AARHUS UNIVERSITY

2015

Optimizing biogasproduction and GHG reduction by pre-treatment and process optimization – experiences from a practical study

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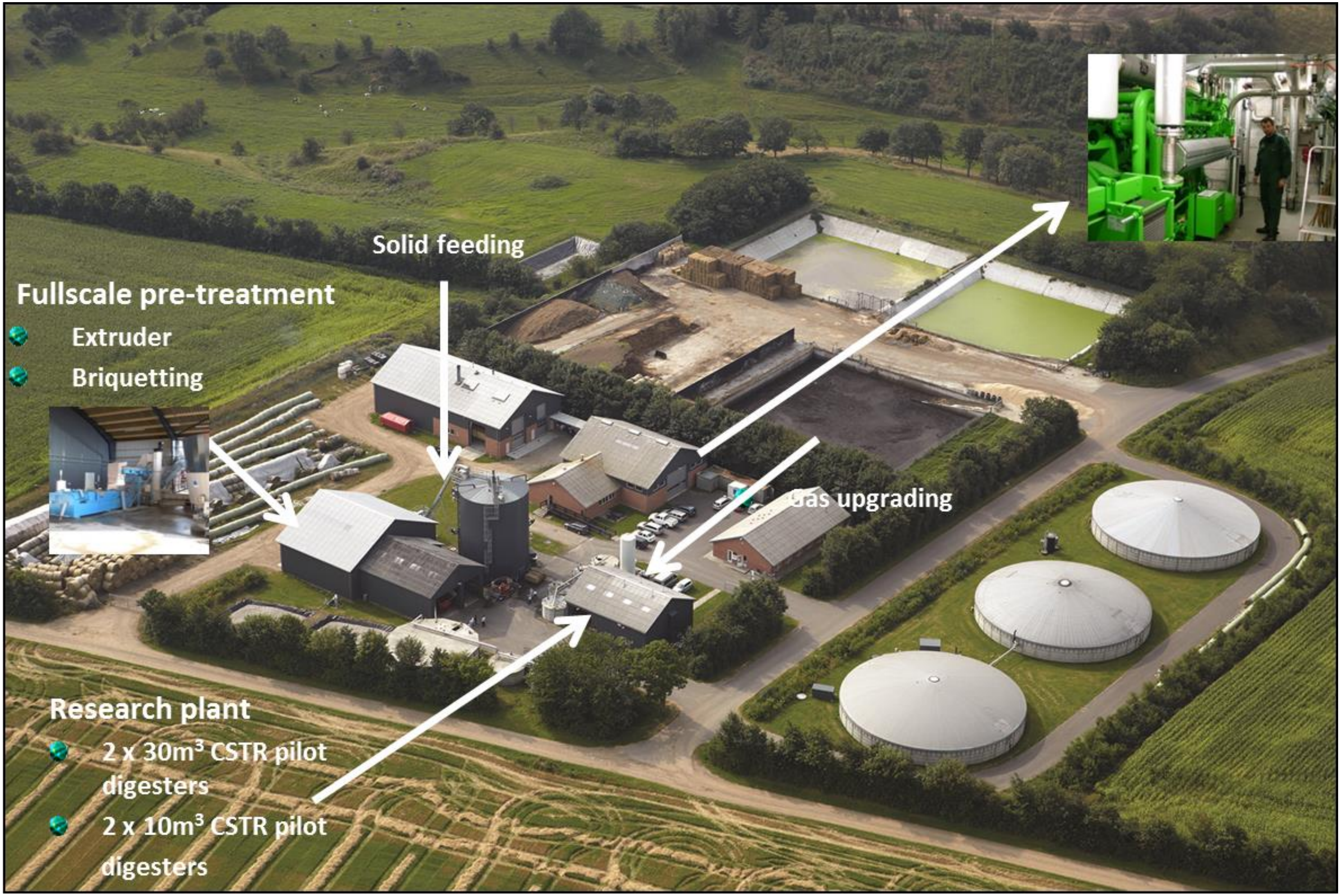
Infrastructure at AU From research to Industry



These are the headline results for 2020:

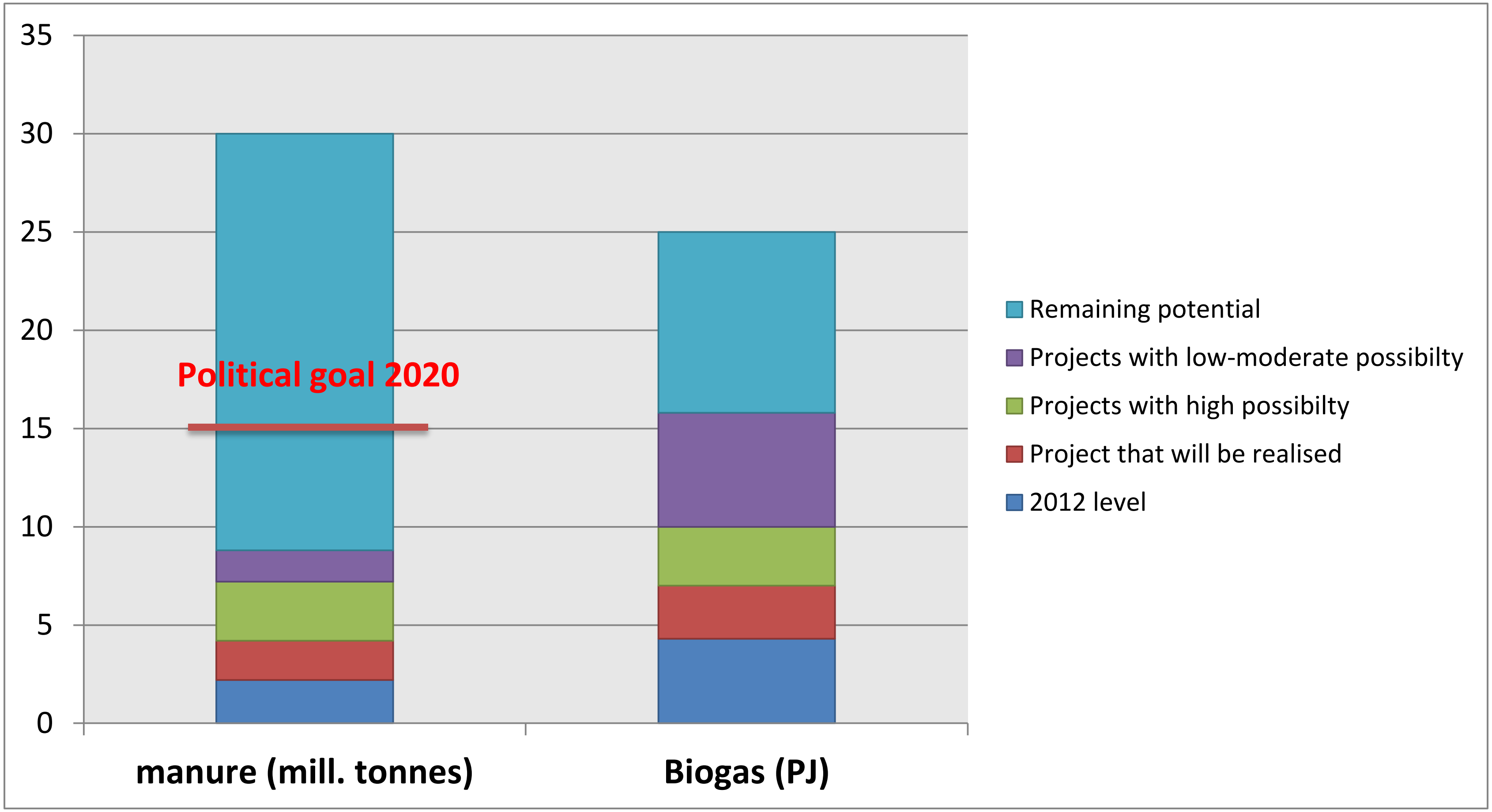
2020

- More than 35% renewable energy in final energy consumption
- Approximately 50% of electricity consumption to be supplied by wind power
- 7,6% reduction in gross energy consumption in relation to 2010
- 34% reduction in greenhouse gas emissions in relation to 1990

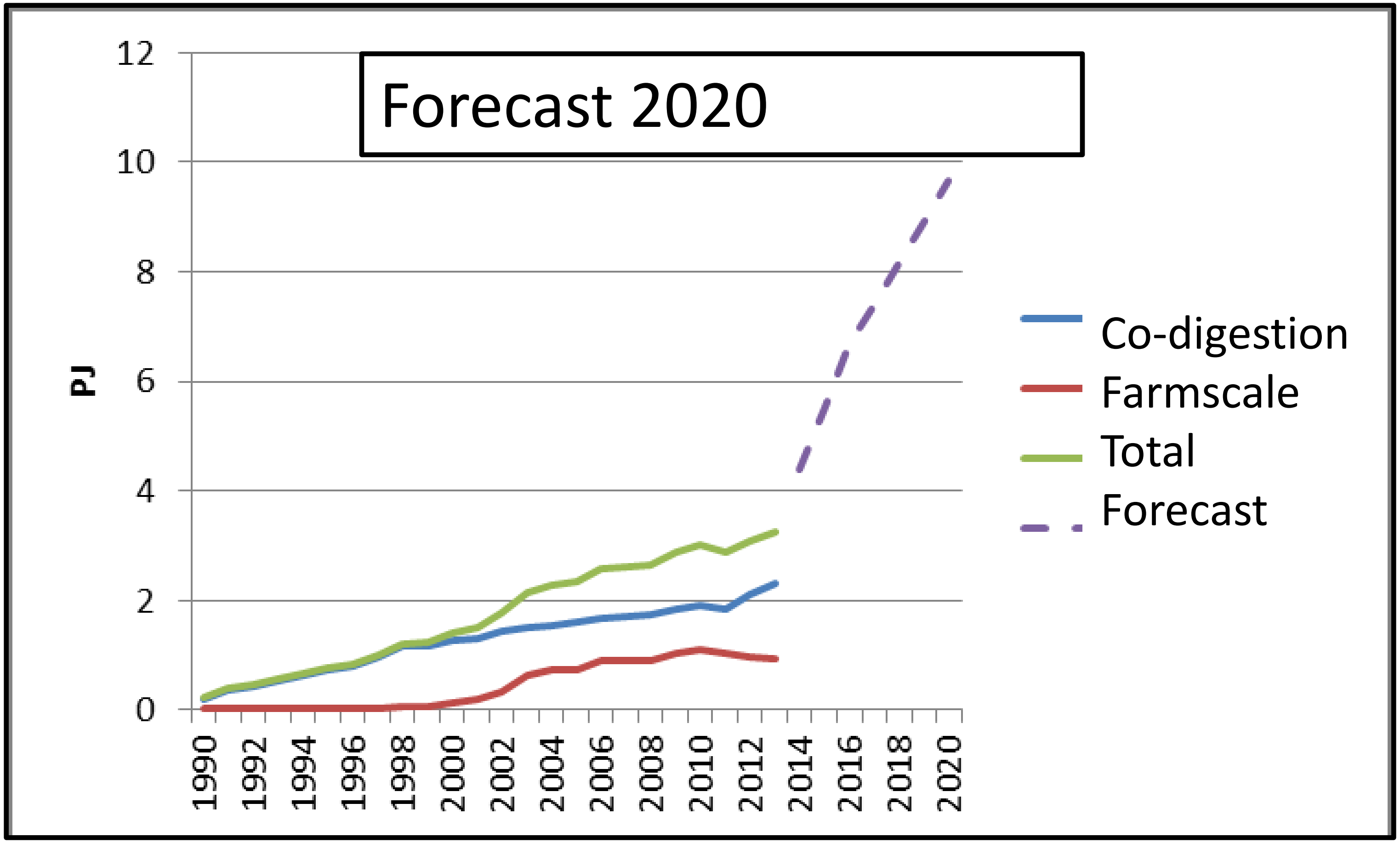
2035: Denmark should be completely free of fossil fuels for heat and electricity

2050: Denmark should be completely free of fossil fuels

Goals for manure

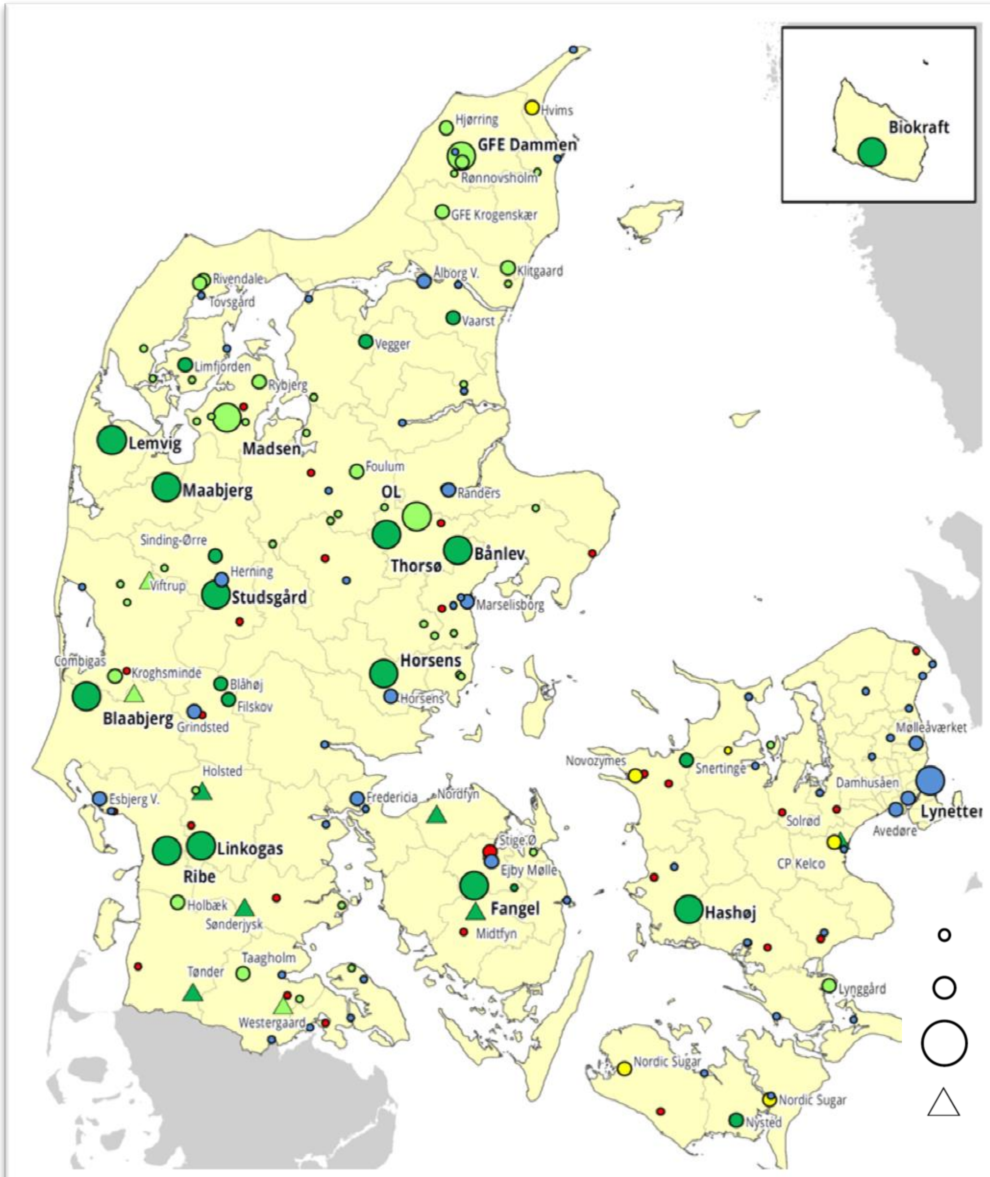


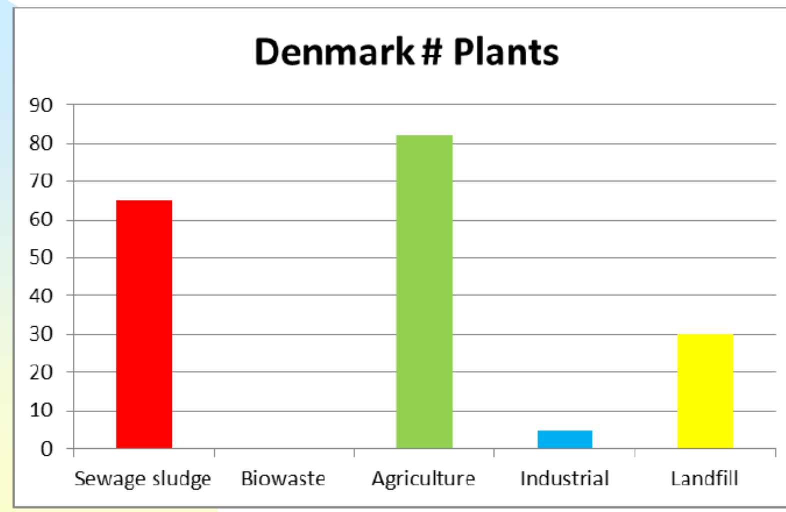
Biogas production

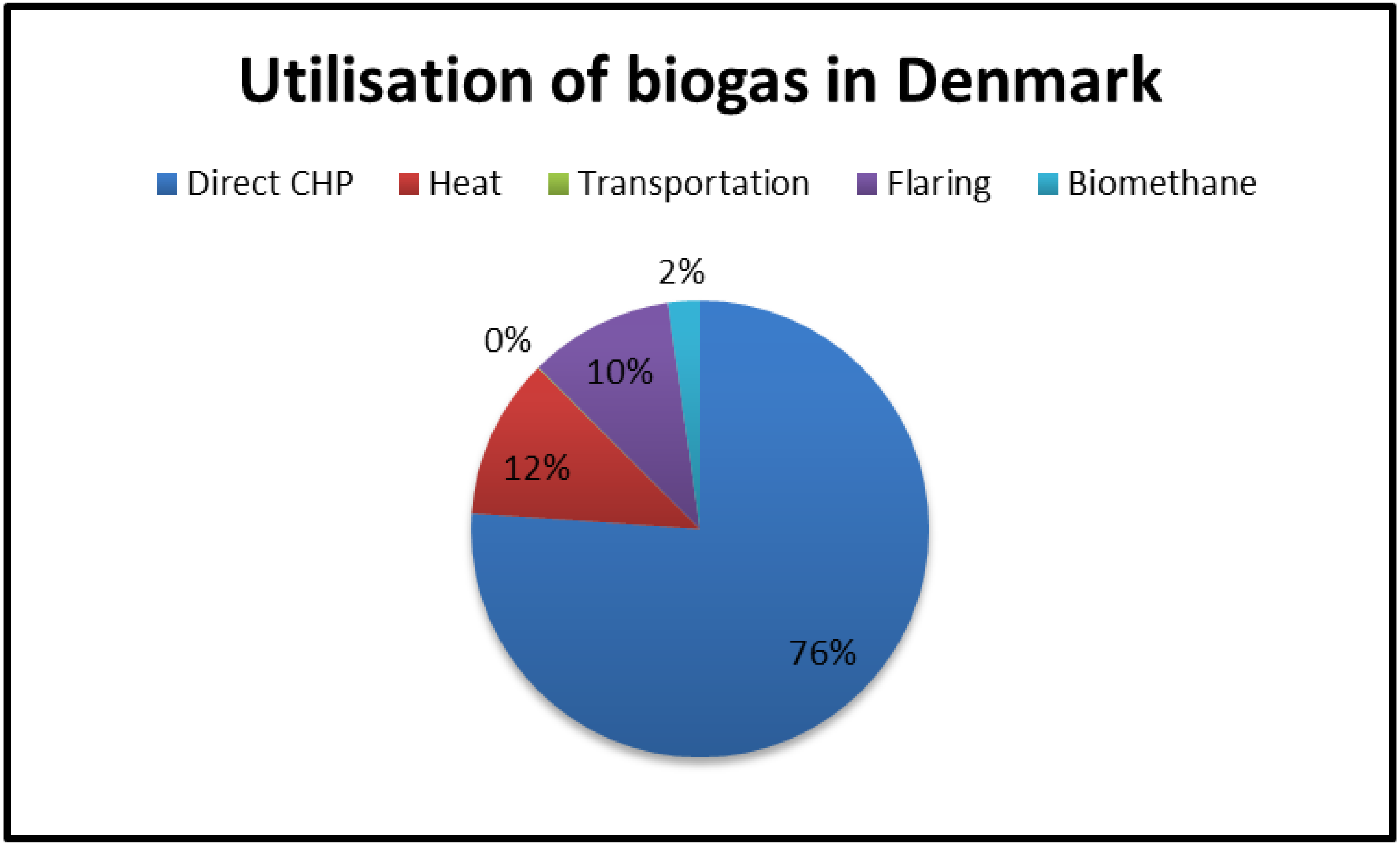


Brancheforeningen for Biogas

Biogas plants






Utilisation of biogas in Denmark
Direct CHP
Heat
Transportation
Flaring
Biomethane
2%
0%
10%
12%
76%

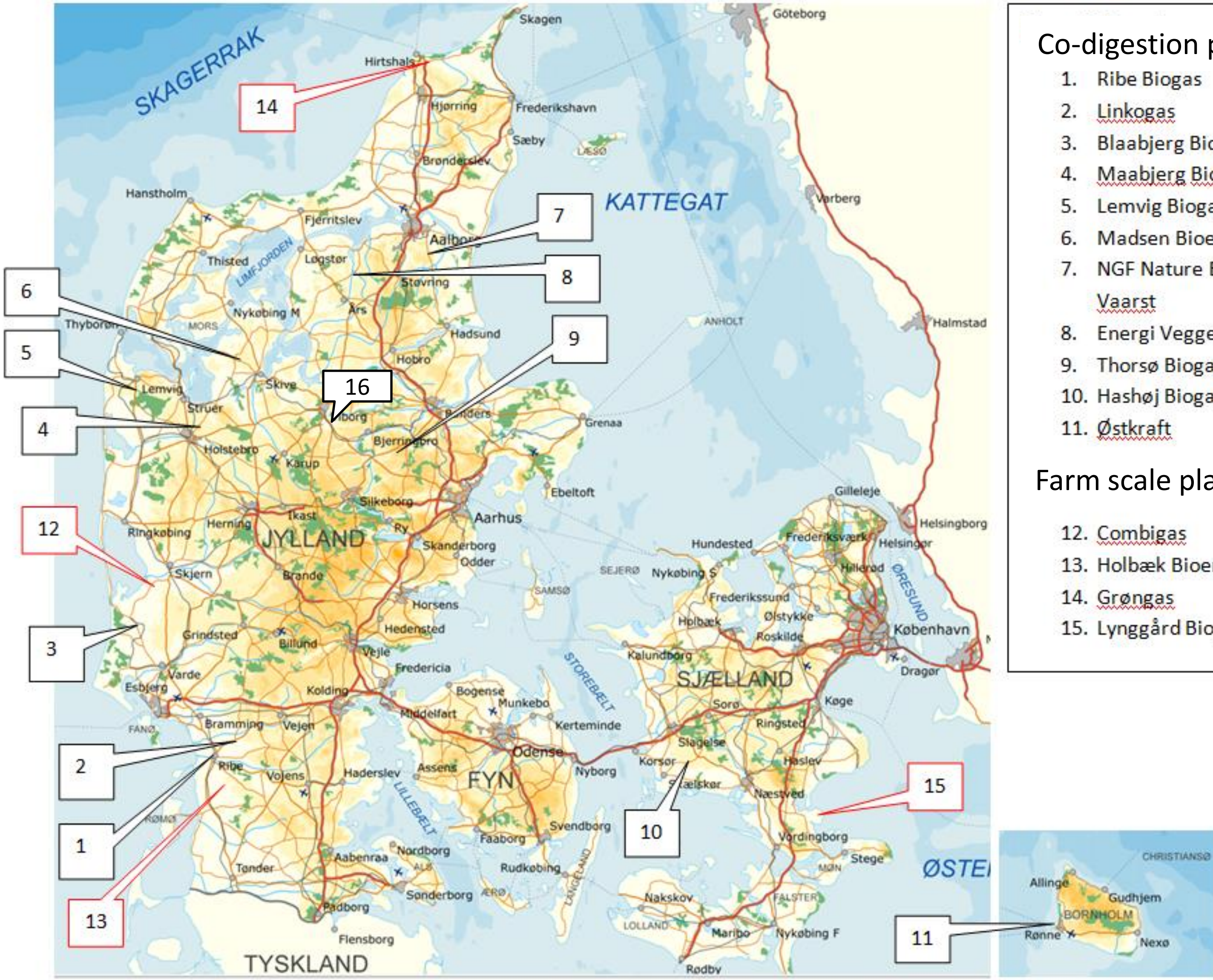
Agricultural based biogas

Large scale centralized biogas plant

”Aiming at economies of scale”

- 500,000 tons biomass/year, hereof manure 450,000 tons
- Many substrates: Pig, cattle and chicken manure + wastes
- Heat and power
- Manure from 150 farms

Biogasplants participants in the study



Co-digestion plants

1. Ribe Biogas
2. Linkogas
3. Blaabjerg Biogas
4. Maabjerg Bioenergy
5. Lemvig Biogas
6. Madsen Bioenergi
7. NGF Nature Energy Vaarst
8. Energi Vegger
9. Thorsø Biogas
10. Hashøj Biogas
11. Østkraft

Farm scale plants

12. Combigas
13. Holbæk Bioenergi
14. Grøngas
15. Lynggård Biogas

Pre-treatments

Physical

Chemical

Biological

Combinations

- Thermal — Enzymatic activity
- Pressure
- Microwave
- Ultrasonic
- Maceration

(Pressure, Microwave, Ultrasonic, Maceration) — Accesibility

- Extrusion /Briquetting/ Excoriation
- Acid / base — Enzymatic activity — Accesibility
- Oxidation — Accesibility
- Enzymatic / microbial — Enzymatic activity

Pre-treatments in practice

Hüningen hammemill

X-chopper/chaincrusher

Extruder

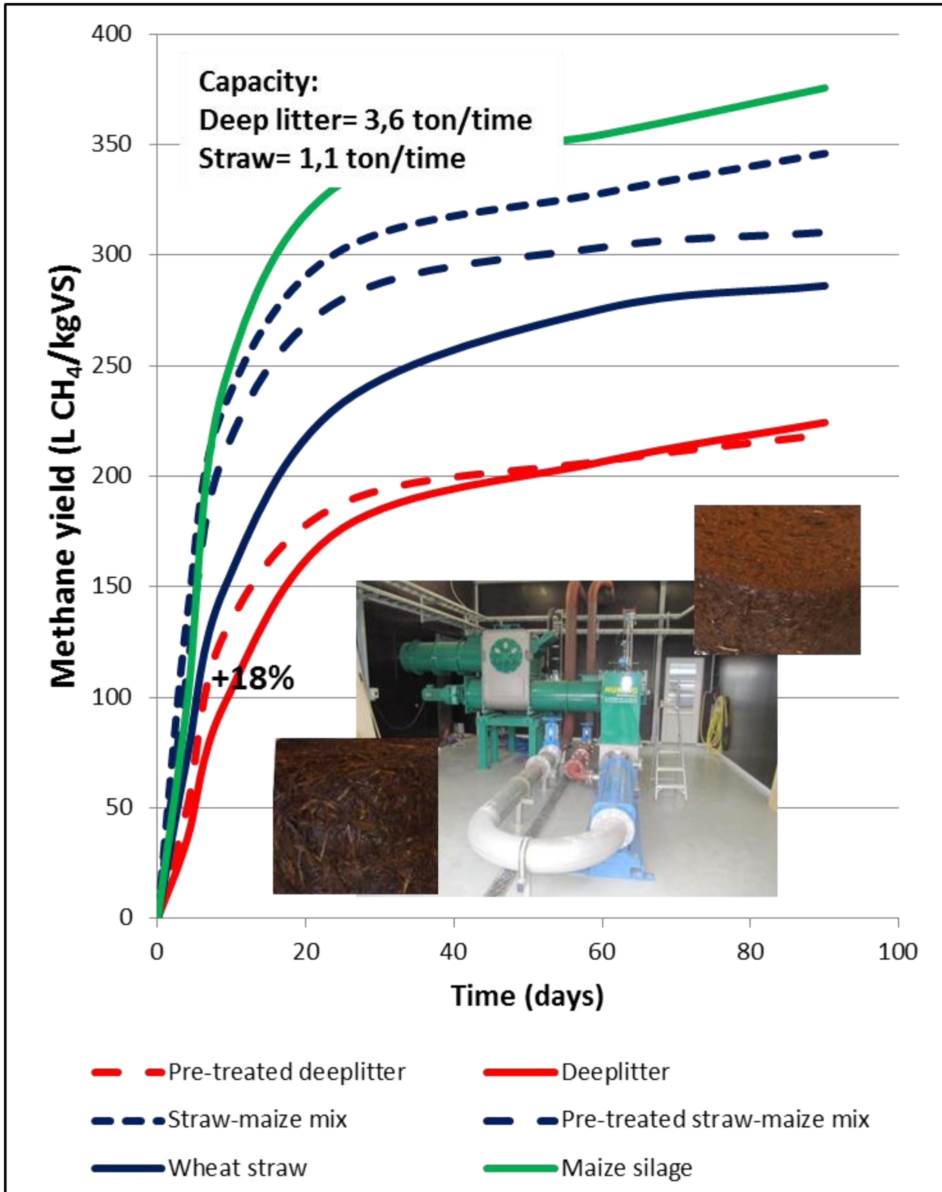
Briquetting +/- alkali

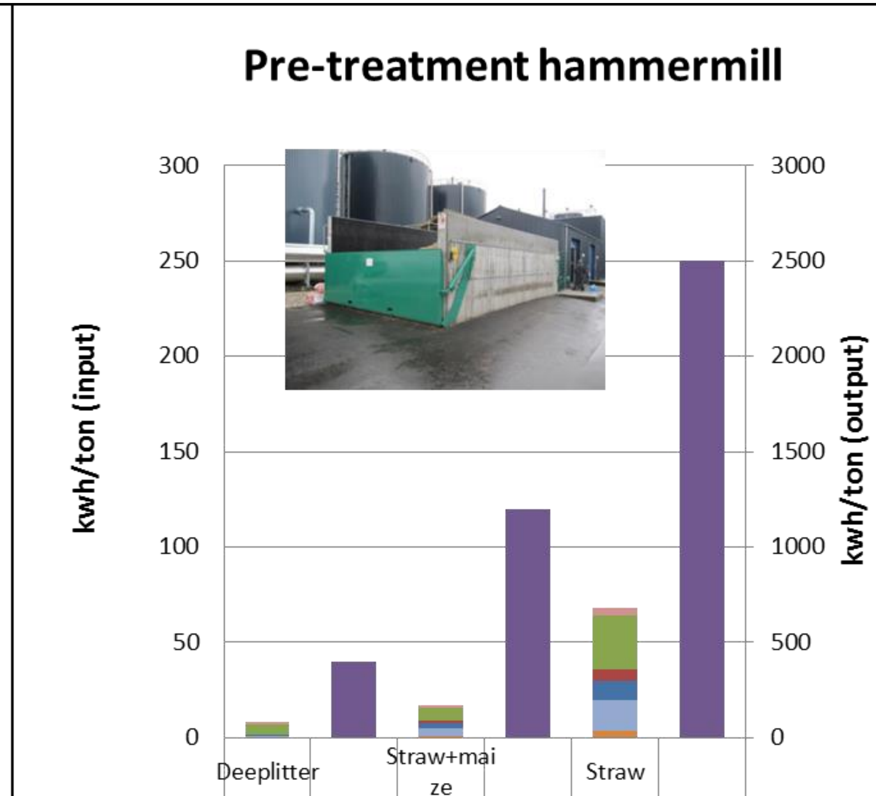
Aerobic composting

Haybuster + ensilage

Euromilling-hammermill

Pre-treatment Hammermill

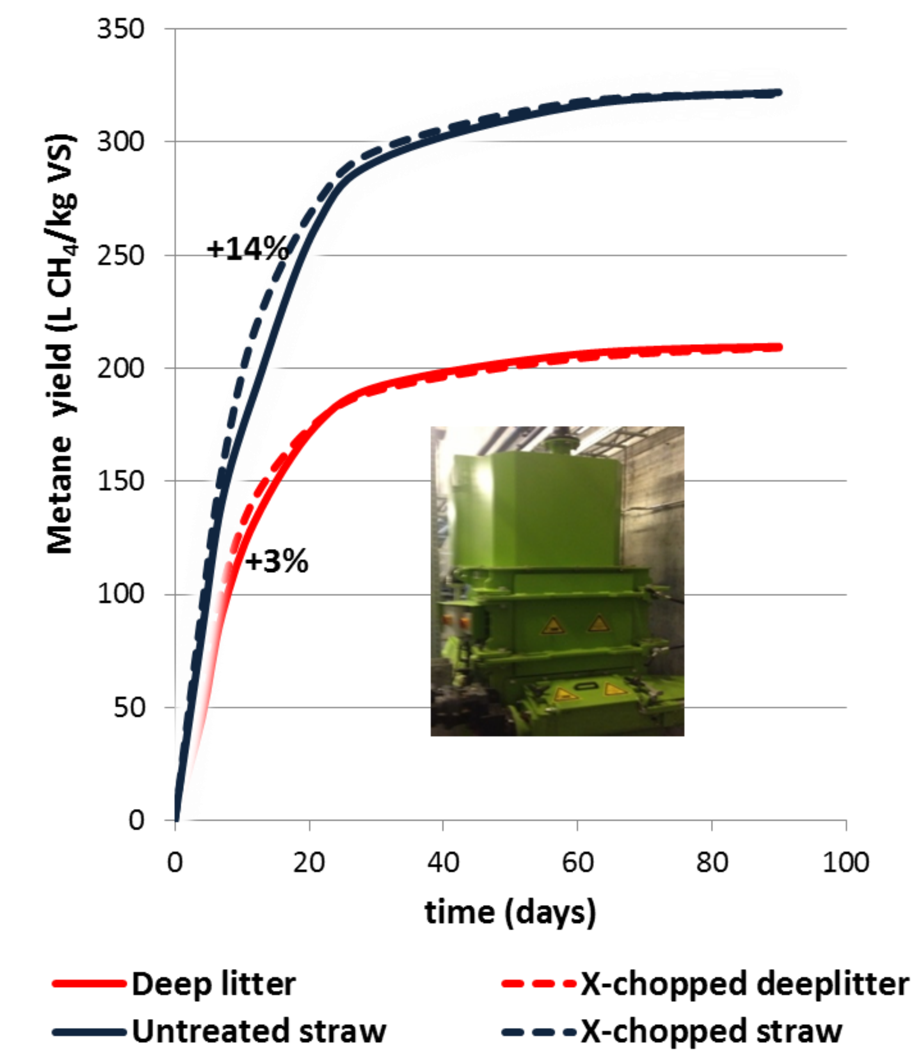


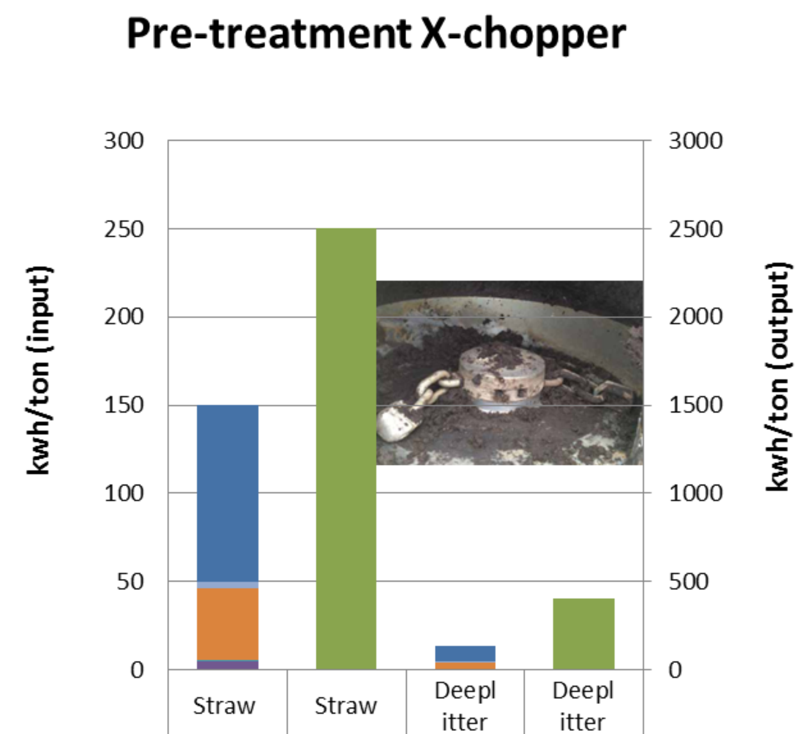


	Deeplitter		Straw+maize		Straw	
Pump	1,02		1,08		4,31	
Hammermill	5,54		7,06		28,26	
Auger 4	0,29		1,50		6,00	
Auger 3	0,46		2,48		9,90	
Auger 2	0,60		4,09		16,37	
Auger 1	0,24		0,76		3,03	
Dosing	0,08		0,10		0,41	
Output		400		1200		2500

Pre-treatment

X-chopper

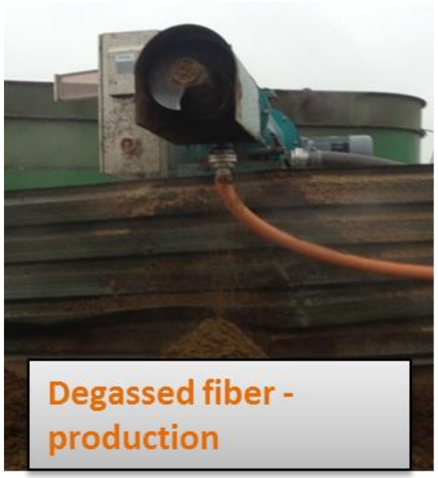




	Straw	Straw	Deeplitter	Deeplitter
X-chopper	100,0		8,7	
Hopper auger	4,1		0,4	
X-hopper	40,5		3,8	
Filling band	1,0		0,1	
Auger	4,4		0,3	
Output		2500		400

Capacity
Deeplitter= 5,17 ton/hour
Straw=0,37 ton/hour

Pre-treatment Composting


Degassed fiber - production


Degassed fiber

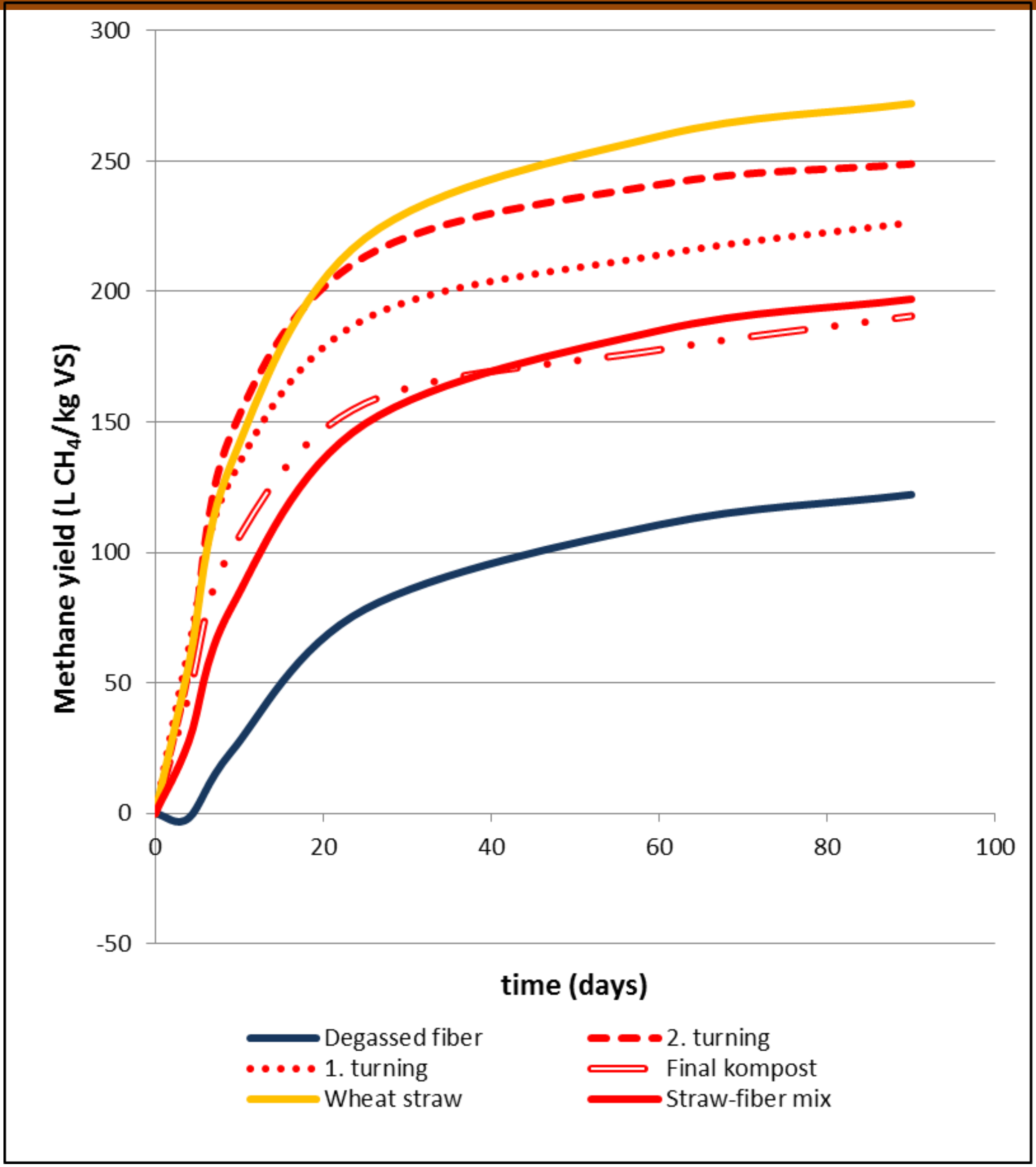
Temperature

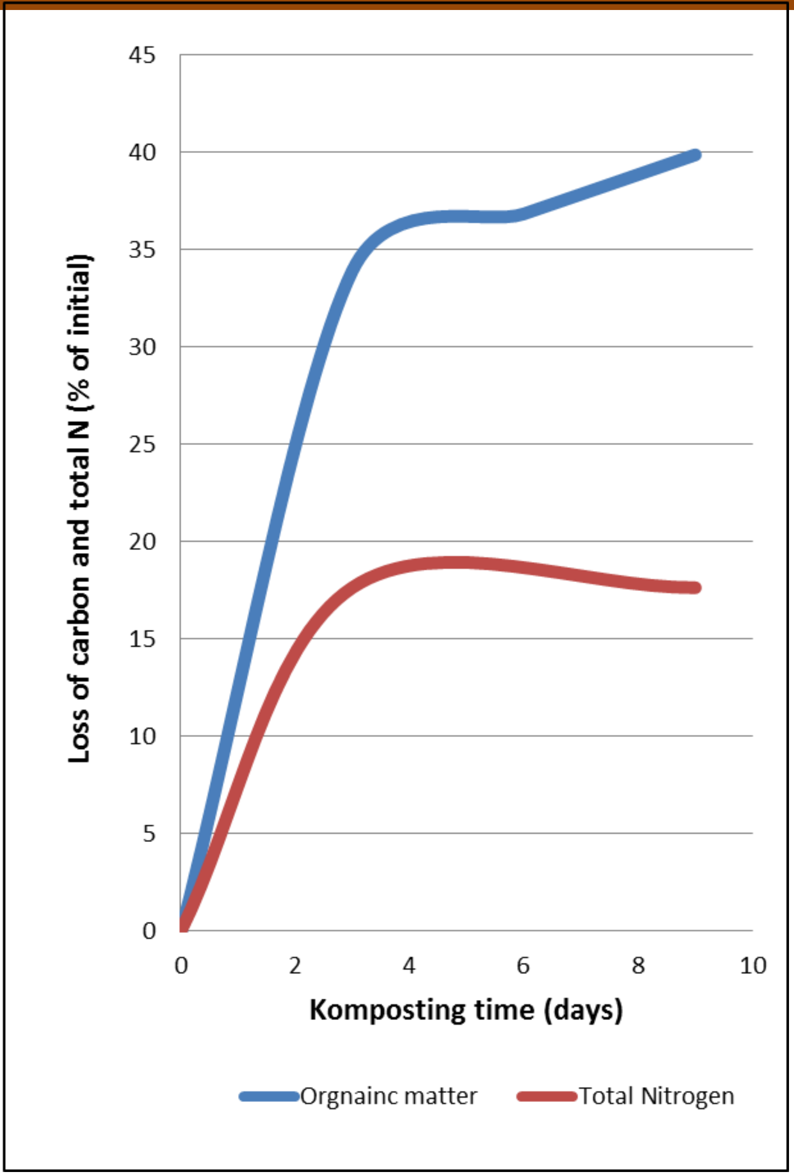
Mixture of straw and fiber

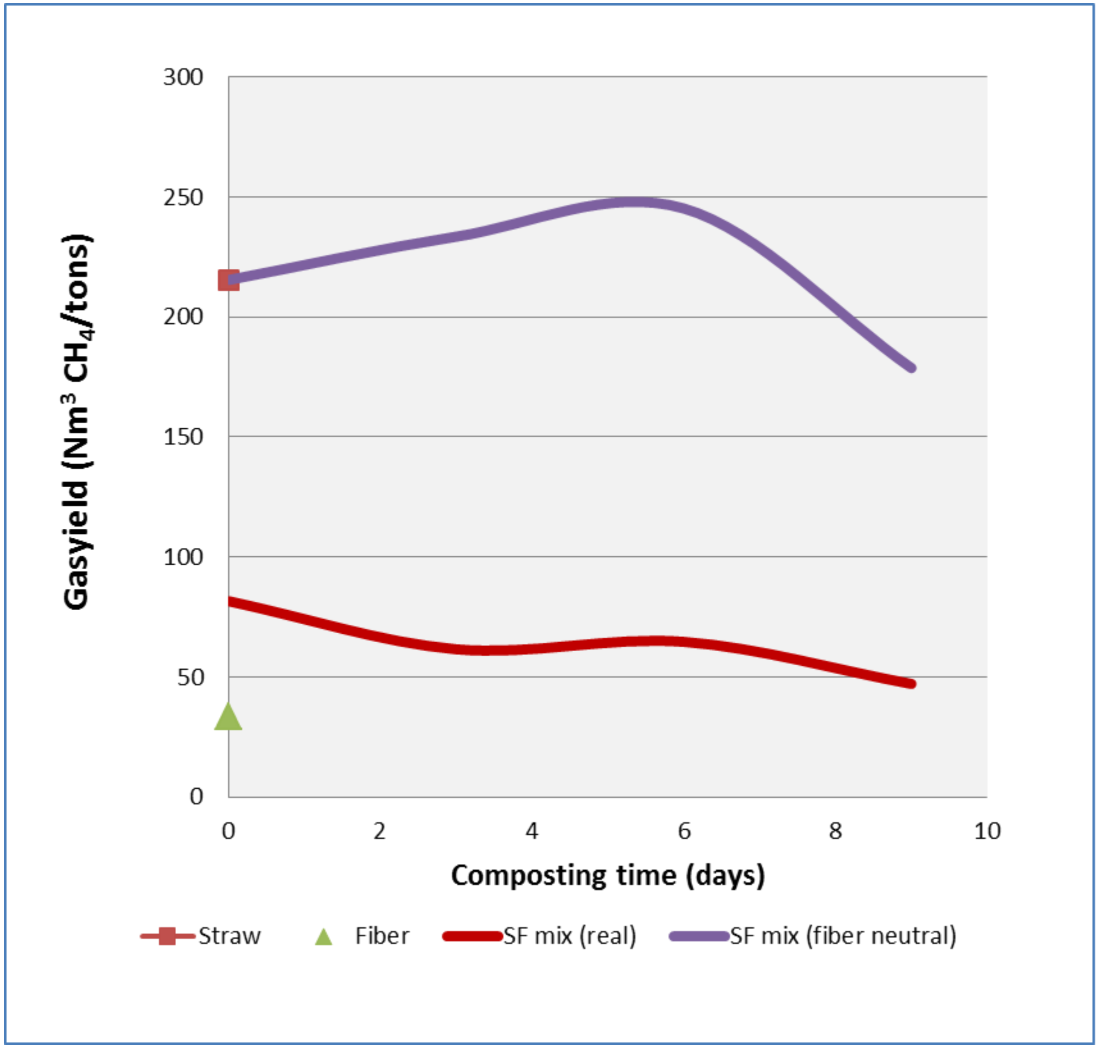

Compost pile of straw and fiber

Pre-treatment

Composting





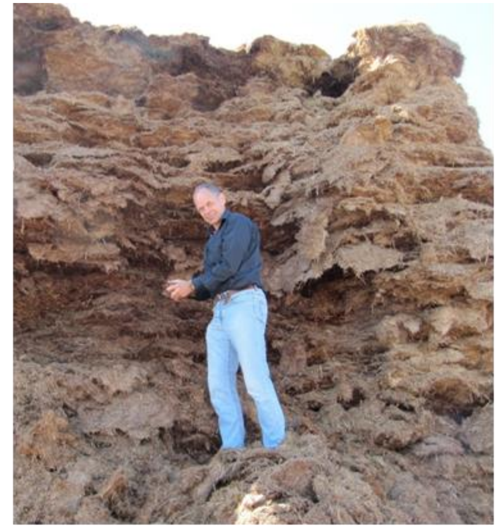


Preconditions:

- Long HRT
- SF mix=real mass balance
- SF mix (fiber neutral=fiber is not included in mass balance

Pre-treatment

Ensilage process



- Material is pushed through a restricted orifice

- Smaller orifice = greater energy input

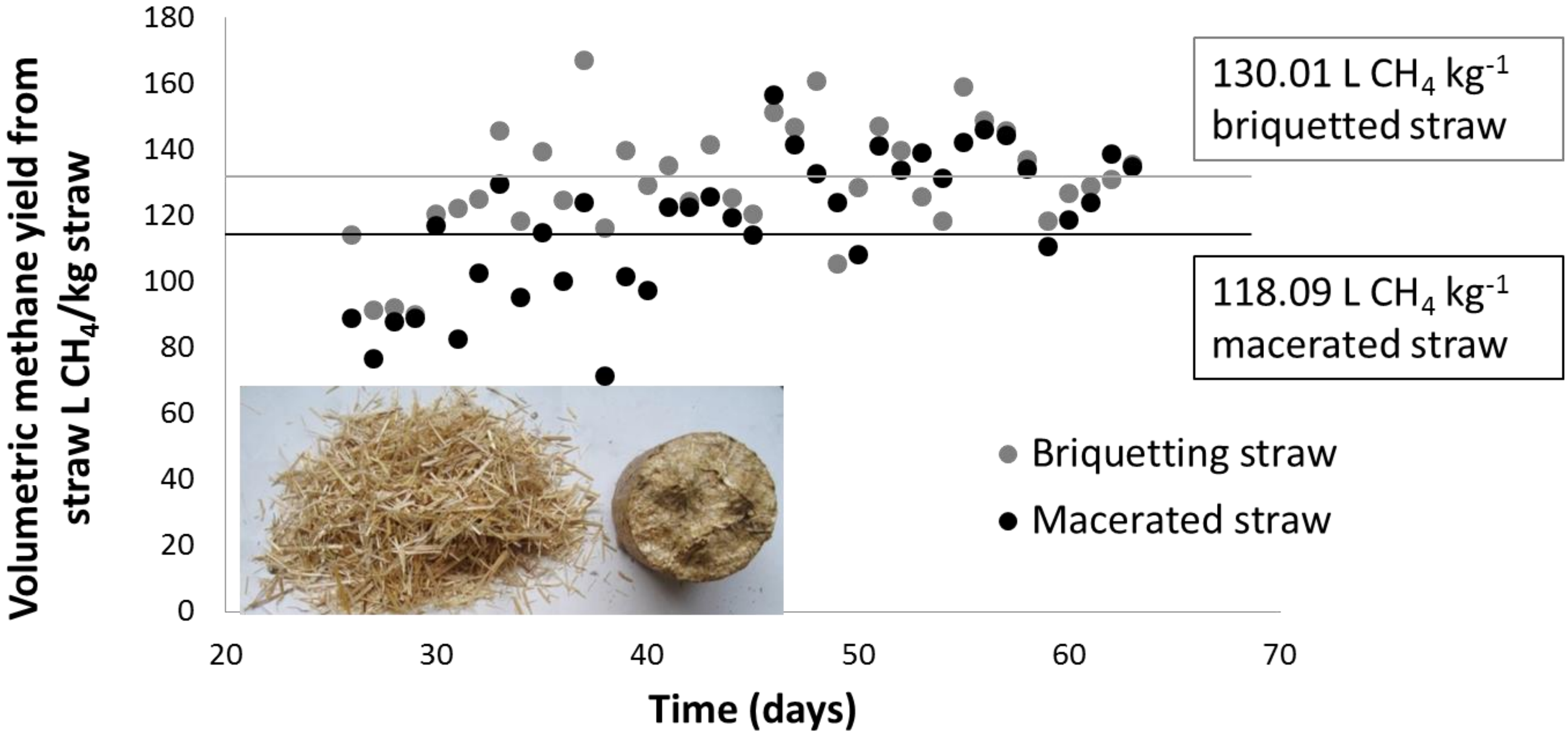
- Temperature increase

- Densification / Mixture

Pre-treatments

Briquetting

Enzymatic accessibility



10% more CH4 per kg VS in briquetted compared with macerated wheat straw – Effect reduced over time

Base addition + briquetting

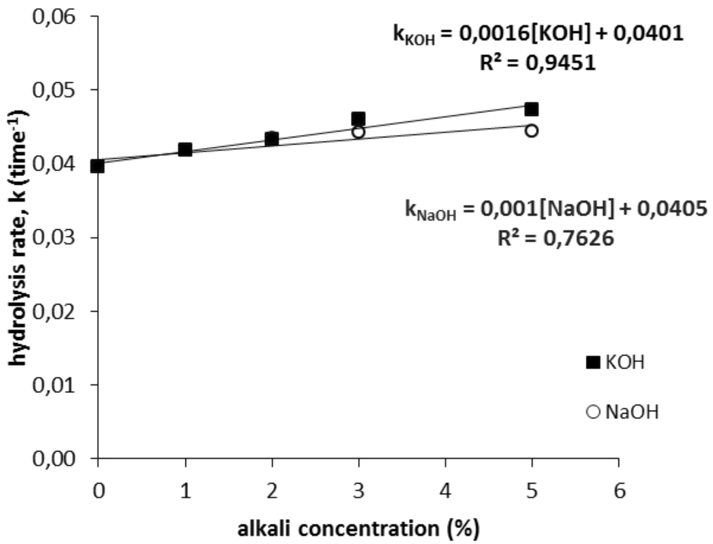


Figure 1.- Correlation between hydrolysis rate (k) and alkali (KOH and NaOH) concentration

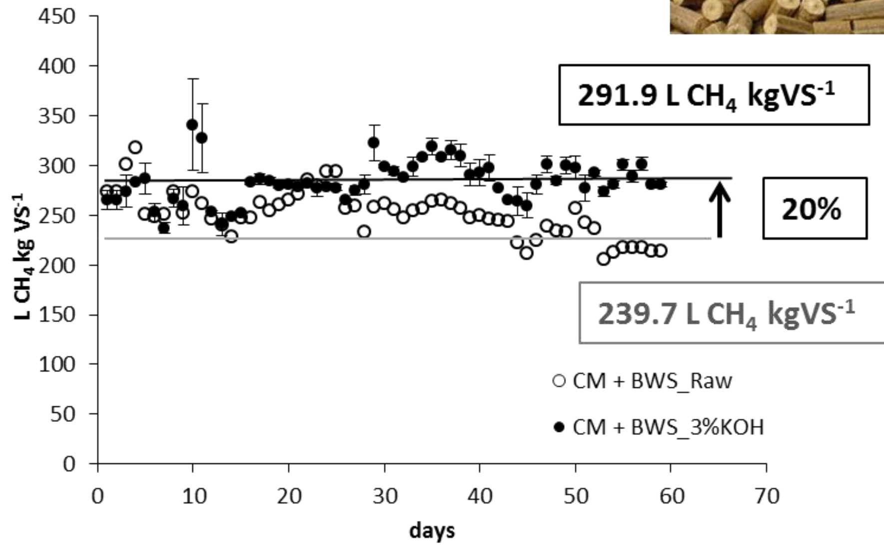
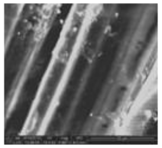
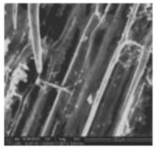


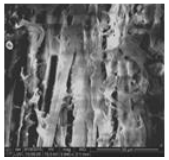
Figure 2.- Methane production in reactors in terms of L CH4 per kg volatile solids introduced in the reactors (CH4 kg VS-1).

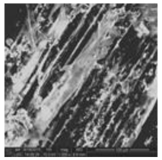
Degassed briqutted
Wheat straw





Degassed briquetted+alkali
Wheat straw





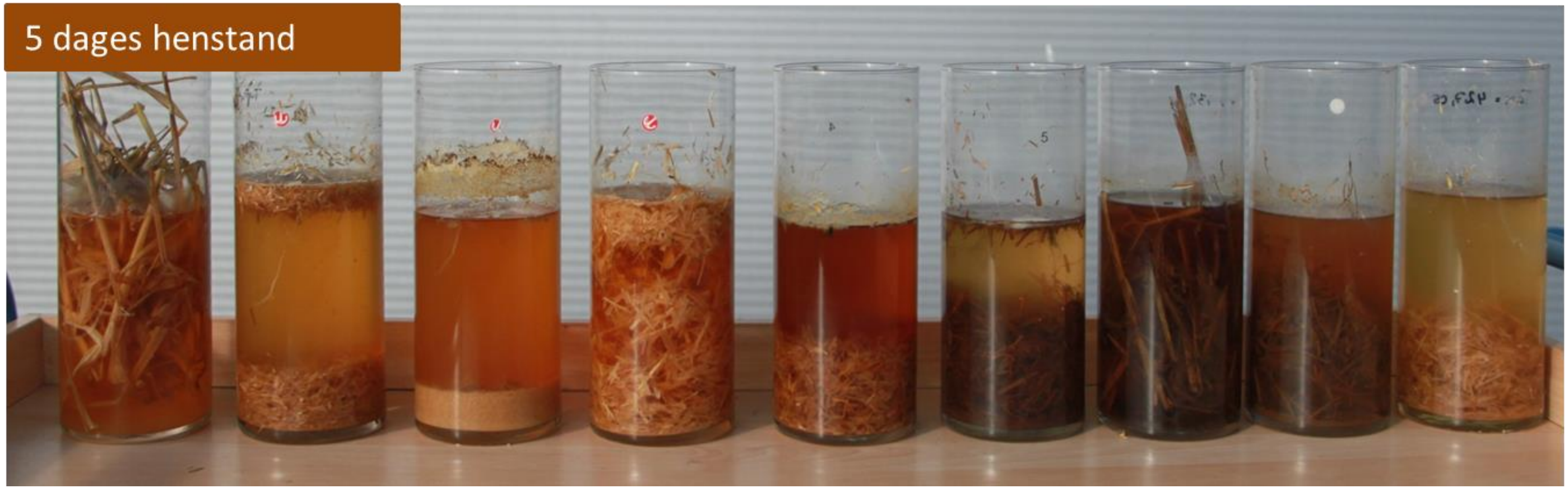
CM + BWS_Raw *reactor fed with a mixture of cattle manure and briquetted wheat straw,*
CM + BWS_3%KOH *average from two reactor fed with a mixture of cattle manure and briquetted wheat straw pre-treated with 3%KOH.*
Bars in BWS_3%KOH indicate the standard error of the mean from the two reactors

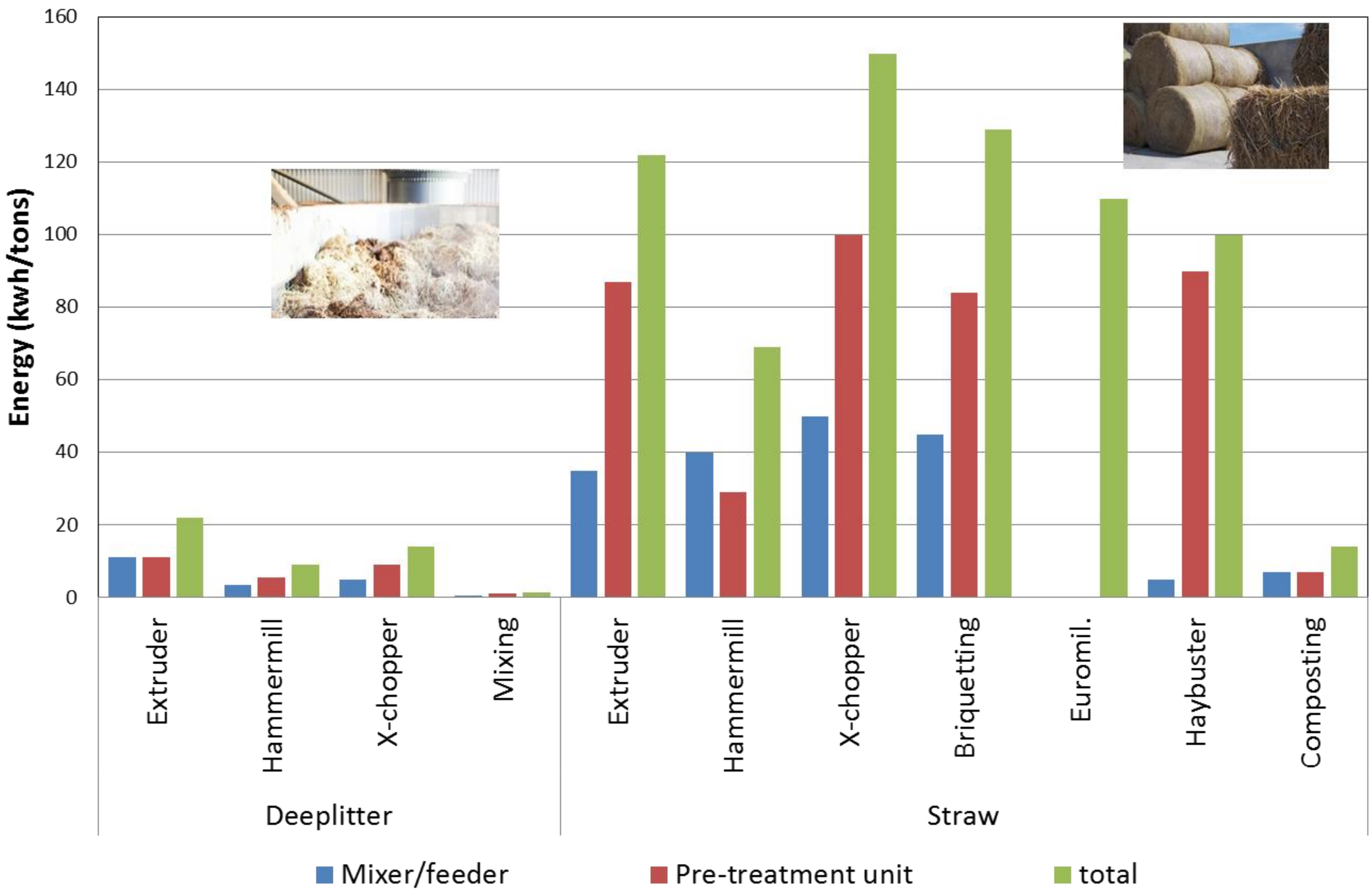
Pre-treatment test in practise

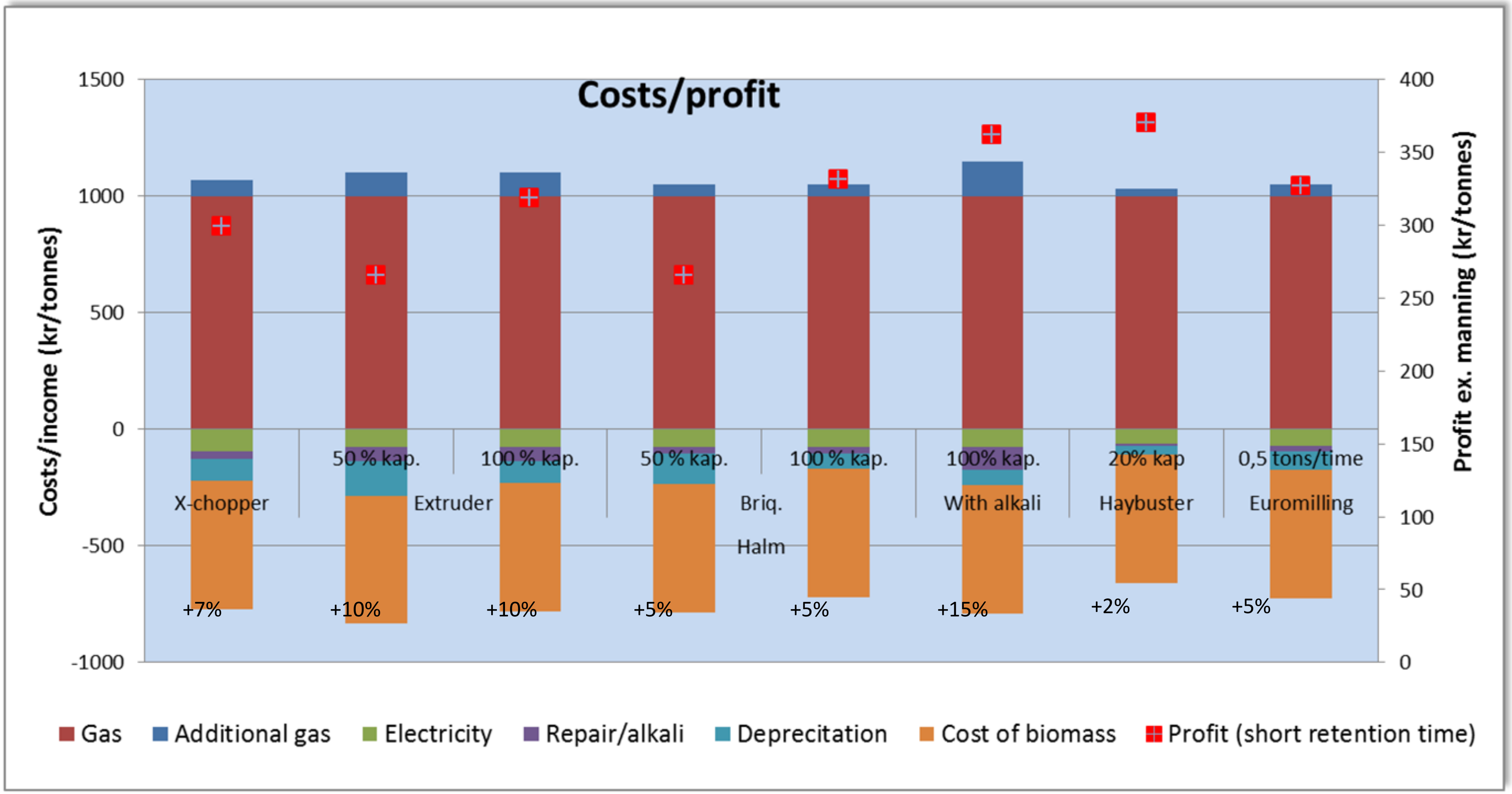
Mixing/floating abilities

Halm behandlet med forskellige forbehandlings metoder opblandet i vand, ½ time efter tilsætning

5 dages henstand




Energy (kwh/tons)
160
140
120
100
80
60
40
20
0
Extruder
Hammermill
X-chopper
Mixing
Deeplitter
Extruder
Hammermill
X-chopper
Briquetting
Euromil.
Haybuster
Composting
Straw
Mixer/feeder
Pre-treatment unit
total



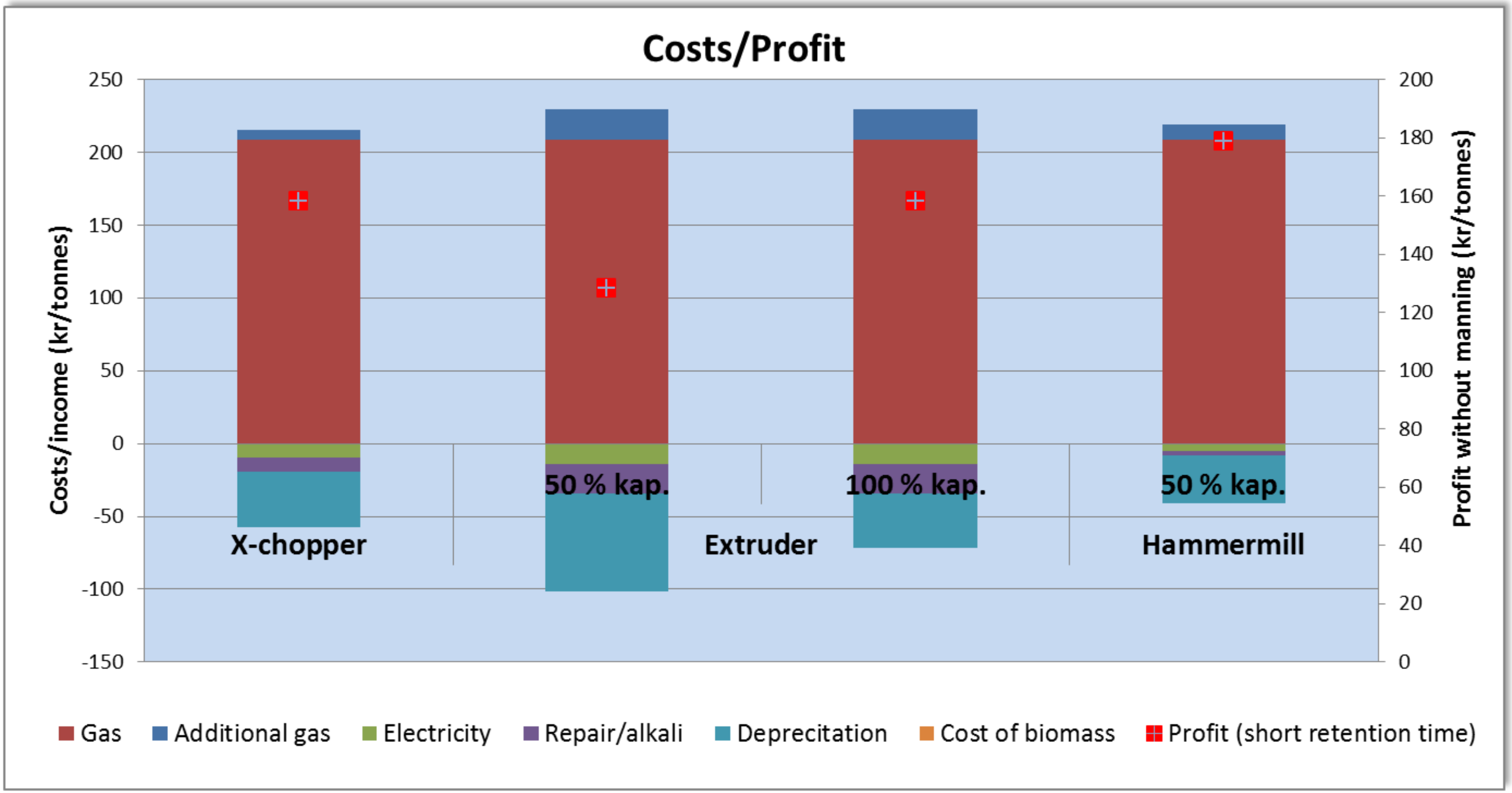
Forudsætninger

El pris (køb) - diesel	0,8kr/kwh - 6 kr/l
Afskrivning/forrentning	15%
Værdi af Methan	5 kr/m3

Biomasse: 550 kr/tons halm
Gas: 200 m^3 CH_4/ton

Pre-treatment of deeplitter

Economy



Forudsætninger

El pris (køb) - diesel	0,8kr/kwh - 6 kr/l
Afskrivning/forrentning	15%
Værdi af Methan	5 kr/m3

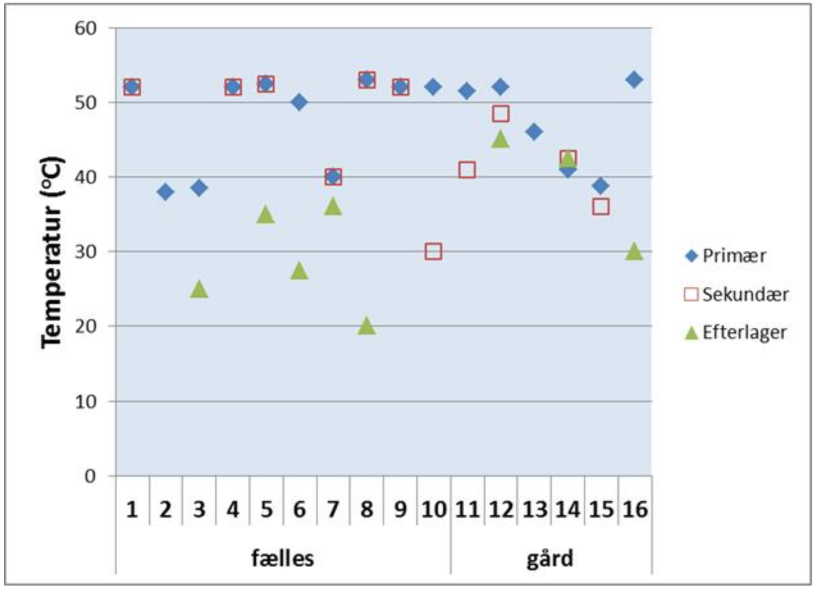
Gas: 190 m^3 CH_4/ton

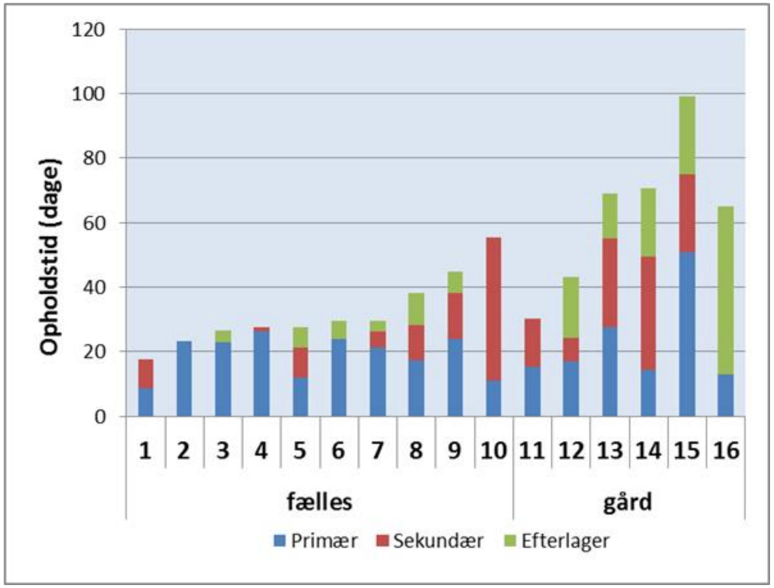
Part 1 – pre-treatment conclusion

- Energy consumption is ranging from 70 to 150 kWh / ton of straw and 9-23 kwh / ton in deep litter.
- Effect of biogas potential depends on residence time and by more than 40 days of retention is minimal effect on gas potential.
- Biogas plants ability to degrade straw varies widely. Inoculation from plants that are effective to less efficient plants could be an option.
- Floating/sinking characteristics are widely influenced by technology.
- The gain by using straw depends on the conditions , straw price, technology and effect on gas yield . Approximately 300 kr / tons of straw excl. cost of labor is realistic.
- The gain by using deep litter varies from approximately 120-180 kr/ tons of straw excl. cost of labor.
- It is difficult to compare the different methods of handling straw and it is not possible to identify a particular "winner technology" . The choice will largely depend on how the biogas plant is designed , including the retention time in digesters.

Plant characteristics

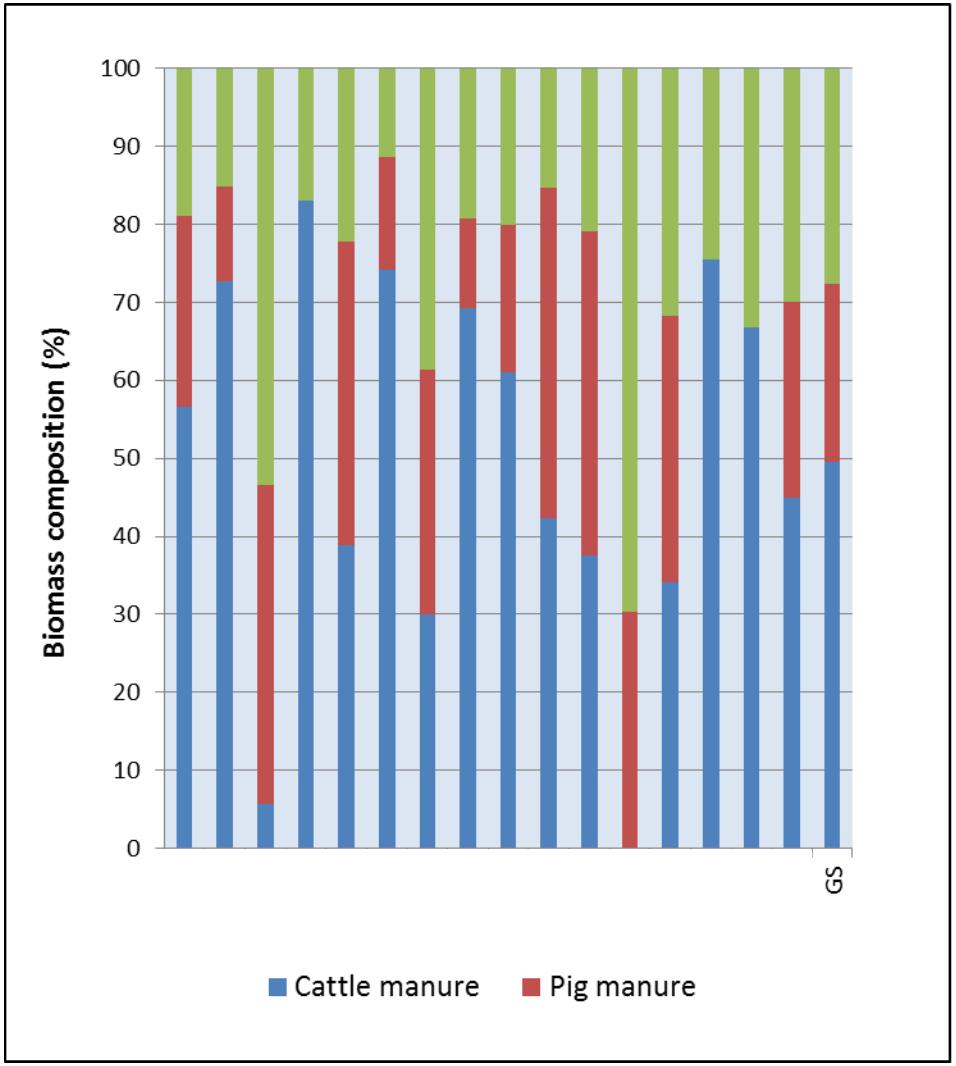
survey

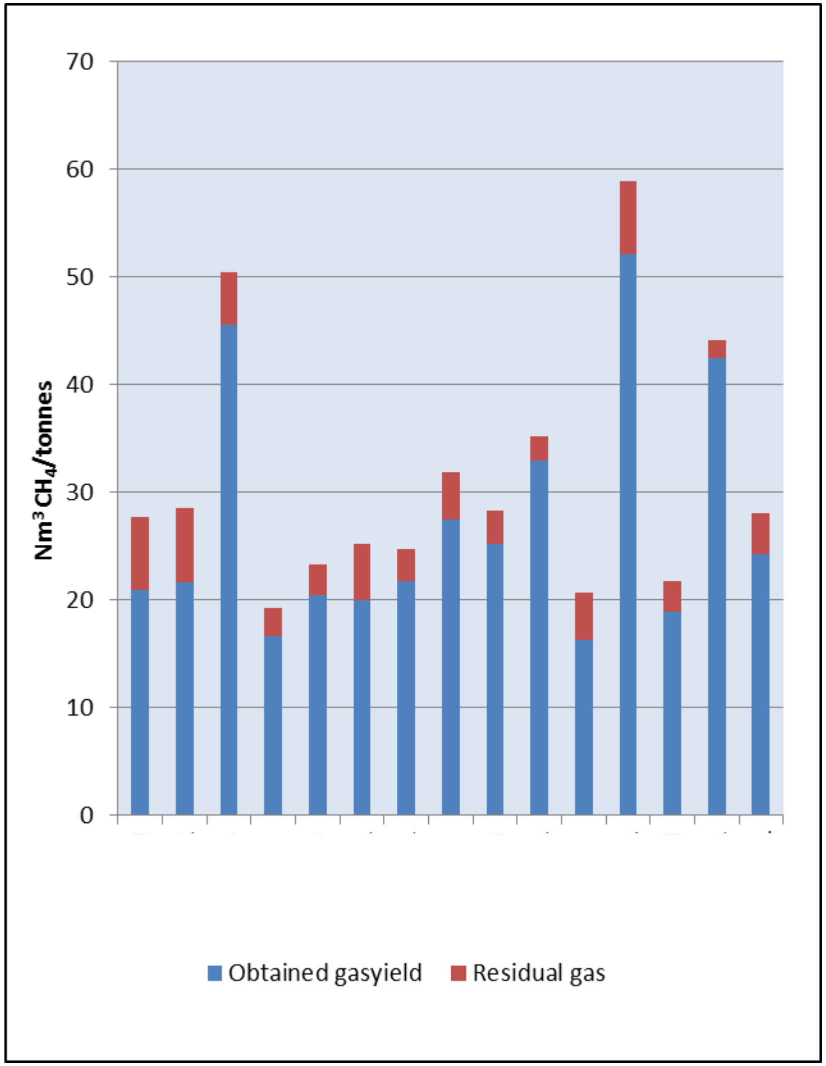




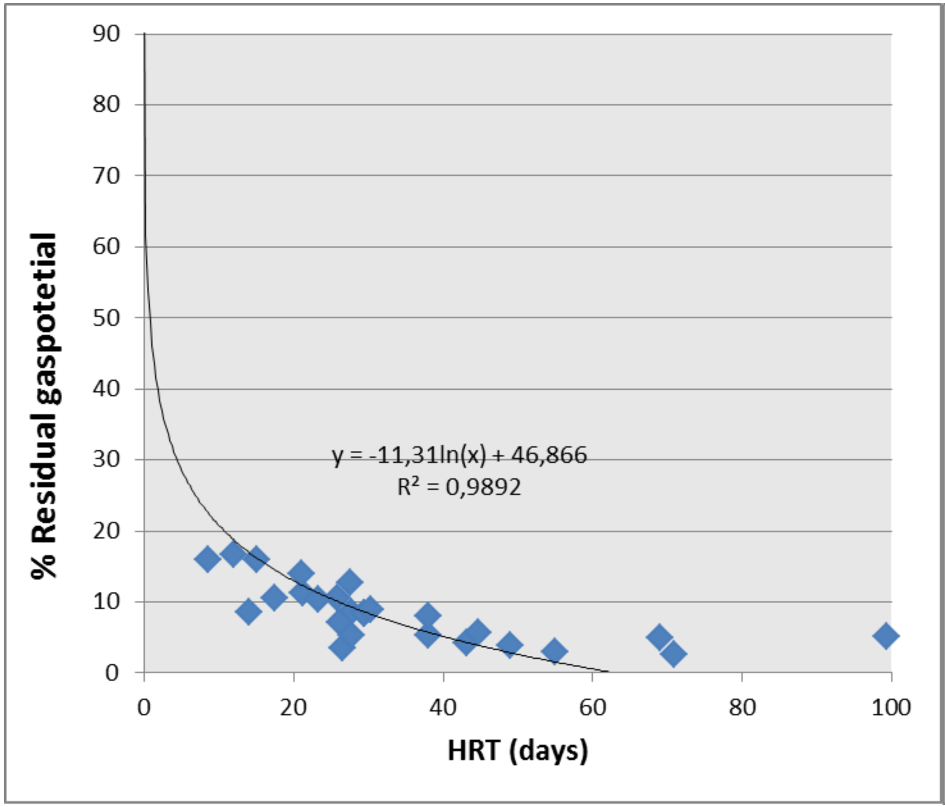
Plant characteristics

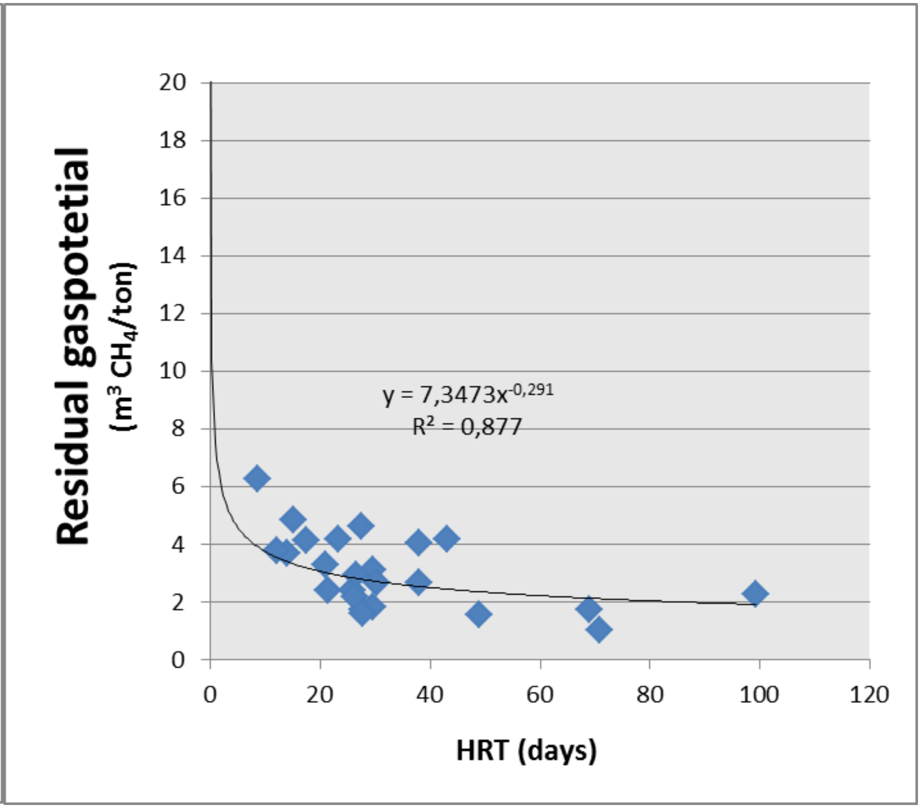
Biomass



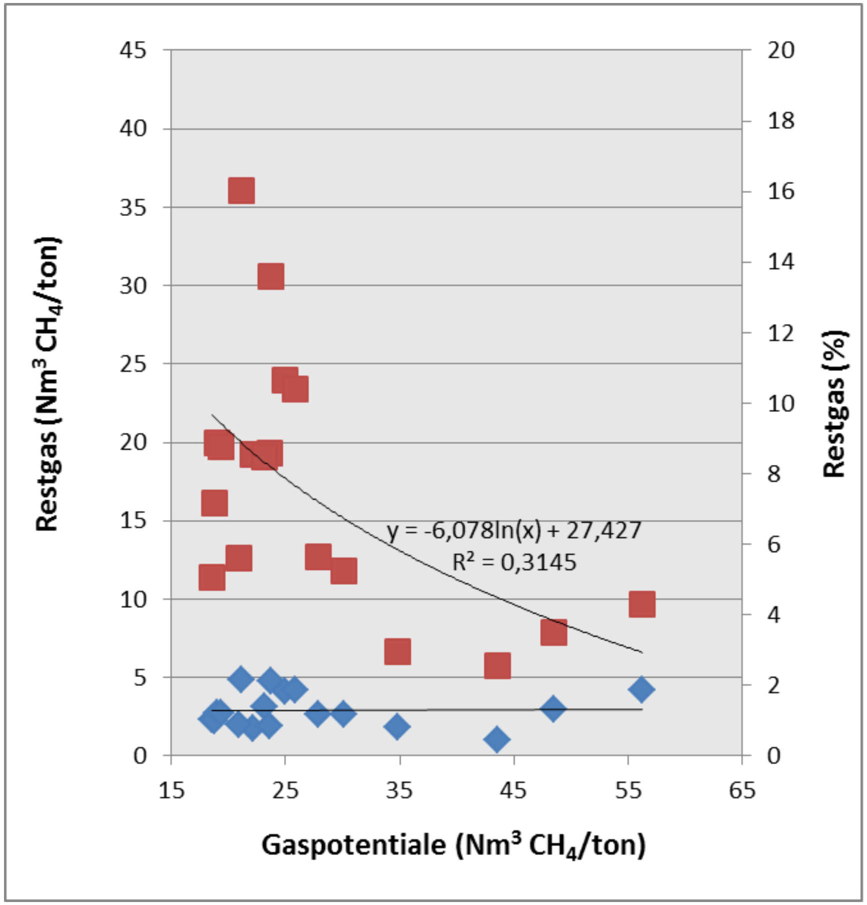


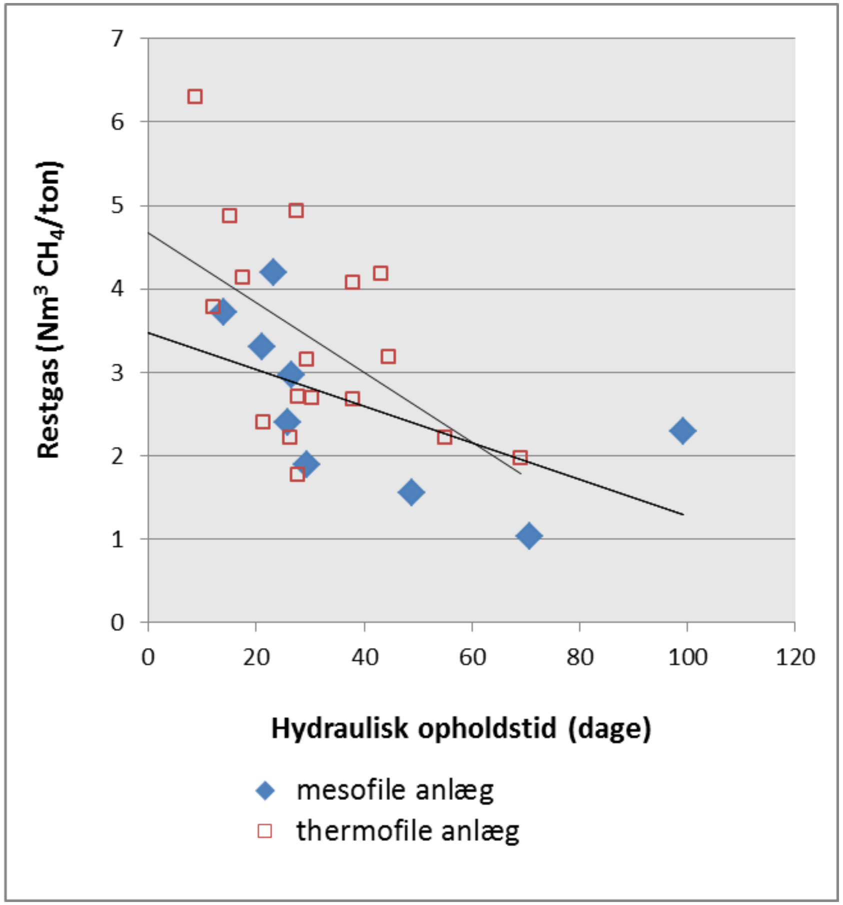
Restgaspotentialer resultater



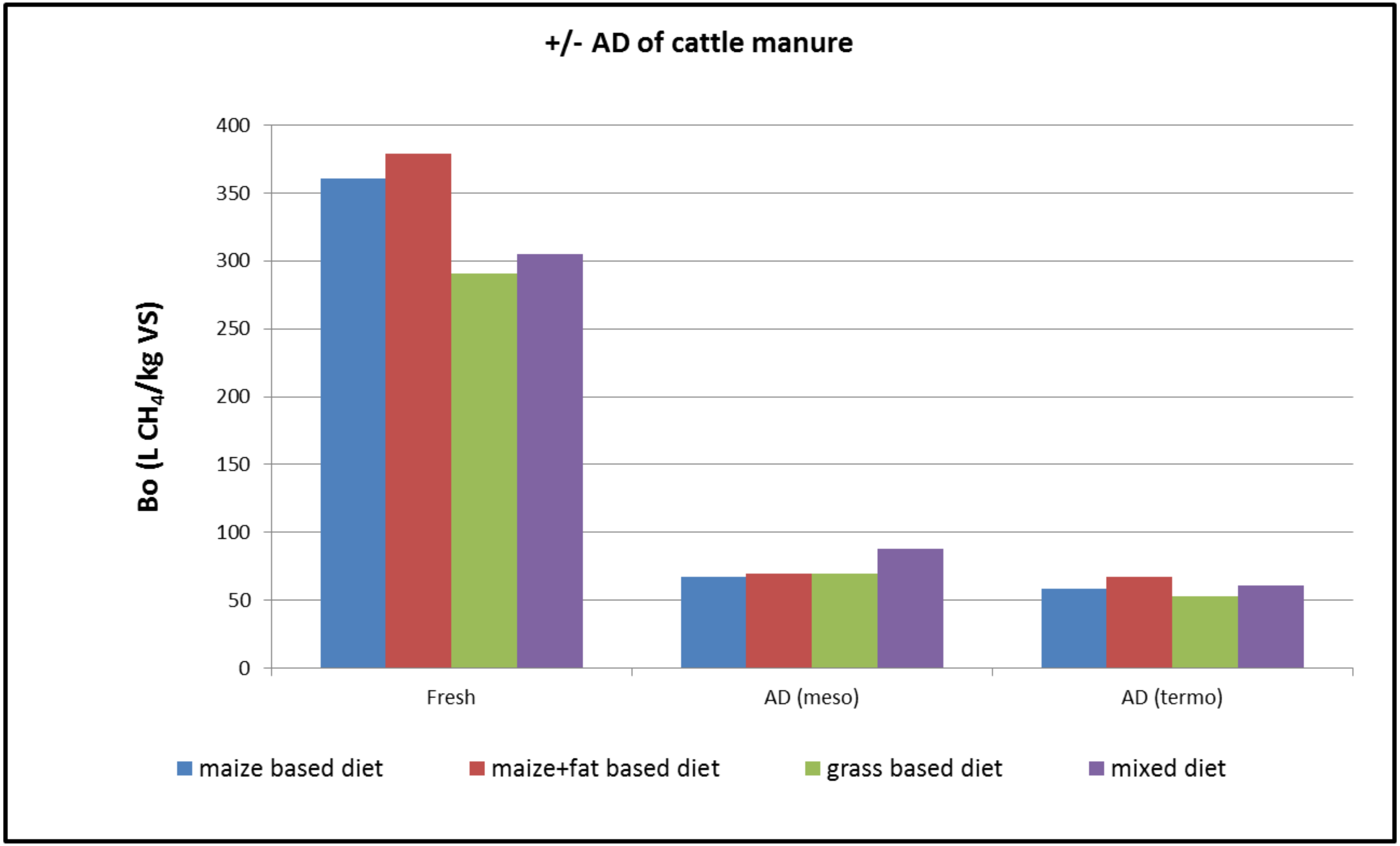


Residual gas results

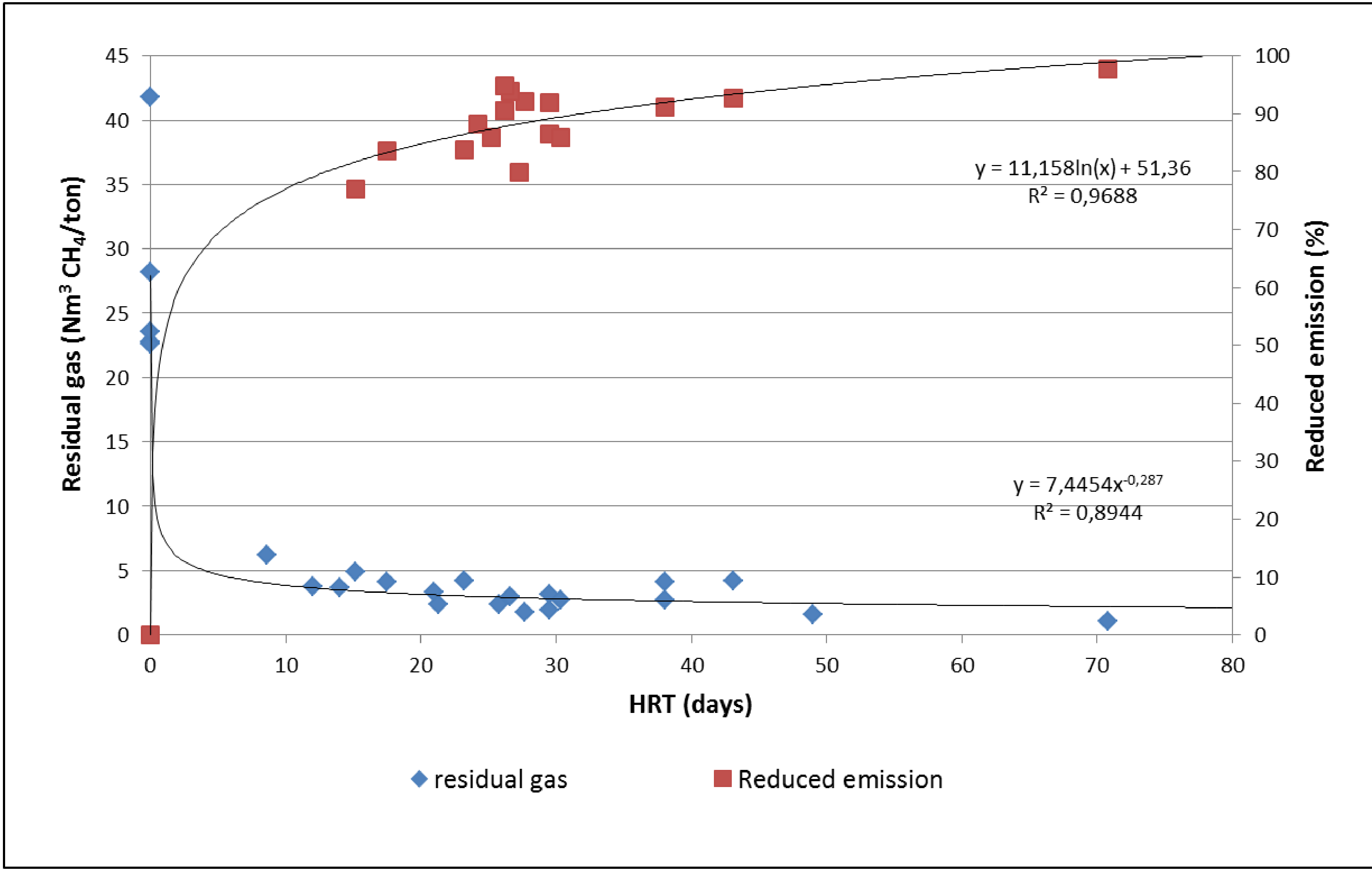




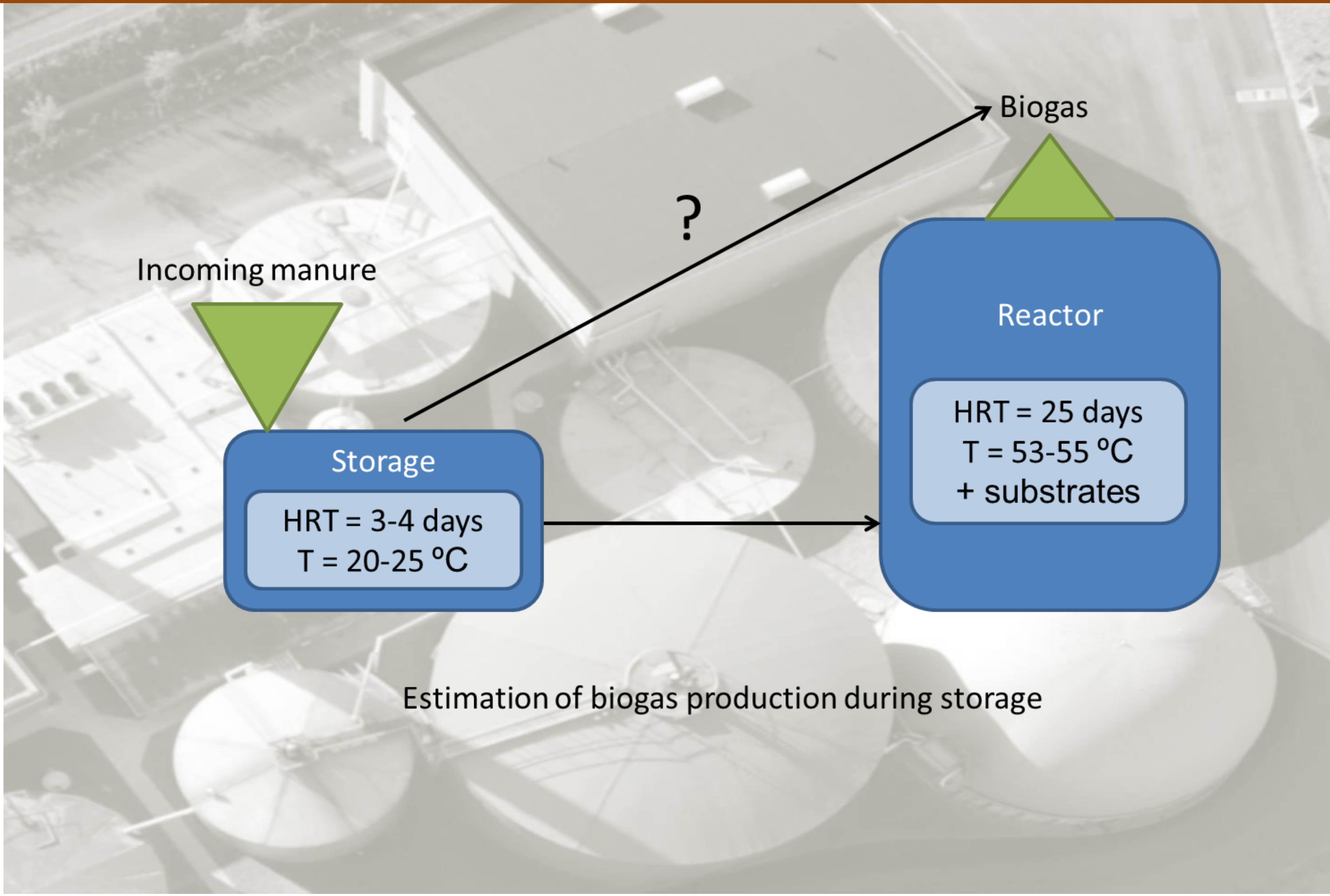
Residual gas Results VS



Reduction potential HRT

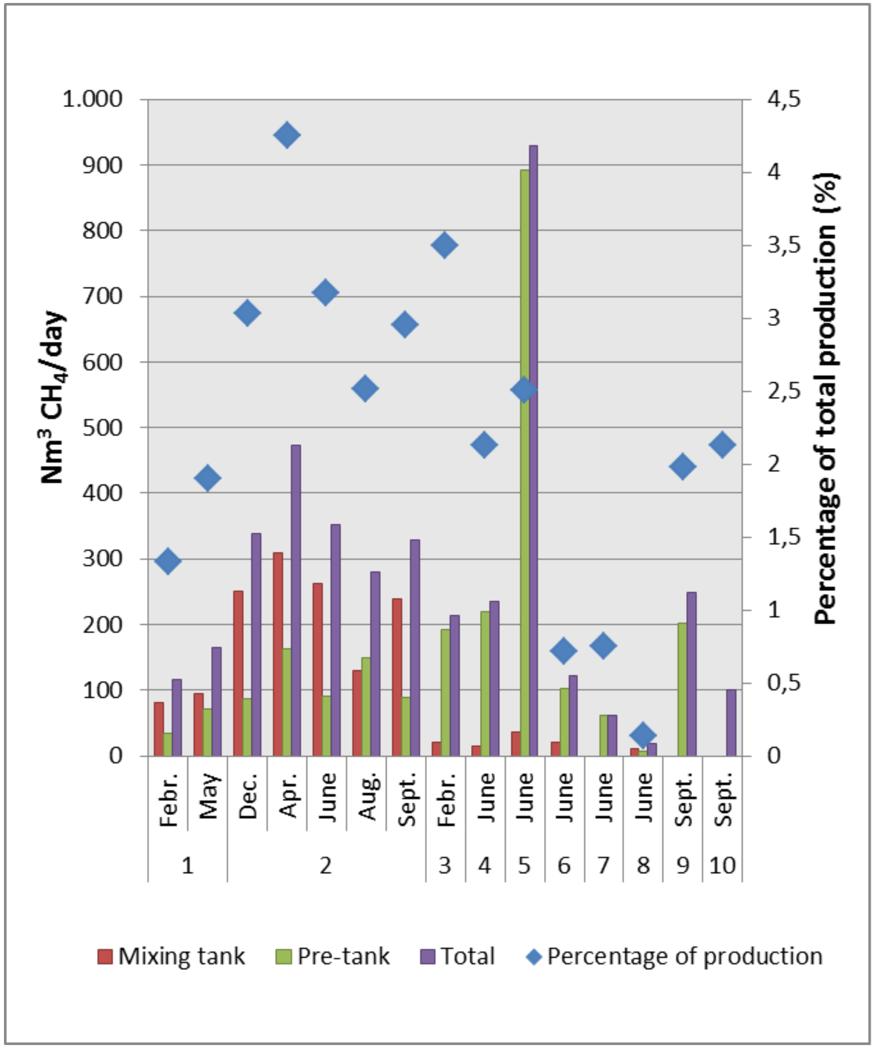


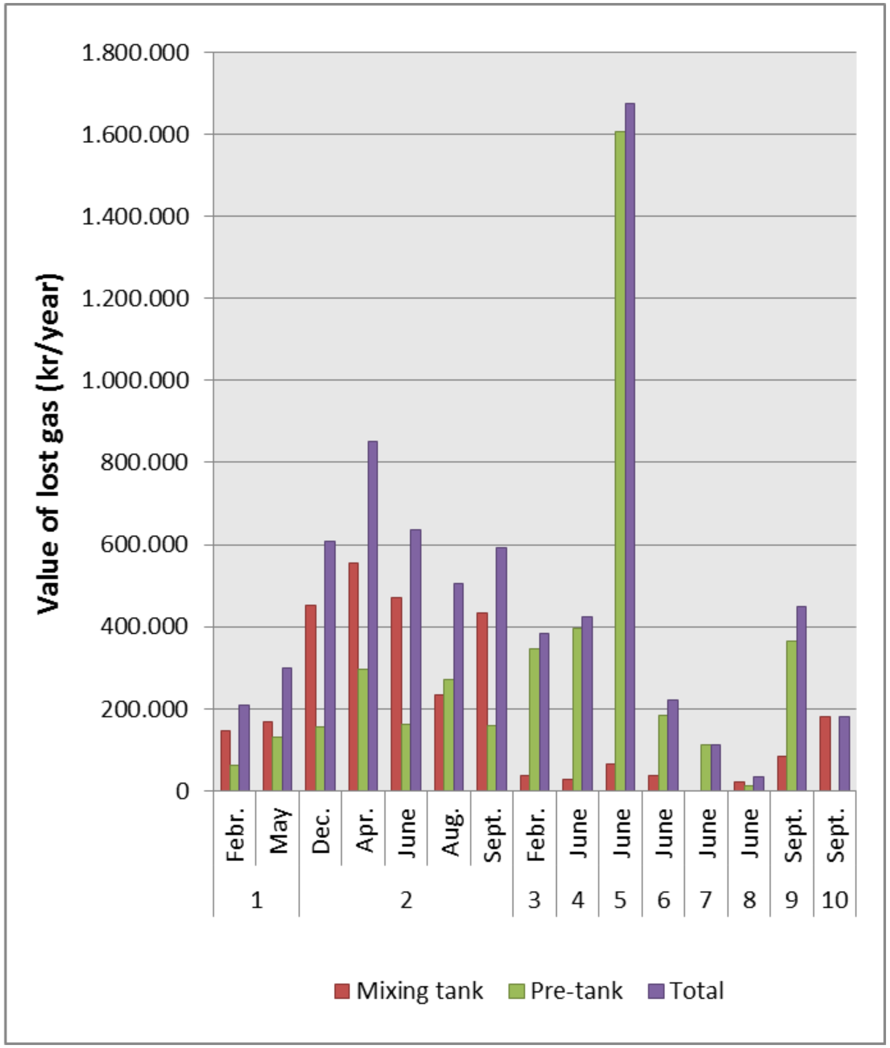
Pre-storage at biogasplant Losses



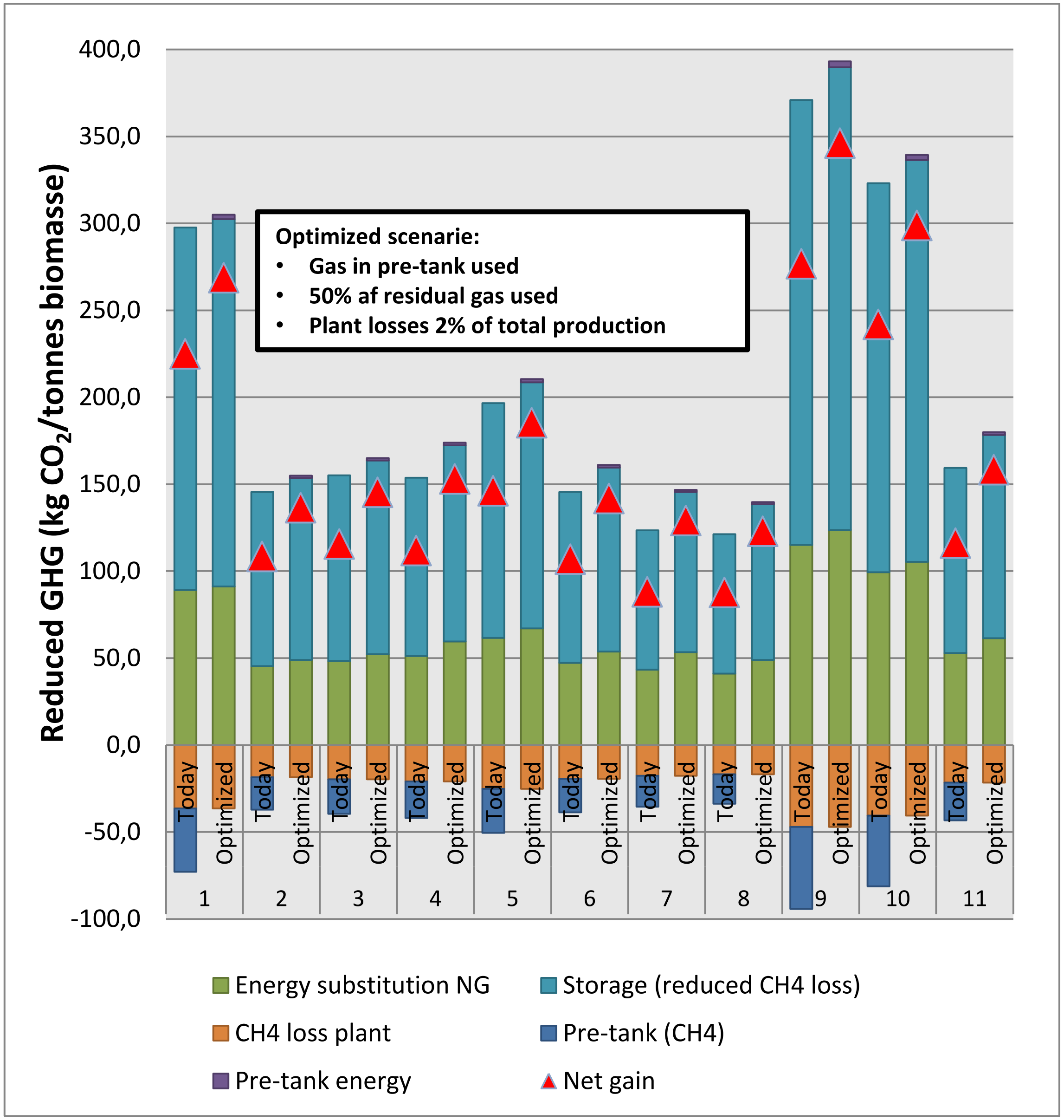
Estimation of biogas production during storage

Pre-storage at biogasplant Losses

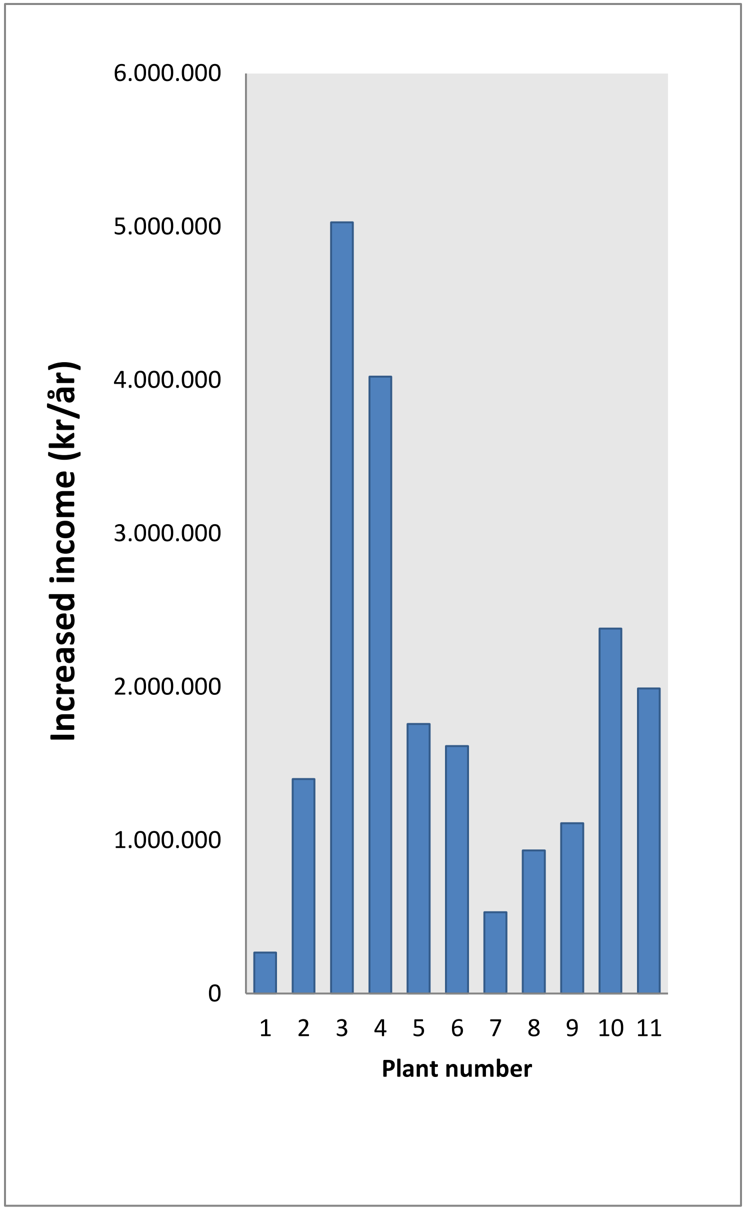




GHG by AD



Reduced GHG (kg CO_2/tonnes biomasse)
400,0
350,0
300,0
250,0
200,0
150,0
100,0
50,0
0,0
-50,0
-100,0
Optimized scenarie:
• Gas in pre-tank used
• 50% af residual gas used
• Plant losses 2% of total production
Today
Optimized
1
2
3
4
5
6
7
8
9
10
11
Energy substitution NG
Storage (reduced CH4 loss)
CH4 loss plant
Pre-tank (CH4)
Pre-tank energy
Net gain



Increased income (kr/år)
6.000.000
5.000.000
4.000.000
3.000.000
2.000.000
1.000.000
0
1 2 3 4 5 6 7 8 9 10 11
Plant number

Part 2 GHG opimization
Conclusion

- The reduction potential from AD has been calculated from 16 biogas plants and is in average 85%.
- In controlled experiments with CM an average reduction potential of 86% was achieved.
- There is a sigificant correlation with HRT, in general increased retention time will reduce the potential for CH_4 emissions.
- CH4 production in pre-tanks at biogasplants is around 2% of CH4 production in average
- The GHG reduction potential of a biogasplants can be improved significant by collecting gas from pre- and post digestion and at the same time create an income.

Thanks for your attention