Xavier et al. [2015].

It is likely that manures during storage develop components that are inhibitors for anaerobic digestion [Oosterkamp 2016]. There are indications that heat pretreatment of the manures will destroy this inhibition [Ward et al. 2010; Nielsen et al.2004]. The thermal energy of the combined power and heat generators is sufficient to heat the manure up to the required temperature.

Manures in the Netherlands have a 30 % higher volatile solids content (64 kg/m3)[Boer et al. 2012] and this type of manure will increase the methane production by 15 %.

Methane yields with straw depend on the pre-treatment, digestion time and total solids of the substrate. The tests on the addition 25 - 50 % VS straw are difficult to compare (Straw length, Total Solids, freshness of manure and digestion period) [Robins et al.1979; Lehtomaeki 2006; Risberg et al. 2013, Xavier et al. 2015] (Table 1).

Robbins et al. [1979], Lehtomaeki (2006) and Xavier et al. [2015] show a increase of 15 % and 40 % in methane yield and Risberg et al. (2013) a small decrease (10%). The straw was cut to 10 mm (Risberg) in order to be able to run small CSTR reactors.

**Table 1 Addition of straw**

| Author | Straw type | Digestion period d | Methane yield $m^3/kg$ VS | | Total solids (effluent ) kg/m3 | |
|---|---|---|---|---|---|---|
| | | | Control | | Control | |
| Robbins et al. [1979] | Wheat straw | 16 | 0.120 | 0.135 | 31 | 44 |
| Lehtomaeki [2006] | Barley straw | 20 | 0.151 | 0.215 | 44 | 32 |
| Risberg et al. [2013] | Wheat straw | 25 | 0.165 | 0.150 | 50 | 35 |
| Control is the methane yield without straw | | | | | | |

Slotyuk in Oechsner [2012] found a methane yield of 230 l/kg VS for 10 mm wheat straw particles and 270 l/kg VS for 5 mm particles. The duration of these tests was 35 days.

Raju et al. [2010] performed batch anaerobic tests ( 32 days at 38 $^{o}$C) on the heat pre-treatment of straw (75 % wheat and 25 % rape seed). They found an increase in methane yield from 190 l/kg VS to 260 l/kg VS when the straw was treated to temperatures in the range of 75 $^{o}$C to 125 $^{o}$C for15 min.

Mönch-Tegeder et al. [2013] performed batch tests at 37 $^{o}$C for 35 days on straw pellets and measured a methane yield of 250 l/kg VS. In these tests the micronutrient concentrations were not optimum.

The group at Aarhus University [Moeller and Moeller Hansen 2014; Xavier et al. 2015] did a number of experiments with cattle manure and briquetted straw. Methane yields are between (0.22 - 0.35 $m^3/kg$ VS). The differences are most likely due to variations in the freshness of manures.

**Table 2 Addition of straw briquettes**

| Author | Straw type | Digestion period d | Methane yield $m^3$/kg VS | | Ratio | Total solids (Influent ) kg/m3 | |
|---|---|---|---|---|---|---|---|
| | | | Control | | | Control | |
| Xavier et al. 2015 Lab reactors | Wheat | 20 | 0.166 | 0.214 | 1.29 | 68 | 105 |
| Moeller and Moeller Hansen Pilot reactors | Wheat | 25 | 0.200 | 0.264 | 1.32 | 76 | 140 |
| Xavier et al. 2015 Pilot reactors | Wheat | 25 | 0.264 | 0.351 | 1.33 | 62 | 148 |
| Control is the methane yield without straw | | | | | | | |

**Humus**

The choice of anaerobic digestion of biomass as opposed to combustion is based in part on the assumption, that only material is converted into methane and carbon dioxide, that does not contribute to formation of humus.

This assumption is only half true. Data on the humus equivalent [HE] of cattle manure and reactor effluent indicate that cattle manure at a TS 70 kg/$m^3$ is equivalent to 9 kg humus ( a ratio of 0.13 between HE and TS) and reactor effluent at 40 kg/m3 is equivalent to 7 kg humus ( A ratio of 0.18) [Ebertseder  et al. 2014] and not a ratio of 0.23).

There is in the last twenty years an equilibrium in the humus content of the soils in the Netherlands [Burgt et al. 2008]. The anaerobic digestion of manure and straw requires an extra source of organic material e.g. extra compost or imported straw [Note 1]

The fields of the dairy farm of the university of Wageningen have been fertilised by the effluent of an anaerobic reactor. This reactor converts 30 % of the organic material into biogas (methane and carbon dioxide). The organic content in the fields increased slightly from 4.2% to 4.5 % in a period of fifteen years [Hogenkamp 2016]. This is not only due to the effluent but also by crop rotation ( three years maize and three years gras). During the maize years gras seed was sown in the end of June when the maize was 0.4 m high. The gras is worked under before the maize was sown in the next season and the decaying gras contributes to the organic content of the soil [Vechte no date].

Fifteen years is fairly short for such an experiment. Heim and Schmidt [ 2005] found an half live of lignin derived monomers varies between ten and forty years. Elfering and Vlaar [2010] use a half-life of soil organic material of fifty years ( a reduction of 2% per year). The reduction depends much on the type of crop grown on the soil [Eberseder et al. 2014]

It seems prudent that the humus equivalent that is exported in the processed manures is compensated by the import of straw.

**Surplus Phosphate**

There is a phosphate surplus in the Netherlands as a whole, due to the import of fodder with a high protein content. The arable land in the Netherlands is insufficient to accept all the phosphate contained in the manures of cattle, swines and poultry. There is a surplus of phosphate on around 80 % of the dairy farms in the Netherlands [Ann. 2015]. The disposal costs for extra phosphate in the straw are given by the need to transport effluent over a distance of also more than 500 km. The regulations for export of manures and reactor effluents are getting more and more stringent increasing the costs of disposal even further.

The dairy farm of the University of Wageningen has no surplus of phosphate [Oenema 2013] and the manure has less phosphate than the average in the Netherlands [Hilhorst and Verloop 2010; Boer et al. 2012].

Straw has 1.2 g phosphate per kg. [ann. 2009] and this extra phosphate must be removed from the farm. Extra straw used in anaerobic digestion will increase the amount of effluent that has to be removed from these farms and exported.

## Cost calculation

**Cost of pellets**

Schindler [2014] gives an overview of the cost components of straw in Germany delivered at the farm.

**Table 3 costs of square straw bales**

| | |
|---|---|
| Fertiliser value | 0.025 €/kg |
| Baling | 0.015 €/kg |
| Loading | 0.010 €/kg |
| Transport (10 km) | 0.010 €/kg |
| Unloading | 0.005 €/kg |
| Storage | 0.030 €/kg |
| Profit | 0.010 €/kg |
| Total | 0.105 €/kg |

Cost of the production of straw pellets is given in Table 3.

**Cost of the anaerobic digestion plant**

We use the following data for a costs calculation:
- A methane yield of 0.35 m3/kg VS [Xavier et al. 2015]
- A price of 0.180 €/kg VS ( 0.155 €/kg for pellets with a correction for humidity and

ash) (Table 3) [Note 4].

- VS of cattle manure in the substrate is 37 kg/m3 kg/$m^3$ ( Xaver et al. 2015).
- A straw load VS of 41 kg/$m^3$ of substrate [ Xavier et al. 2015].
- Investment for the reactor and peripherals is 300 000 € [Dobbelaere et al. 2015].
- Interest and deprecation for the reactor and peripherals 16 %/a [Dobbelaere et al. 2015]
- We use data for the investment of the combined heat and power plant of 135 kWe of Ruhnau et al. [2011] with a correction of 35 % based on the data of Dobbelaere et al. [2015] [Note 3].
- No data on the phosphate content of the manure used by Xavier et al. [2015] has been published. The manure is diluted by water compared to the manures reported by Boer et al. and 0.001 $m^3$/kg effluent needs to be removed from the farm per kg VS of straw.
- Cost for removal of excess phosphate is 19 €/$m^3$ manure [Schotman 2015] based on the gate fee of a proposed centralised manure processing plant [note 6].

**Table 3 Cost of straw pellets**

| | | |
|---|---|---|
| Baled straw at the factory | 0.105 €/kg | Table I |
| Shredding of straw bale, milling, pelleting and cooling | 0.035 €/kg | Nolan et al. 2010 |
| Loading, transport and off-loading of pellets at the anaerobic reactor (70 km) | 0.015 €/kg | Plomp 2015 |
| Total | 0.155 €/kg | |

**Table 4 Cost of combined heat and power plants [Ruhnau et al. 2011]**

| | 65 kWe | 135 kWe |
|---|---|---|
| **Investment** | 1 700 €/kWe | 1 000 €/kWe |
| **Efficiency** | 0.36 | 0.38 |
| **Maintenance costs** | 0.025 €/kWhe | 0.015 €/kWhe |
| | - Factory stated efficiencies of reciprocating engines used in combined heat and power plant after 10 000 h are too high by about 3 % absolute and about 8 % relative [Ashmann and Effenberger 2012]. | |

We obtain 120 kWh/$m^3$ substrate, using an electric methane efficiency of 3.5 kWh/$m^3$ methane (The energy content of methane is 10 kWh/$m^3$; electric energy efficiency is 0.35 [Ruhnau et al. 2011][ note 6].

**Table 4 Electricity cost of anaerobic digestion of manure with straw pellets**

| | €/kWhe |
|---|---|
| **Pellet costs** | 0.060 |
| **Disposal of surplus phosphate** | 0.005 |
| **Maintenance reactor and peripherals** | 0.010 |
| **Maintenance combined heat and power plant** | 0.015 |
| **Interest and depreciation reactor and peripherals** | 0.050 |
| **Interest and depreciation combined heat and power plant** | 0.025 |
| **Electricity costs** | 0.165 |

## Discussion

The electricity production costs are lower than the costs of the farm described by Dobbelaere et al. [2015] of 0.195 €/kWh$_e$ and slightly more than the median value of Velghe and Wierinck. [2013] of 0.155 €/kWh$_e$ for all operation biogas plants in the Netherlands in 2013. Costs have to be reduced to below 0.125 €/kWe, as this is the maximum that the government will subsidise in 2017 - 2018 [Kamp 2016] for manure mono digesters. This requires a number of measures: Reduced costs and extra income

- Pellets are nearly as expensive as straw. Prices in the Netherlands ( Fall of 2016) for straw are 0.100 kg [Souman 2016]. Extra storage costa are between .02 €/kg and .03 €/kg. [Schindler 2014]. Straw pellets are 0.155 €/kg [Sinnige 2016] delivered at the site of the anaerobic reactor. Straw pellets are more attractive for bedding, than straw bales. Pellets can be first used as bedding and the spent bedding can substitute part of the the fresh pellets. Around 1 000 kg/d of pellets are required for the digester. Bedding can substitute about 40 % of this [Linde 2016]. A reduction of .01€/kWe is possible assuming a 50 % cost sharing..
- Lower pellet costs. There is an offer for pellets for of 0.12 €/kg ( 0.05 for the pellets and 0.07 for the transport of the Ukraine to the Netherlands; Pellets are produced at a loss in the Ukraine [Sharaienko 2016]). kWh costs will be reduced by 0.015 €/kWh.
- Cost reduction by simplifying the peripherals of the reactor. e.g. it is possible to operate without mixing device [Zemke 2011].
- Cost reduction is possible using a reduced percentage for interest and depreciation [Klein Gunnewik 2015]
- Excess heat from the CHP plant can be used to heat buildings in the late fall, winter and early spring period. There are extra costs involved for a heat distribution network estimated at 0.04 €/kWh$_e$ [Schepers and Valkengoed 2009]. Extra income of the order of 0.01 €/kWh$_e$ can be generated.
- Excess heat, when it can not be used for building, can be used in the drying of the reactor effluent. This is only economic, when manure from other farms, that need to export excess phosphate, can be used at a reasonable gate fee [Schotman 2016]. The net income from the heat is equivalent to about 0.01 €/kWh$_e$ [Note 7].

- Biogas or biomethane can be exported from the farm instead of electricity. This requires a pipeline from the farm. [Note 8]. Heat must be provided for the heat-up of the substrate to the operating temperature of the reactor, when the biogas is not used at the farm [note8]. A plant in Den Bommel Netherlands obtained a price of 1.2 €/$m^3$ methane [Klein Gunnewiek 2015]. This is an extraordinary high value. A more realistic price is 0.75 €/$m^3$ [Kwant 2016b].

## Conclusions and recommendations

A number of measures need to be taken in order to reduce the cost per $kWh_e$ to a level of 0.125 €/$kWh_e$ [Kamp 2016]. The best choice depends on the local circumstances (e.g. what energy users there are  in the neighbourhood of the farm, that can use the heat or biogas directly; can biogas be combined with that of other farms; connection with the natural gas grid).

Attractive is the option where part of the biogas is exported by a pipeline and combined with biogas from other farms and used in boilers or upgraded to natural gas pipeline quality.

The option where the effluent is separated into a thick fraction and this fraction is dried and exported is also worth of consideration.

The cost of the transport of straw pellets combined with a return freight of the dried thick fraction of the reactor effluent should be further explored.

## Notes

[Note 1]
The 250 million kg/a ( 250 000 ton/a) of straw, that is now shredded and used to keep the humus content of the soil at the optimum level can be used, for the production of straw pellets as co-substrate for anaerobic digestion. Schneider [2011] demonstrates that it is for farmers more economic to sell all their straw and to use instead compost in order to keep the organic content of the soil at the most productive level.

[Note 2]
Kasper and Peters give a value for the reactor and peripherals of 315 000 Euro for a similar plant using swine manure.

[Note 3]
Dobbelaere et al. [2015] give an investment for the combined heat and power plant of 2300 €/kWe. Ruhau et al. [2011] give a value of 1 700 €/kWe. Kasper and Peters [2012] use a value of 2 000 €/kWe.

[Note 4]
Xavier  et al. [2015] found that the methane yield of shredded straw was the same as for straw briquettes. Straw requires storage ( 0.030 €/kg [Schindler]) and shredding (0,015 €/kg [Tröster and Bleisteiner 2012] ) before it can be used in the anaerobic reactor.  There is an extra investment for a de-baler at the digester plant. Total costs are over 0.135 €/kg.

[Note 5]

Snoo [2016] quotes values of  or 18 - 25 €/m$^3$ in the beginning of 2016 for removal of cattle manure from the farm.

[Note 6]
Ashmann and Effenberger [2012] found a difference of 7 % relative between efficiency of reciprocating engines given by the factory ( similar to those of Ruhau et al. [ 2011]) and what they measured after several thousand hours of operation. This results in 7% higher total costs per kWh.

[Note 6]
Farms with anaerobic digestion plants can take in manure at a gate fee of around 16 €/m3 [Schotman 2016]. The manure can be digested together with the own manure. The reactor effluent should be separated into a thick fraction and a thin fraction [Zevenbergen 2011]. Around 75 % of the phosphate is in the thick fraction [Hilhorst and Verloop 2009]. The thick fraction can be hygenised and exported [Leible et al. 2011] or the thick fraction can be dried [Ann. no date] and then exported .

[Note 7]
The set-up of a biogas distribution network has a number of advantages. The gas can be directly used in boilers or further processed at a central facility into biomethane for injection into the natural gas grid; compressed  for vehicle fuel or cooled into liquid biomethane.

[Note 8]
Heat must be supplied to the substrate to heat it up to the operating temperature of the reactor and to compensate of heat losses of the reactor. This can be done by a heat pump using the thermal energy of the milk cooler, the biogas compressor and the reactor effluent. The temperature in the secondary reactor/effluent storage should however remain above 20 $^{o}$C in order to obtain an extra 20 % of methane [Dobbelaere et al. 2015].

Alternatives are:
- A boiler on biogas with a thermal efficiency of about 100 %.
- A combined heat and power plant with reciprocating engine.
- A combined heat and power plant with micro-turbine engine.

The micro-turbine is an attractive option as it has reduced operating costs and a higher usable heat output than reciprocating engines. In 2012 they had  20 % lower investment and 0.028 €/kWh lower maintenance costs [Kasper and Peters 2012]. In 2016 this was no longer the case. Investment cost are 10 % higher [Darrow et al. 2016].

**Literature**

Ann. 2015 "Fosfaat overschot op de bodembalans"
LLM-Nieuws RIVM, Bilthoven Netherlands Aug. 2015
Ann. no date " Screw heat exchanger for biogas and water treatment plant for potato processor Pizzoli in Italy" van Beek, Drunen, Netherlands
Ann. 2009 "Assessing the nutrient content of cereal straw" AHDB-HGCA Kenilworth Warwickshire United Kingdo
Ashmann, V. and Effenberger, M., 2012, "Verlauf des elektrischen Wirkungsgrades biogasbetriebener BHKW über die Betriebsdauer" Bayerisches Staatsministerium für

Ernährung, Landwirtschaft und Forsten München

Boekel E. "Monovergisting: Kansrijk maar moeizaam" Boerderij Sep. 2014

Boer, D.J. den, Reijneveld, J.A. and Middelkoop, J.C. 2012 " Mestsamenstelling en adviesbasis bemesting grasland en voedergewassen" Commisie bemesting grasland en voedergewassen, Wageningen, Netherlands

B. Bosma and H.M. Vermeer, Voldoende stro voorhanden, Praktijkkompas Varkens, 2004

Breen, J. 2009 "Clash of the silage titans" Farm Ireland April 2009

Burgt, G.J.H.M. van der, J.J.M. Staps, B.G.H. Timmermans. 2008. Dutch (organic) agriculture, carbon sequestration and energy production. p. 88-91. In: The 5th International Scientific Conference on Sustainable Farming Systems - ECOMIT. Piestany, Slovakia. November 5-7, 2008.

Darrow, K., Tidball, R., Wang, J. and Hampson, A. 2015 "Catalog of CHP Technologies"U.S. Environmental Protection Agency Combined Heat and Power Partnership, Washington 2015

Dobbelaere, A., Keulenaere, B. de, Mey, J. de, Lebuf, V., Meers, E., Ryckaert, B., Scholier, C. and Vriesche, J. de 2015 "Small-Scale Anaerobic digestion" Inagro, Rumbeke-Beitum Belgium

Dorp, R. van "Groen Gas: een overzicht van innovatieve technieken en leveranciers" Stichting groen gas Nederland, Utrecht, Netherlands 2013

Euwema, K, 2016 "De lucht eruit" Landbouwmechanisatie juli 2016

Ebertseder, T., Engels, C., Heyn, J., Hülsbergen, K-J, Isermann, K., Kolbe, H., Leithold, G., Reinhold, J., Schmid, H., Schweitzer, K., Willms M. and J. Zimmer, 2014 "Humusbilanzierung Eine Methode zur Analyse und Bewertung der Humusversorgung von Ackerland Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten (VDLUFA) Speyer, Germany

Elferink, E. and Vlaar , L. 2010 "Compost, Carbon en Credits Een verkennende discussienota" CLM Onderzoek en Advies BV Culemborg, Netherlands

Haan, J.J. de and Geel, W. van 2013 "Adviesbasis voor de bemesting van akkerbouwgewassen - Organische stof" kennisakker.nl, Zoetermeer, Netherlands

Hartmann, 1997 "Bereistellungskette fuer Halmgutbrennstoffe" Landtechnik 3/1997 pp 138 - 139

Heim, A. & Schmidt, M.W.I. 20005 "Lignin is not a main contributor to the stable soil organic carbon fraction" Soil Science and Biogeography Group, Department of Geography, University of Zurich, Switzerland

Hering, Th. 2012"Aktueller Stand der Kompaktierung von Stroh in Deutschland – eine Marktübersicht" Thüringer Landesanstalt für Landwirtschaft, Jena, Germany

Hilhorst, G. and Verloop, K. 2010 "Scheiden van rundveemest met decanter van GEA Westfalia Separator" Wageningen UR Livestock Research, Wageningen, Netherlands

Hogenkamp W. 2016 "Geen effect digestaat op bodemkwaliteit De Marke" Boerderij Aug 2016

Kamp, 2016 "Letter to: De Voorzitter van de Tweede Kamer der Staten-Generaal", Ministry of economic affairs, the Hague, Netherlands

Kasper, G.J and Peters, B. 2012 "Monovergisting varkensmest op boerderijschaal Wageningen UR Livestock Research rapport 632, Wageningen Netherlands

Klein Gunnewiek, 2016 "Ontwikkeling en realisatie van de mono-vergister bij Ras in Den Bommel" Host, Enschede, Netherlands

Knudsen,M.S. no date "Mobile briqueting plants" C.F. Nielsen, Baelum Denmark

Koppejan, J., Eilbersen, W., Meeusen, M. and Bindraban, P.2009 " Beschikbaarheid van Nederlandse biomassa voor elektriciteit en warmte in 2020"

Senter Novem, Utrecht Netherland

Kwant K.W. 2016b personal communication Zwolle, Netherlands
Lehtomaeki, A. 2006 “Biogas Production from Energy Crops and Crop Residues”, Dissertation University of Jyvaeskylae Finland
Leible,L., Kälber,S. and Kappler, G. 2011 “Systemanalyse zur Gaserzeugung aus Biomasse“ KIT scientific reports 7580
Linde, A-M van der, 2016 “Droge boxen en schone koeien met stropellets” Melkvee100Plus , July 2016
Møller, H.B. and Møller Hansen, M. 2014 “Briketter af halm og toert graes kan fordoble gasproduktionen” FIB Forskning i Bioenergi, Brint &Braendselsceller 11(47) pp 3-6
Mönch-Tegeder, M, Lemmer,A. , Oechsner, H. and Jungbluth , T. 2013 “Investigation of the methane potential of horse manure” Agric Eng Int: CIGR Journal 15(2) pp 161 - 172
Nielsen, H.B., Mladenovska, Z., Westermann, P. and Ahring, B.K. 2004 “Comparison of Two Stage Thermophilic ( 68 °C/55 °C) anaerobic digestion with One—Stage Thermophilic ( 55 °C) Digestion of Cattle Manure” Biotechnology and bioengineering 86(3) pp 291-300
Nielsen, N. 2015 “Briqueting of agricultural biomass, challenges in industrial production” Infres Natural Resource Institute Finland Joensuu, Finland
Nolan, A., McDonnell, K., Devlin, G. et al. 2010 “Economic Analysis of Manufacturing Costs of Pellet Production in the Republic of Ireland Using Non-Woody Biomass” The Open Renewable Energy Journal, 3 (2010): 1-11
Oechsner, H., 2012. Forschungsinitiative und -projecte zur bio-gasforschung. In: Kranert, M. (Ed.), 8e Biogastag Baden Wuertenberg 13 Maerz 2012 Hohenheim. Oldenbourg Industrie Verlag, Essen Germany, pp. 1-144.
Oenema, J. 2013 “Benutting van stikstof en fosfaat op melkveebedrijven is verder op te voeren” Plant Research International Wageningen University, Wageningen, Netherlands
Oosterkamp, W.J. 2016 “Variation in Methane Yield From Anaerobic Digestion of Cattle Manure” Current Biochemical Engineering, 3(2016) pp 66-71
Plomp P. 2015 “Transportkosten” Houtpellets-Direct, Waardenburg, Netherlands 2015
Raju, C.S., Ward, A.J. and Moeller, H.B. 2010 “The effect of thermochemical pre-treatment on the ultimate biogas potential of straw” in proceedings 14th Ramiran conference Lisboa, Portugal 13th to 15 th September 2010
Reinhold, G. 2014 “Standpunkt zur Vergärung von Stroh in Landwirtschaftlichen biogasanlagen” Thüringer Landesanstalt für Landwirtschaft Jena, Germany
Risberg, K., Sun, L. Leven, S.J. Horn and A. Schnuerer A. 2013 “ Biogasproduction from wheat straw and manure-impact of pretreatment and process operating parameters” Bioresource Technology 149 pp 232 - 237
Robbins, J.E., Armold, M.T. and Lachler, S.L. 1979 “Methane production from cattle waste and delignified straw” Infection and Immunity p 175 - 177 July 1979
Ruhnau, S., Fay, P., Kahlert, J., and Ahrtkamp J., 2011 “ BHKW- kenndaten 2011” Arbeitsgemeinschaft für sparsamen und umwelt- freundlichen Energieverbrauch, Berlin, Germany, 2011
Schindler,M., 2014 “Getreidestroh verkaufen oder einarbeiten” Landwirtschaftskammer Niedersachsen, Hanover, Germany
Schwartz, B. and Reinhold, G. 2012 “Potenziale und Wirtschaftlichkeit von Stroh als Substrat in Nassvergärungsanlagen” IKTS, Dresden, Germany
Schepers, B.J. and Valkengoed, M.P.J., 2009 “Overzicht van grootschalige en kleinschalige

warmtenetten in Nederland " CE Delft, Netherlands
Schotman, T. 2016 "Twence wil begin 2017 mestverwerking starten" Melkvee, July 2016
Sharaienko, O. personal communication, Kiev 2016
Schneider, M. 2011 "Doppelt gewinnen mit Kompost statt Stroh"
Getreide magazin 2011(3) pp 1 - 4
Seipp, H. no date "Strohpelletierung" Lohnunternehmen Seipp Ober-Hörgern, Germany
Snoo, E. 2016 "Akkerbouwer casht met mest" GF Actueel, Jan. 2016
Stokkermans, P. 2016 "Lely mestrobot zuigt stalvloer schoon" Veehouderij nov. 2016
Souman, J. 2016 "Stro prijzen" Markenesse, Netherlands
Troester, N and Bleisteiner, M. 2012 "Lang oder gehäkselt pressen?"
Landtechnik 23-11-2012 pp 49-52
Veghte, Z. van der 2016 "Geen effect digestaat op bodemkwaliteit De Marke" Knowledge Transfer Centre De Marke, Hengelo, Gld.) Netherlands.
Velghe, F. and Wierinck, I. 2013 "Evaluation of digesters in The Netherlands"
OWS, Gent, Belgium
Ward, A.J, Moeller, H.B. and Raju, C.S. 2010 "Extreme thermophilic pre-treatment of manures for improved biogas production" " in proceedings 14th Ramiran conference Lisboa, Portugal 13th to 15 th September 2010
Xavier, C.A.N., Moset, V., Wahid, R., Møller, H.B. 2015, "The efficiency of shredded and briquetted wheat straw in anaerobic co-digestion with dairy cattle manure"
Biosystems Engineering 139 pp 16 - 24
Zemke, P.E., Dustin, J.S., Gale, J.A. and Wood, D.E. 2011 " Full-scale performance comparison of an induced bed reactor and a control reactor"
Biological Engineering Transactions 4(3) pp 147 - 156
Zevenbergen, G. 2011 "Decanter slingert mest; Dure mestscheider werkt goed"
Veehouderij jan. 2011