BioChain Workshop 2014

Joint workshop with Norwegian partners

27-29 October 2014

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Visit to Foulum biogas research facility

Henrik B. Møller


Xergi

Presentation of the energy crop/residue project in the field

Jøren E. Olesen

MAABJERG ENERGY CONCEPT
HOLSTEBRO STRUER

The MEC BIOREFINERY


Maabjerg BioEnergy
is now
reality

New challenges

MAABJERG
ENERGY CONCEPT
HOLSTEBRO STRUER

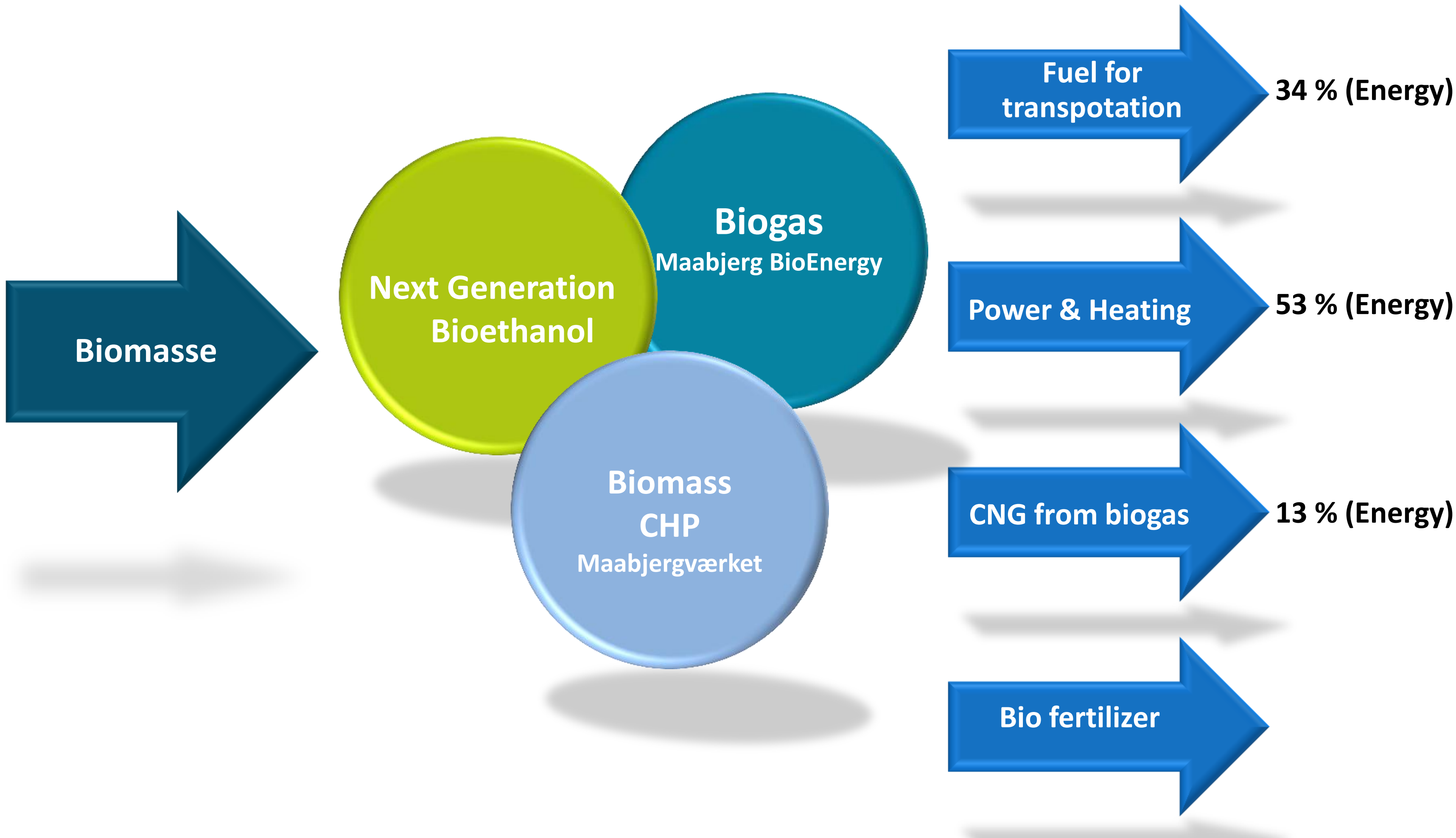
MAABJERG
BIOENERGY

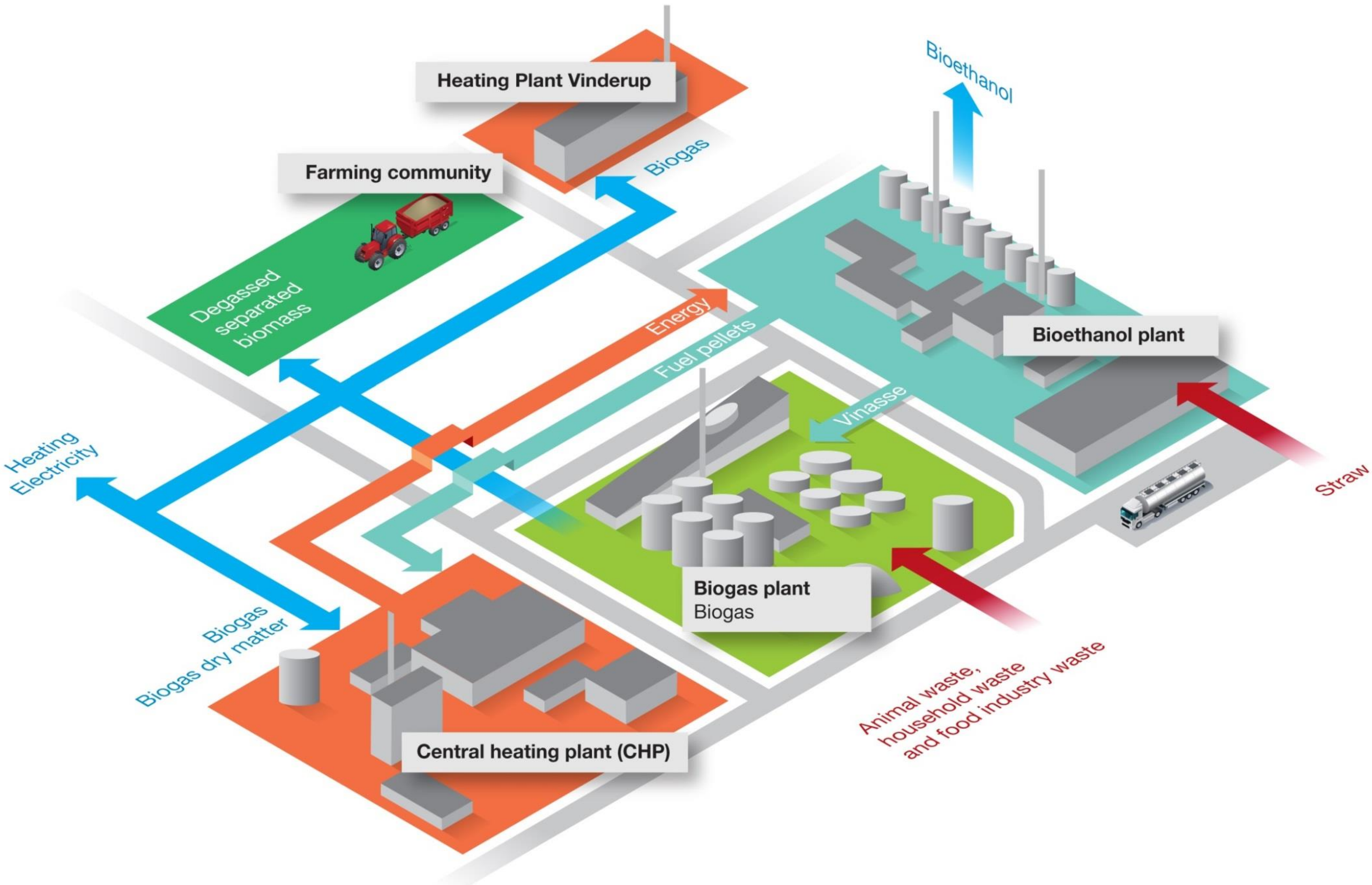
Måbjergværket / CHP Plant

The MEC Vision

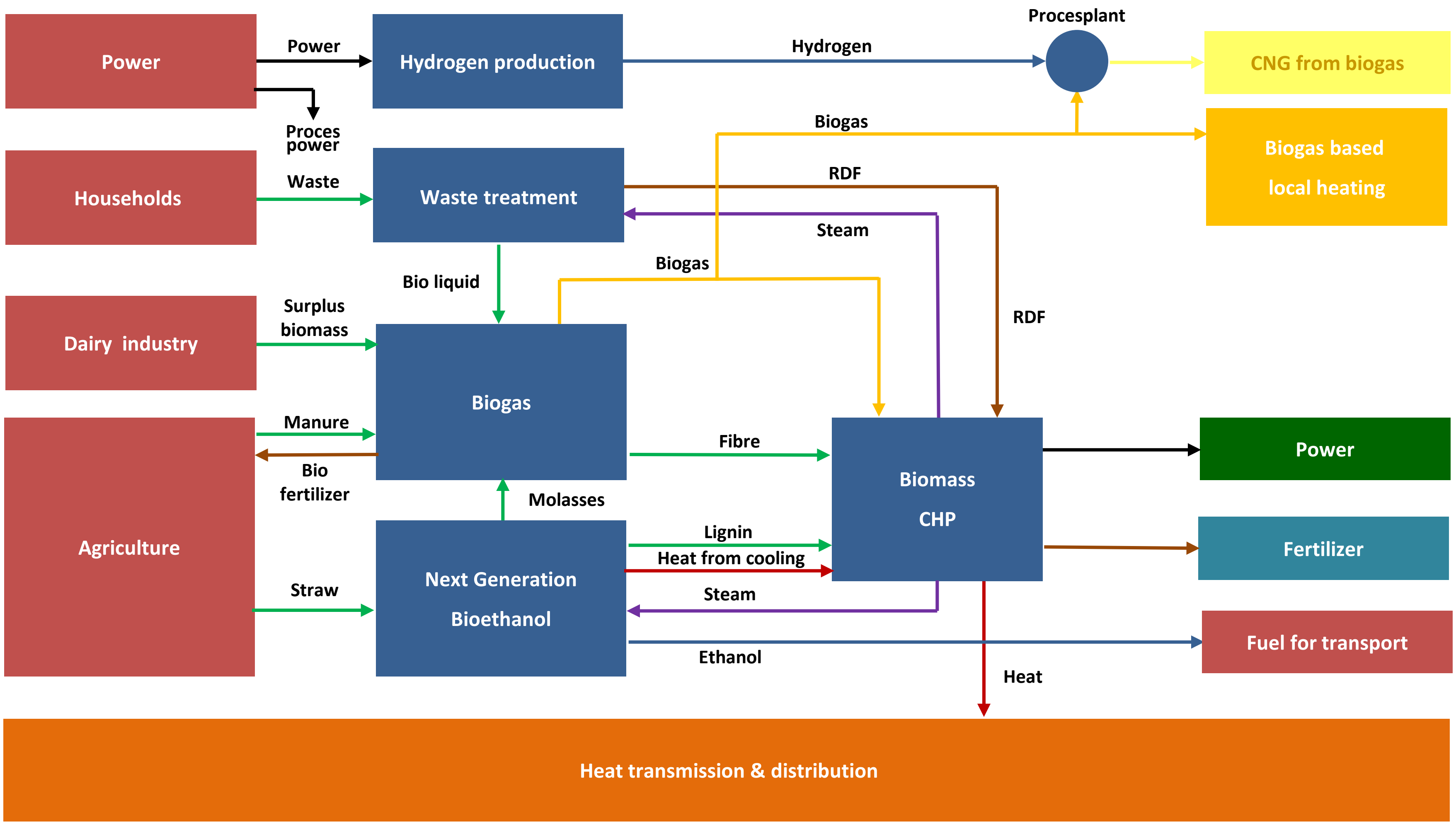
MAABJERG ENERGY CONCEPT HOLSTEBRO STRUER

Biomass based energy production combined into Bio Refinery



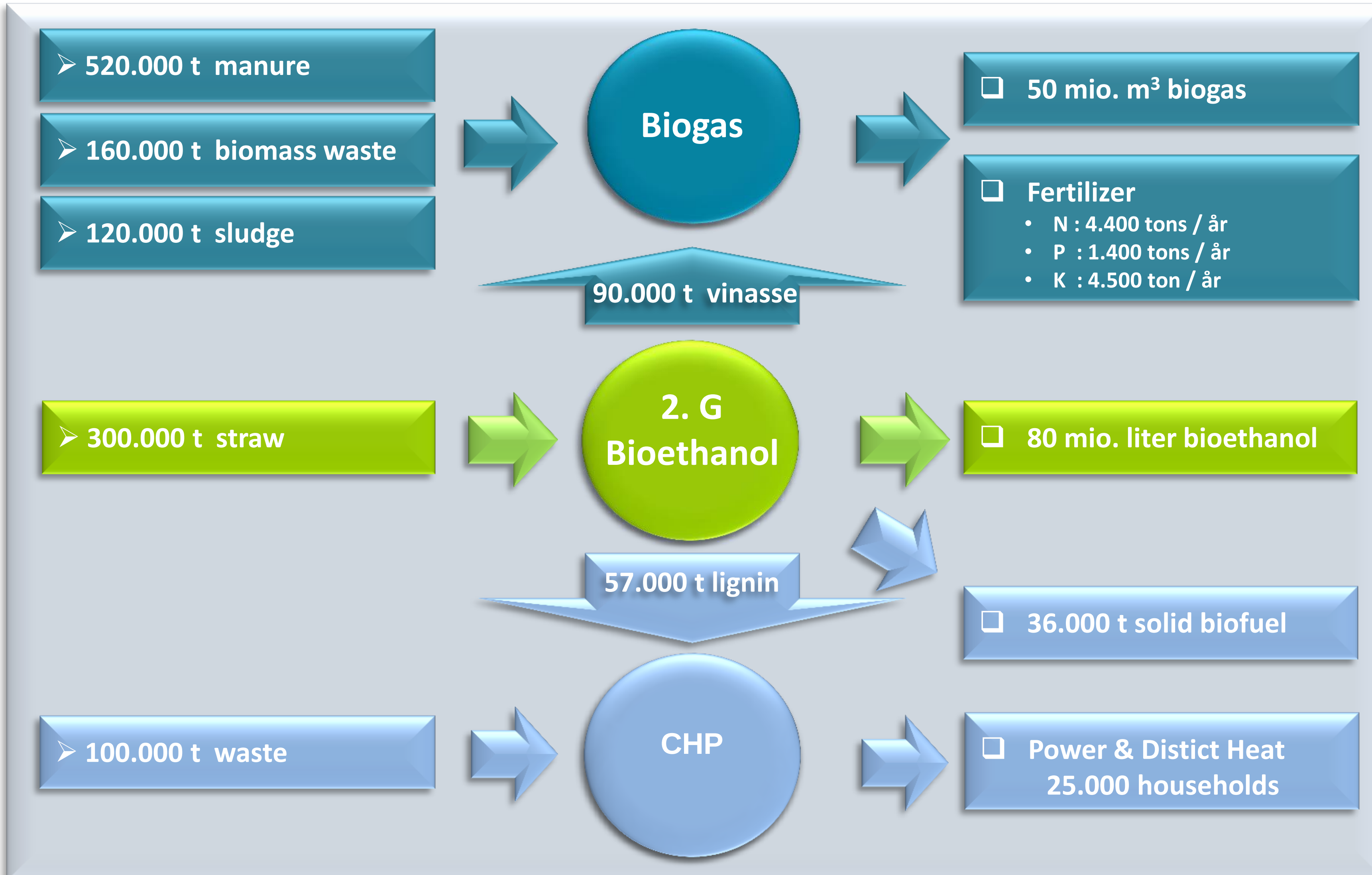

Heating Plant Vinderup
Farming community
Biogas
Bioethanol
Degassed separated biomass
Energy
Fuel pellets
Bioethanol plant
Vinasse
Heating Electricity
Straw
Biogas plant
Biogas
Biogas
Biogas dry matter
Animal waste, household waste and food industry waste
Central heating plant (CHP)

Main streams of materials and energy



MAABJERG ENERGY CONCEPT
HOLSTEBRO STRUER

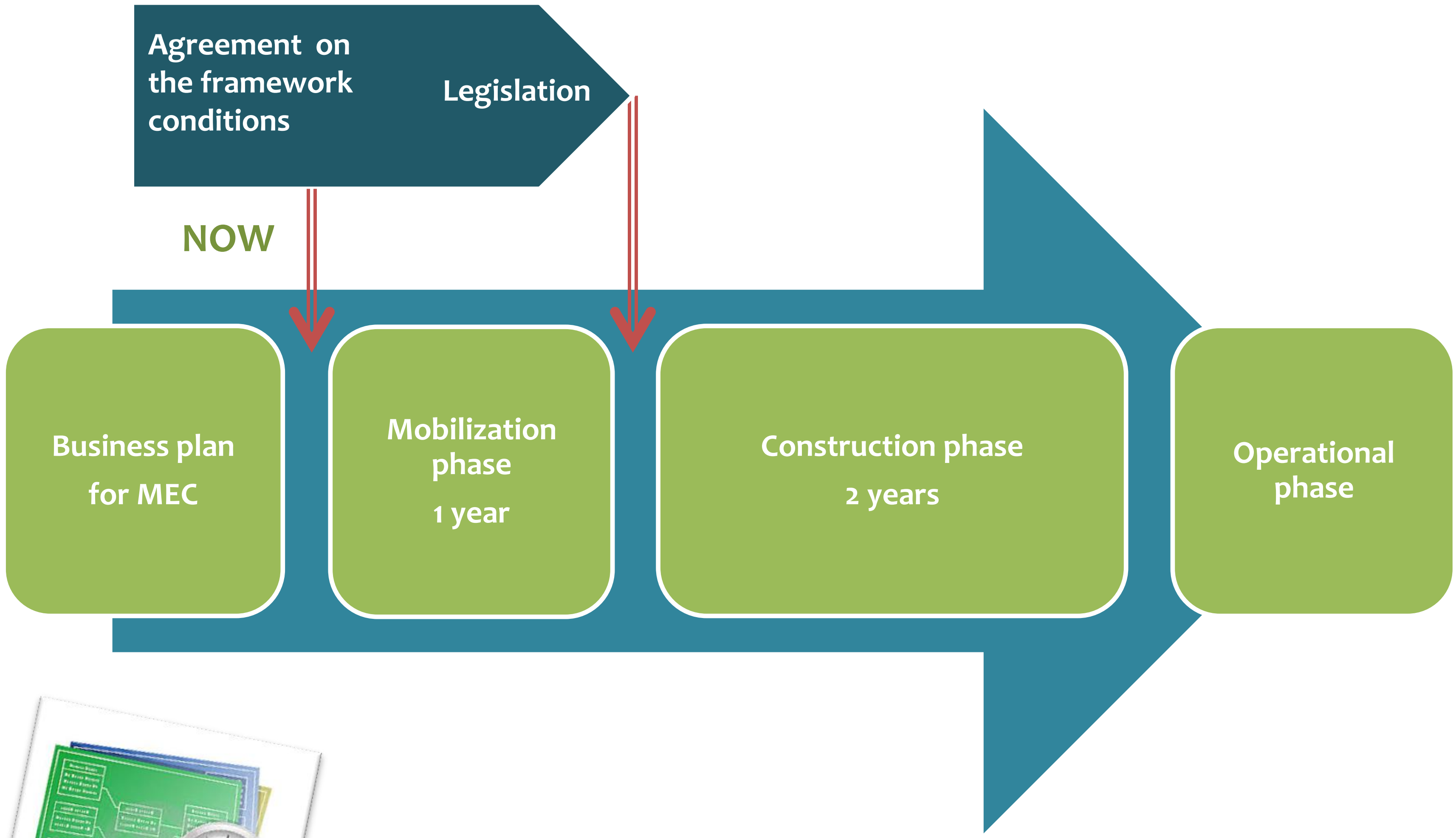
Raw materials and their turnover

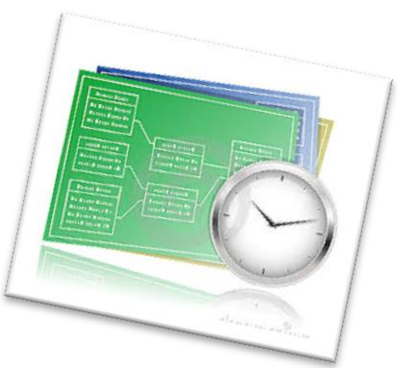


http://www.youtube.com/watch?v=_PnS_tc1YBc

Schedule

MAABJERG ENERGY CONCEPT
HOLSTEBRO STRUER





Maabjerg Energy Center

MAABJERG
ENERGY CONCEPT
HOLSTEBRO STRUER

Questions

Learn more at our website where you can also ask questions

www.maabjergenergyconcept.dk

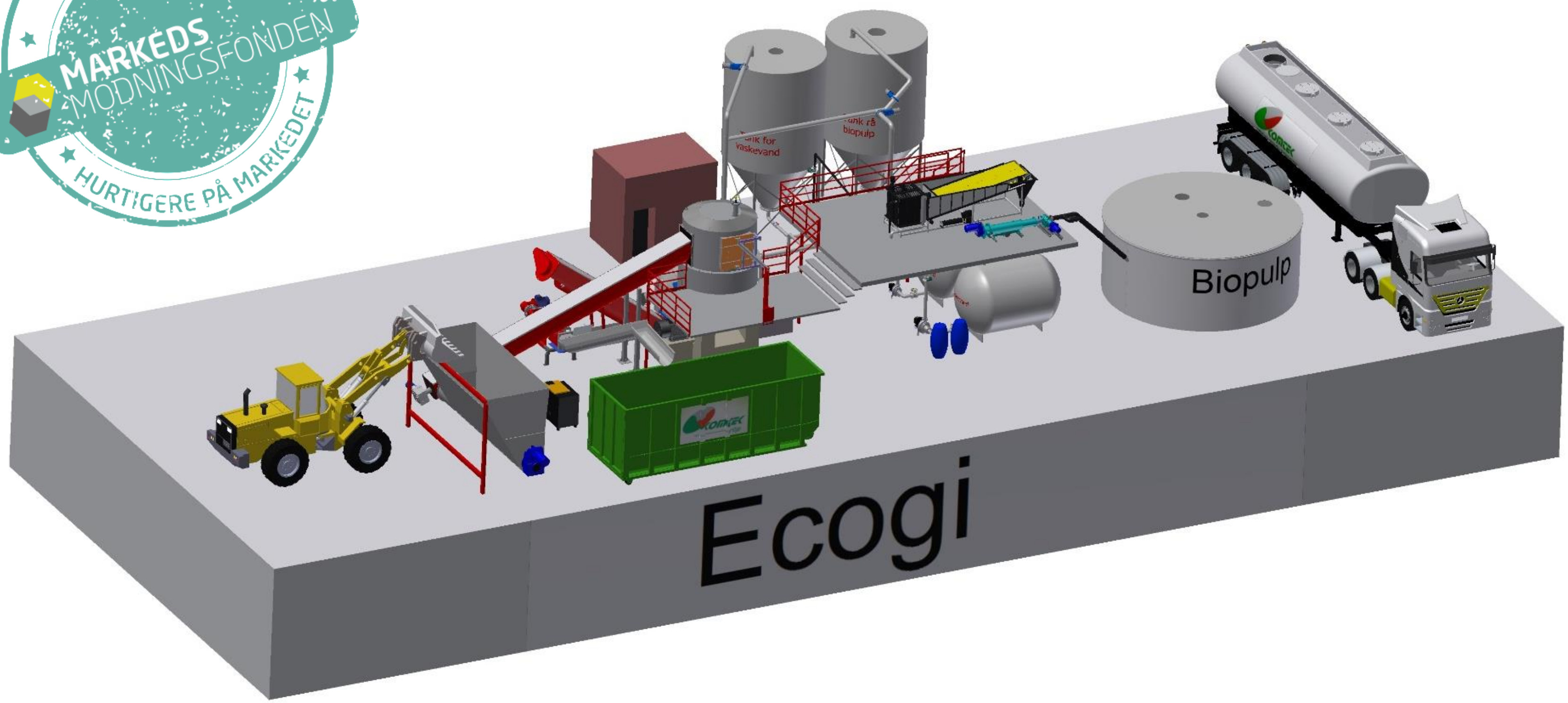




Ecogi – Efficient Refining of Organic Waste

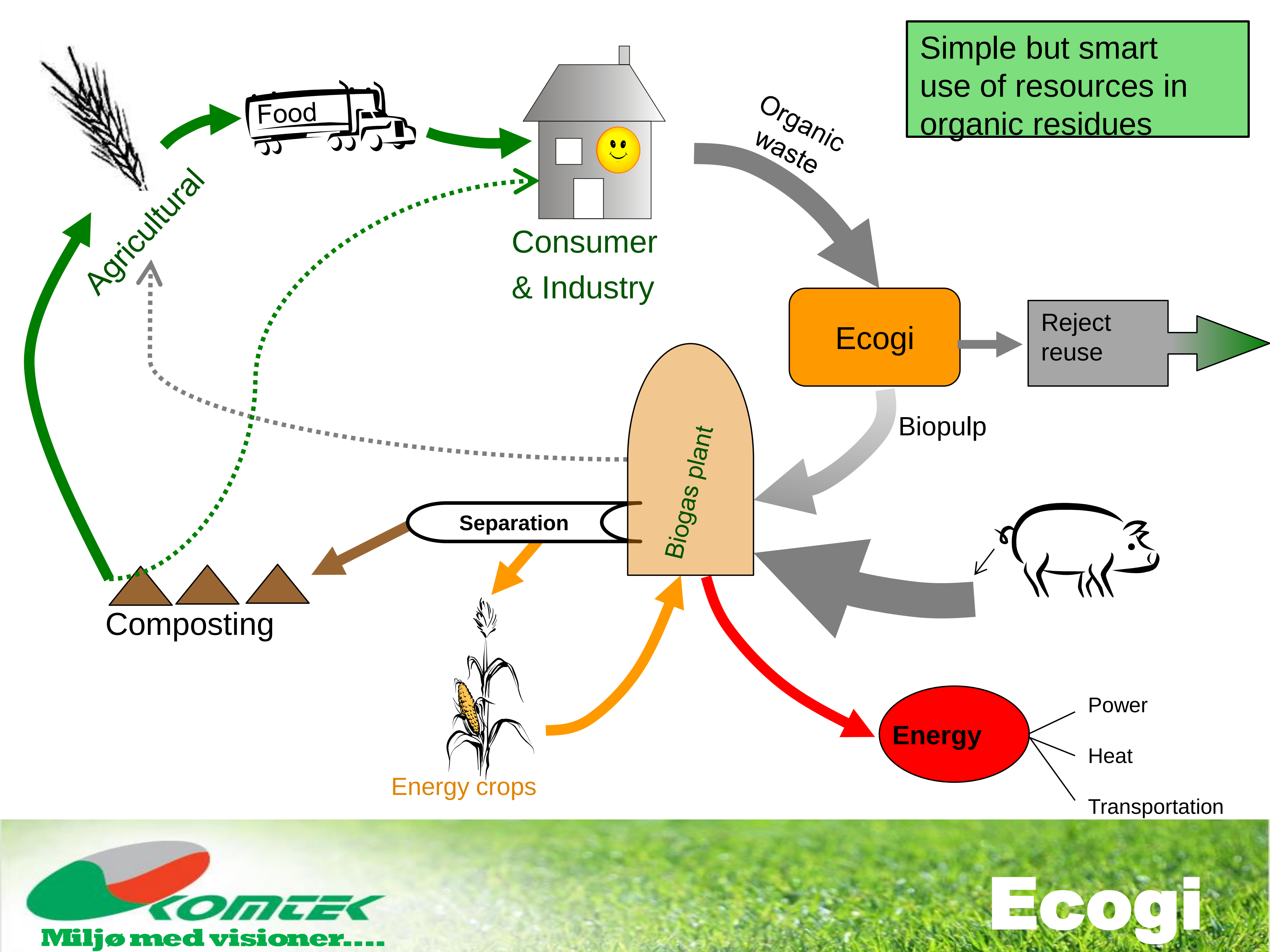
With low energy consumption

UDVALGT AF MARKEDS MODNINGSFONDEN HURTIGERE PÅ MARKEDET



KOMTEK
Miljø med visioner....

Ecogi



Simple but smart use of resources in organic residues
Food
Agricultural
Consumer
& Industry
Organic waste
Ecogi
Reject reuse
Biopulp
Biogas plant
Separation
Composting
Energy crops
Energy
Power
Heat
Transportation
Miljø med visioner....
Ecogi

Organic waste in a perfect world!!!

Miljø med visioner….

Ecogi

Organic waste in reality

KOMTEK
Miljø med visioner….

Ecogi

Normal operating conditions for Ecogi!!!

Or like this!!!

KOMTEK
Miljø med visioner....

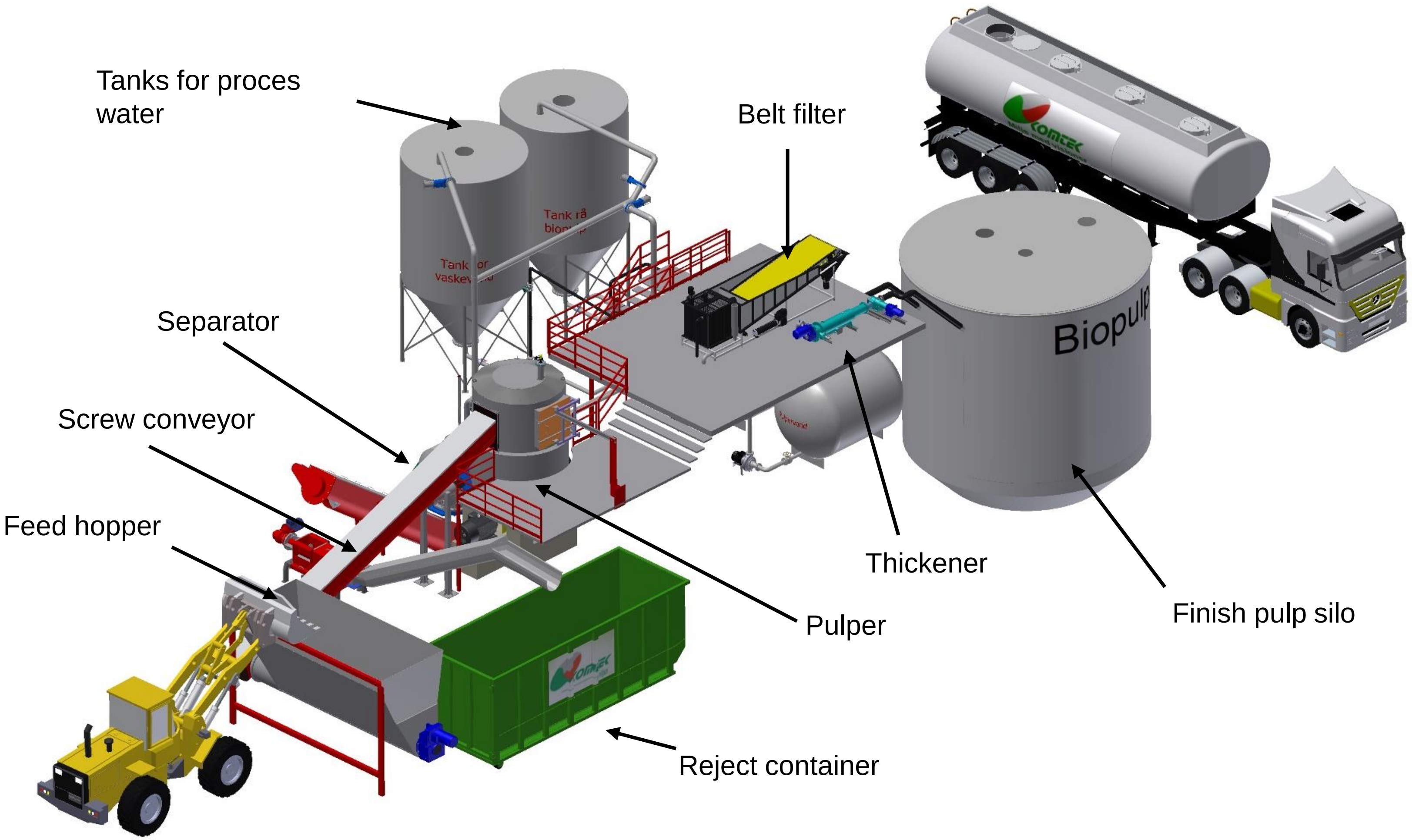
Ecogi

Organic waste for Ecogi-plant

KOMTEK
Miljø med visioner….

Ecogi

The Ecogi facility



Biopulp

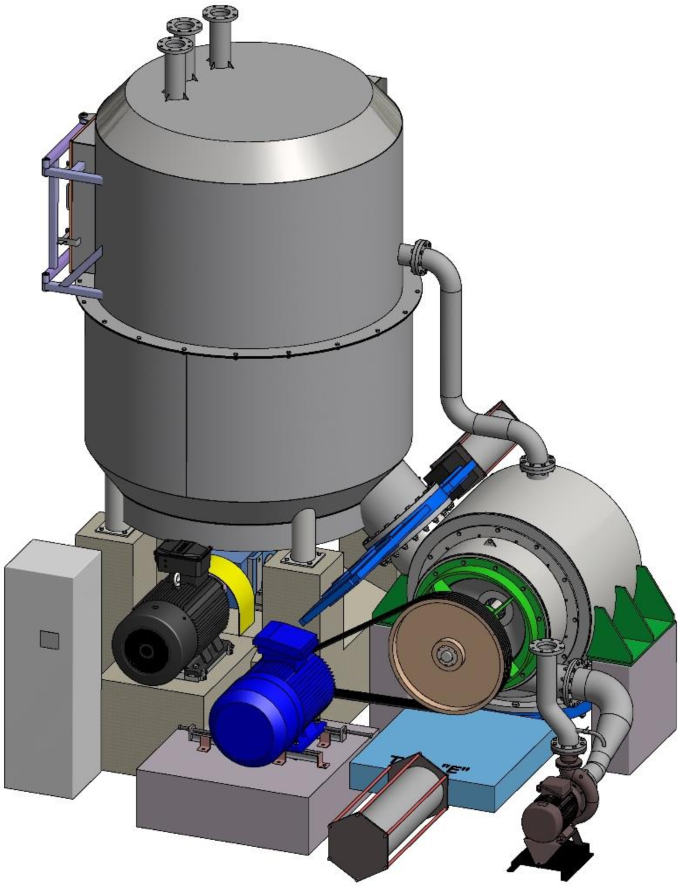
Reject

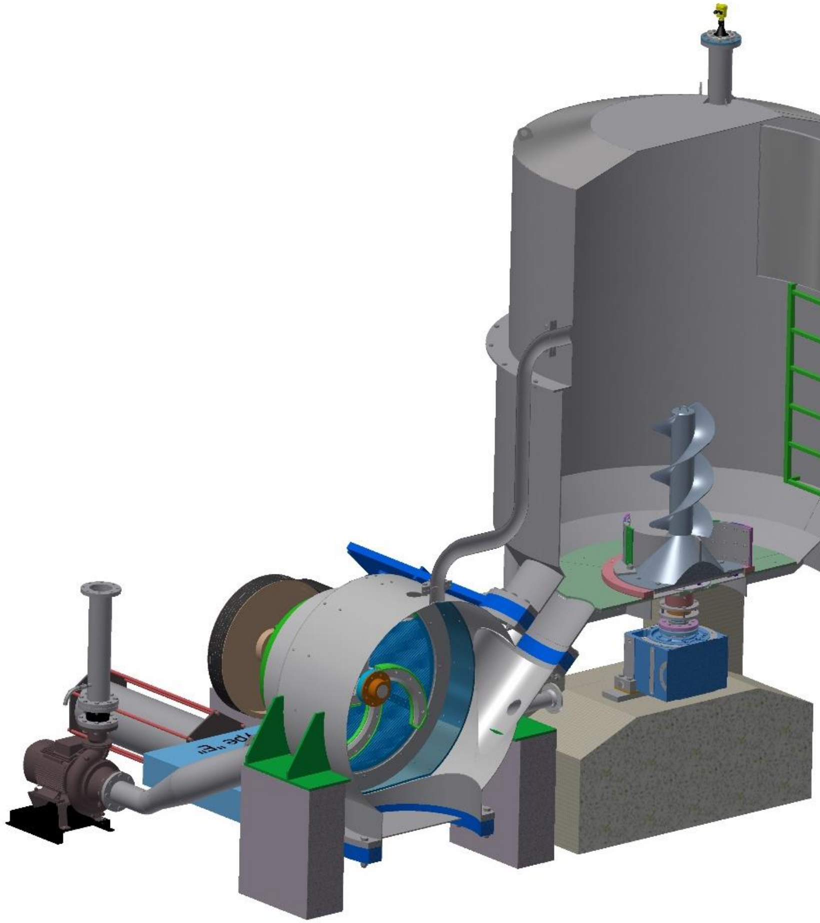
Purity of Bio-pulp

> 99%

Max 5% organic in reject

Core of the process design





Pulping concluded

Finished Bio-pulp

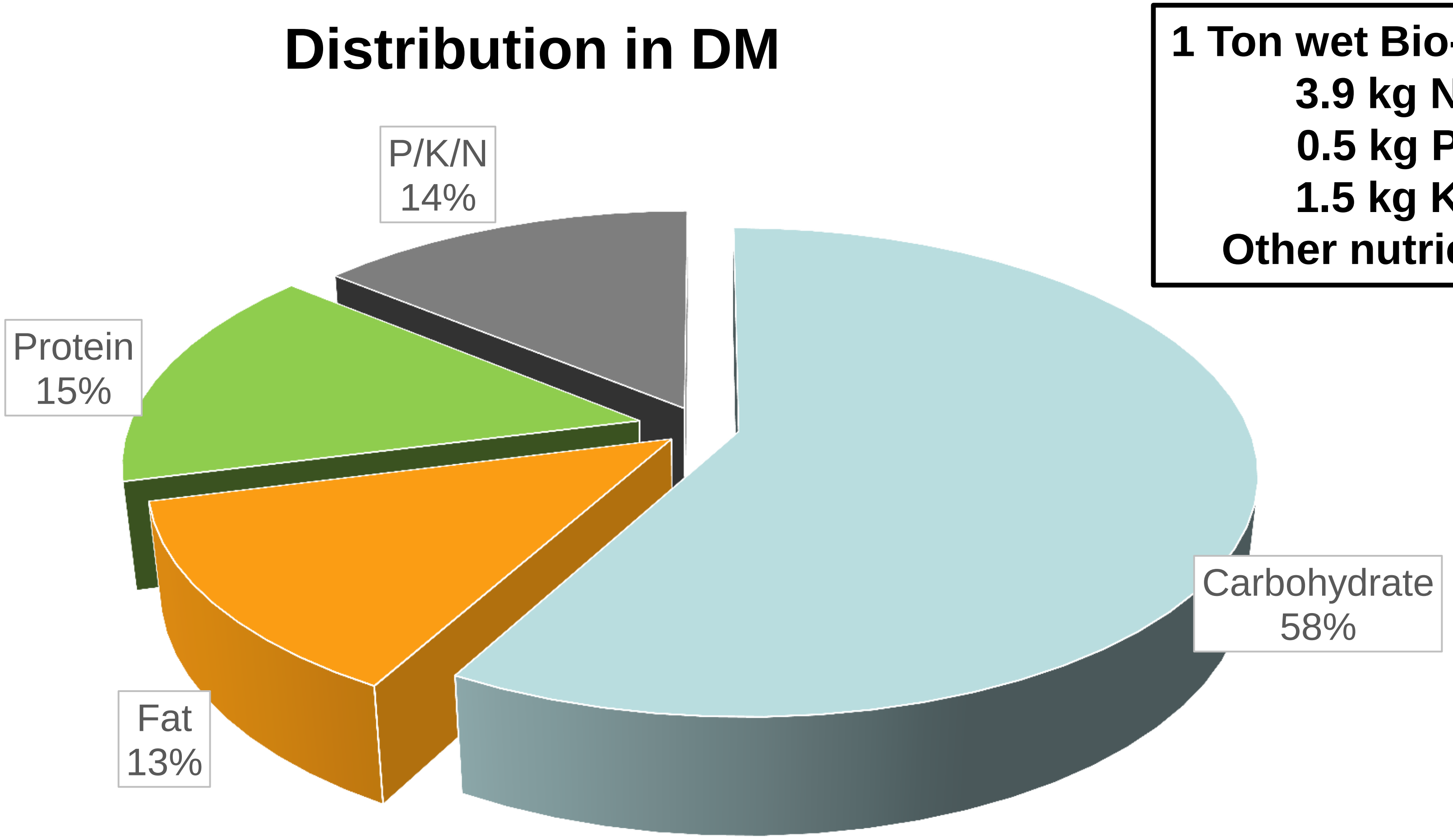
Komtek
Miljø med visioner….

Ecogi

Bio-pulp characteristics

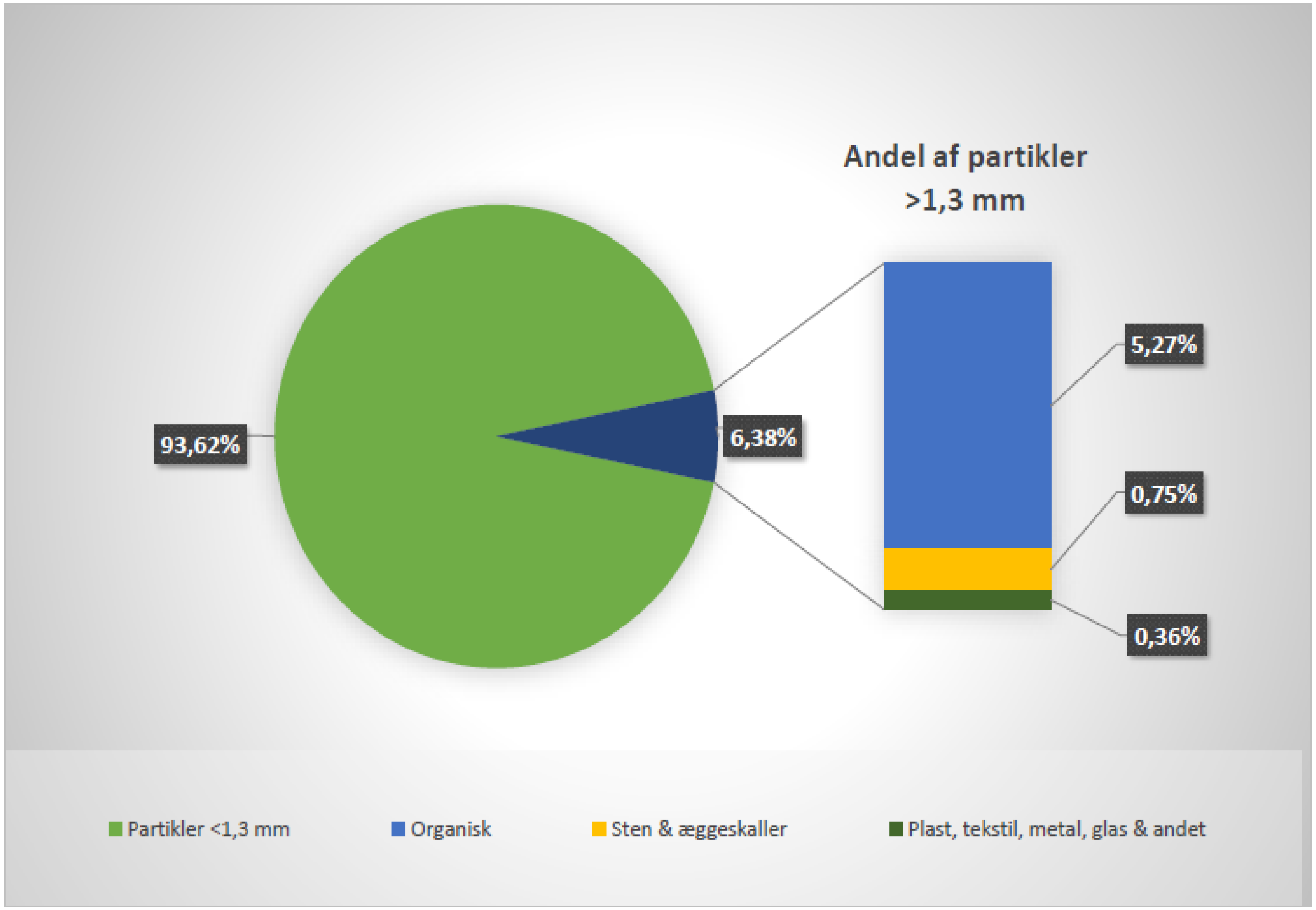
- Typically 17% DM in bio-pulp
- Typically 88% OM in DM
- Particle size (measured from DM):
  - <7% >1.3 mm
  - 60% <100 μ
- Purity of Bio-pulp >99%
- Methane yields typically from 400-500 Nm3 CH4/t VS obtained in less than 25 days
- pH values typically around 4,5
- Low values for hazardous substances

Composition of Bio-pulp with 14% DM

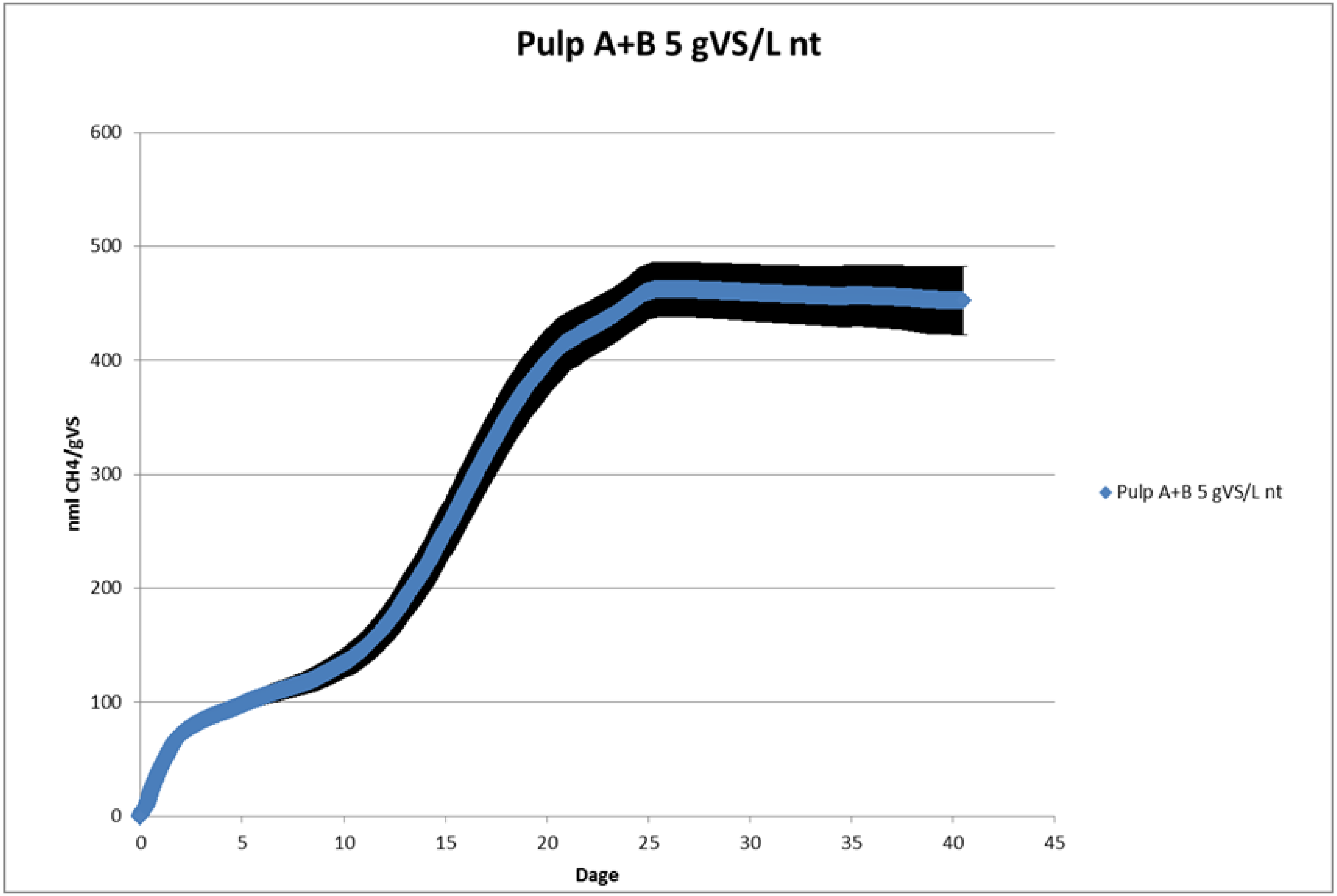


1 Ton wet Bio-pulp:
3.9 kg N
0.5 kg P
1.5 kg K
Other nutrients

Particle size in DM-fraction



Gas yield from Bio-pulp

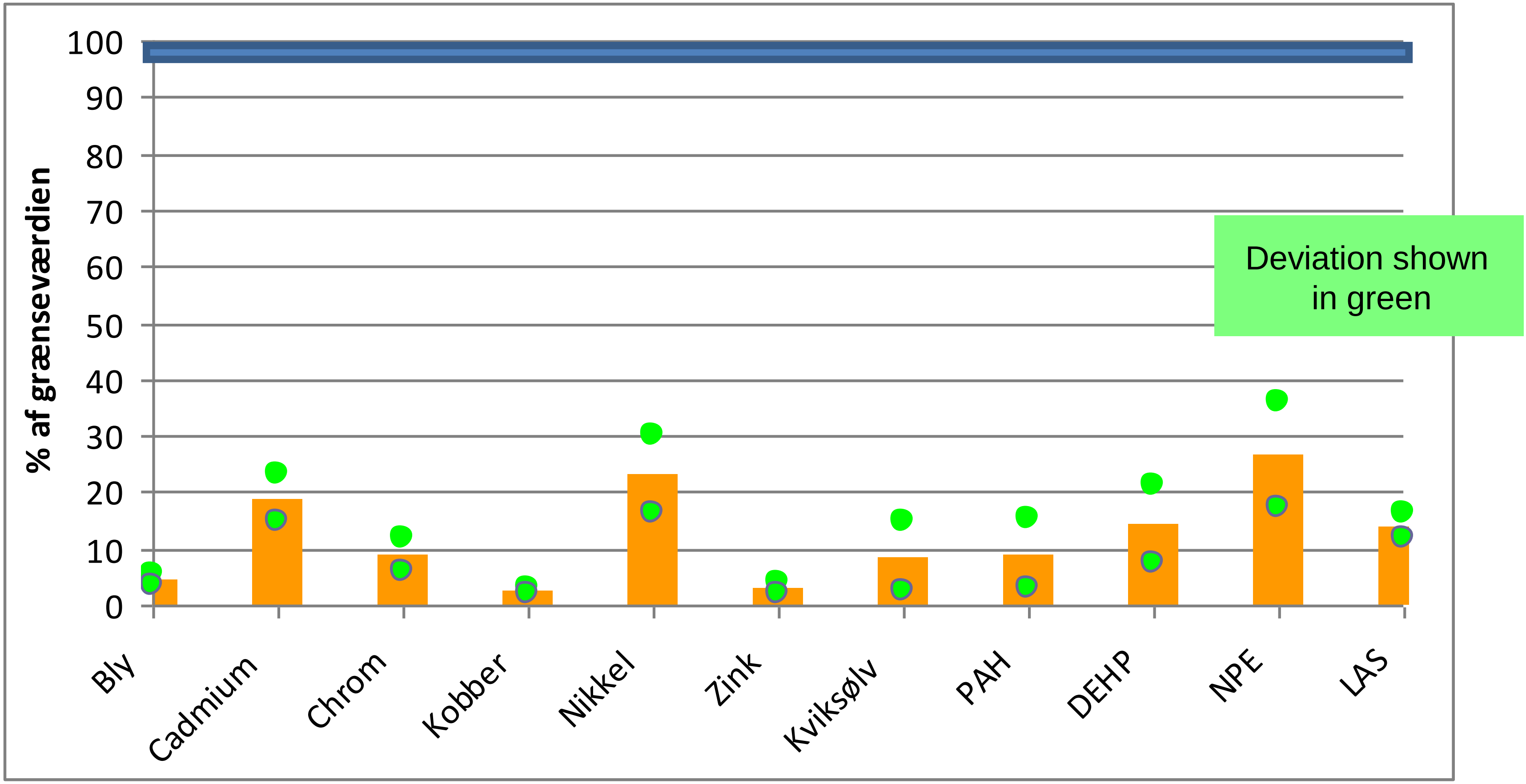


KOMTEK
Miljø med visioner....

Ecogi

Bio-pulp – Quality and purity

Analysis values in per cent of limit values according to ”Slambekendtgørelsen”(Danish version of EU Sludge Directive)



KOMTEK
Miljø med visioner....

Ecogi

Declaration February 2014

Normal figure, supply with 17% DM			Analyses		
			Newest	Avg.	
Total N	4,25	Kg/ton wet weight	29,8	25,0	Kg/ton TS
NH4	0,71		6,0	4,2	
Phosphor	0,53		3,0	3,1	
Kalium	1,59		7,3	9,4	
Magnesium	0,07		0,7	0,4	
Sulphur	0,24		2,6	1,4	
Biogas	**119**	M3 biogas	462	509	M3 CH4 per ton VS

Mg/kg TS	Limit value	Newest analysis Højvang nr. 1302-792-1	Avg. 7 analyses
Lead	120	2,7	4,91
Cadmium	0,8	0,11	0,14
Chromium	100	6,5	8,56
Copper	1000	20	24,1
Nickel	30	2,7	6,19
Zink	4000	50	112
Mercury	0,8	0,04	0,06
PAH	3	0,17	0,21
NPE	20	0,77	2,5
DEPH	50	4,1	13
LAS	1300	<50	143

Miljø med visioner….

Ecogi

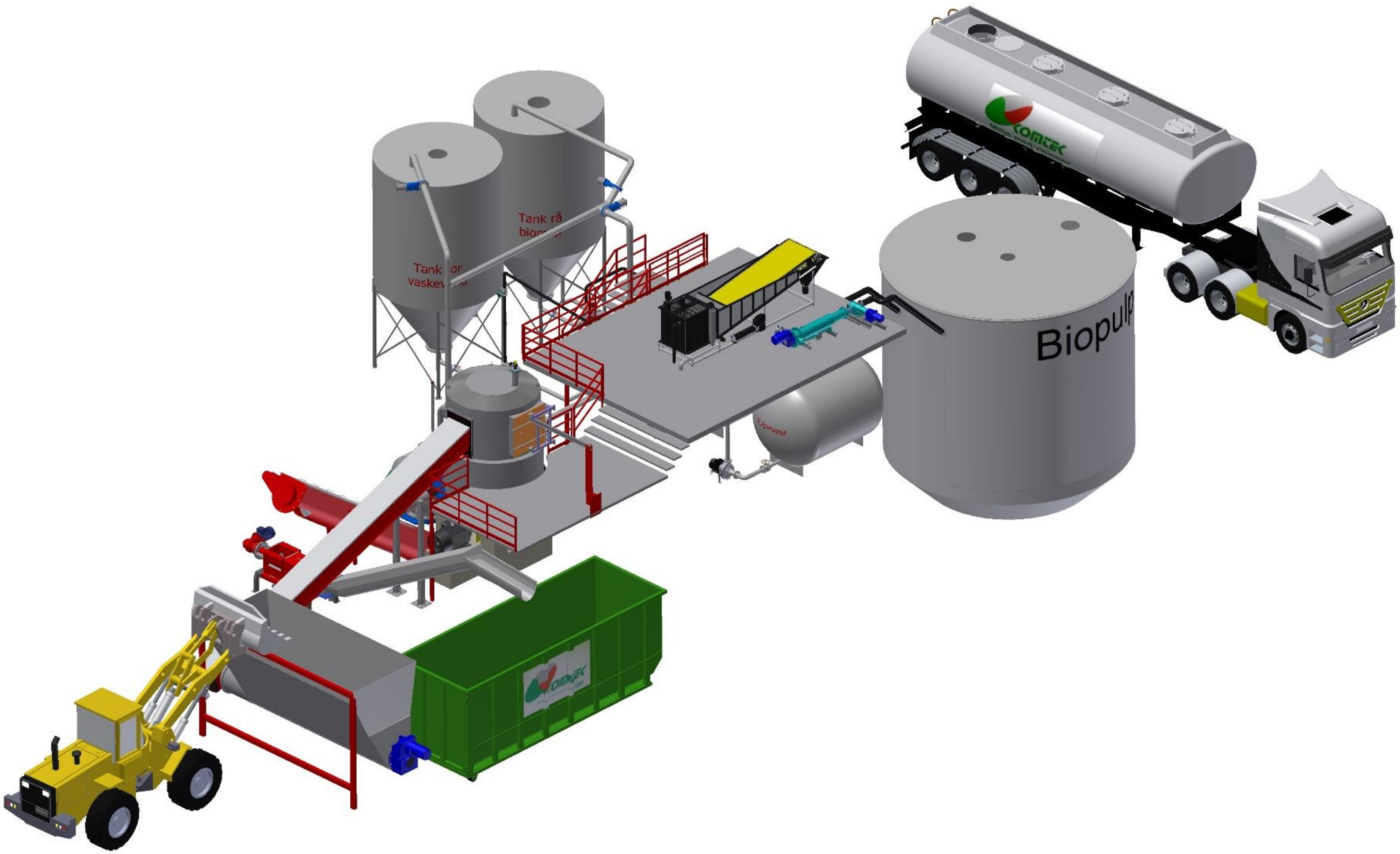
Ecogi operational data

Start-up:	August 2011
Operational hours:	>5.000 operational hours
Capacity:	5-7 t/operational hour. Depending of reject fraction
Power cons.:	20-30 kWh/t
Staffing:	1 person
Water cons.:	Depending on reject fraction. 300-500 l/t wet waste
Polymers:	Depending on DM in Bio-pulp
Waste types:	Source-separated municipal waste, waste from food producing entreprises, convenience stores and agricultural waste products

- Fully automated control system designed by KomTek.

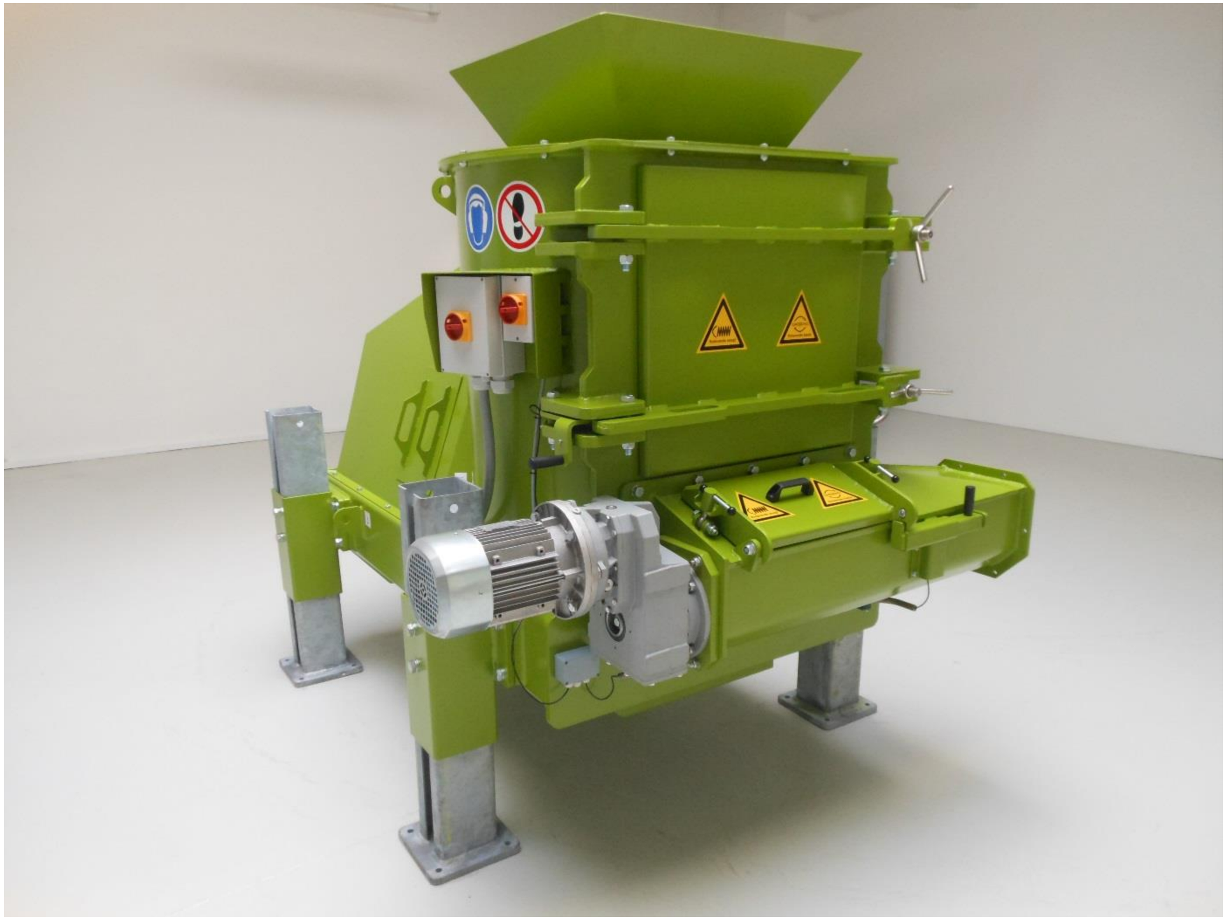
Miljø med visioner….

Ecogi


Tank rå
Tank for
Biopulp

xergi

X-chopper



xergi

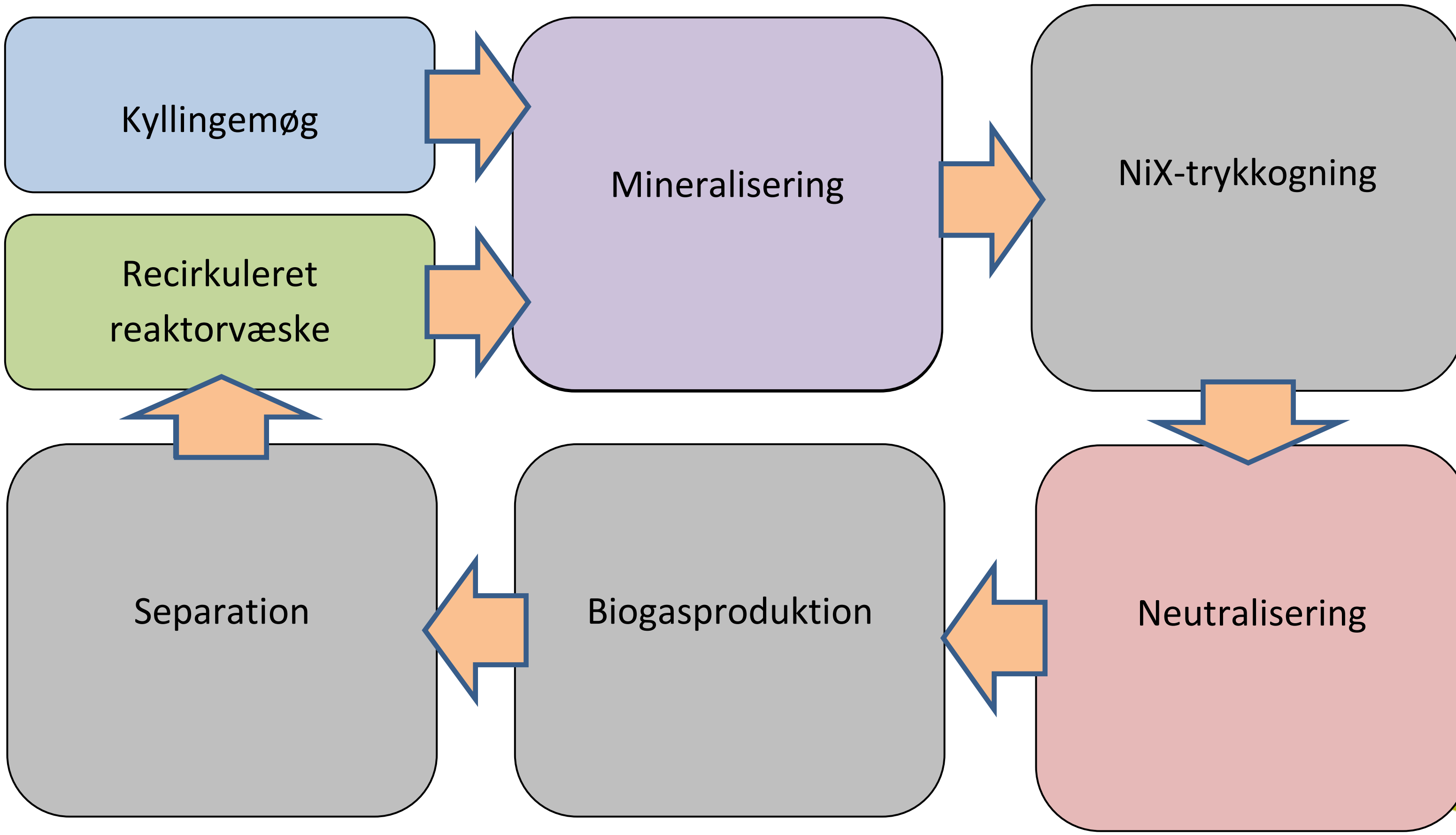
NiX

xergi

NiX

NiX

AD on NiX-treated chicken litter



Economies of scale in biogas and organizational consequences: Common case study

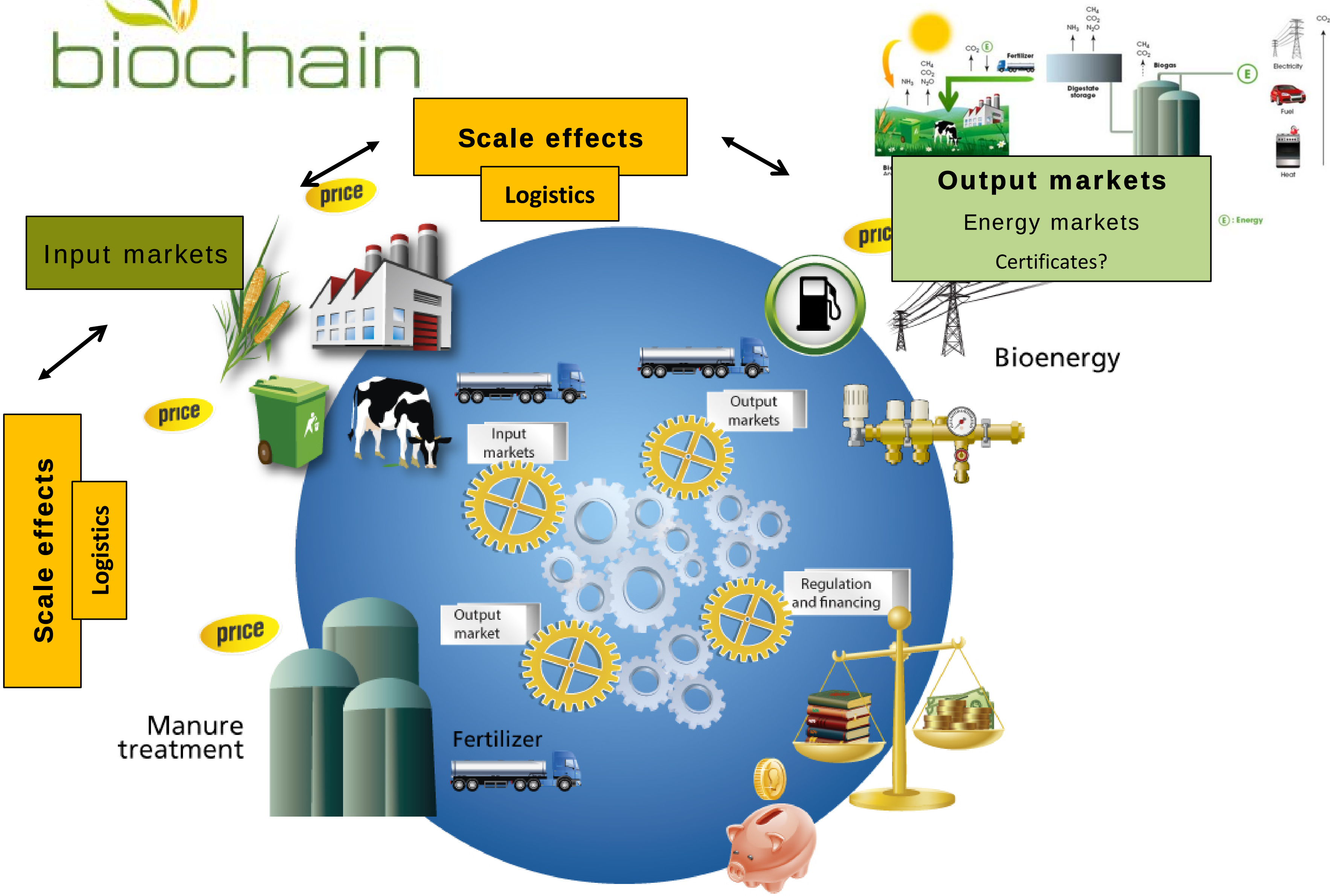
October 28, 2014

Joint BioChain and BioValueChain workshop October 27-29, 2014 Aarhus University, Foulum

Henrik Klinge Jacobsen

DTU Management Engineering
Department of Management Engineering

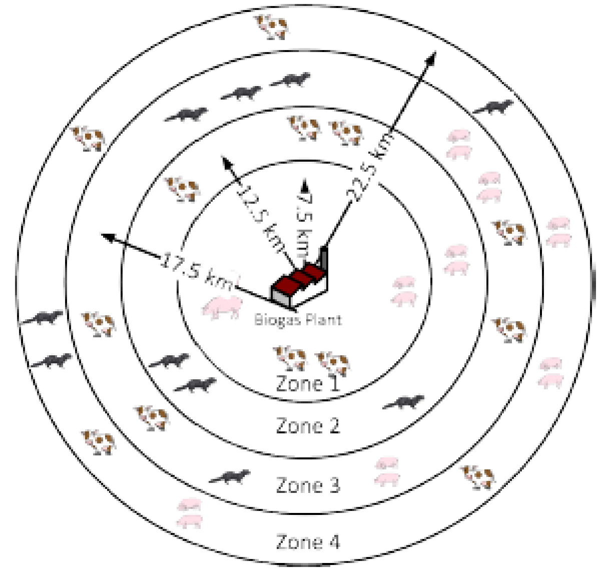
biochain



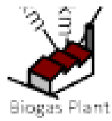
WP1
Value chain optimisation

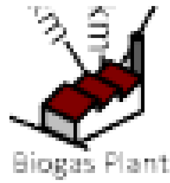
Scale effects – economies of scale

- Collection costs and density of resources
  - trade off between distance and size of resource



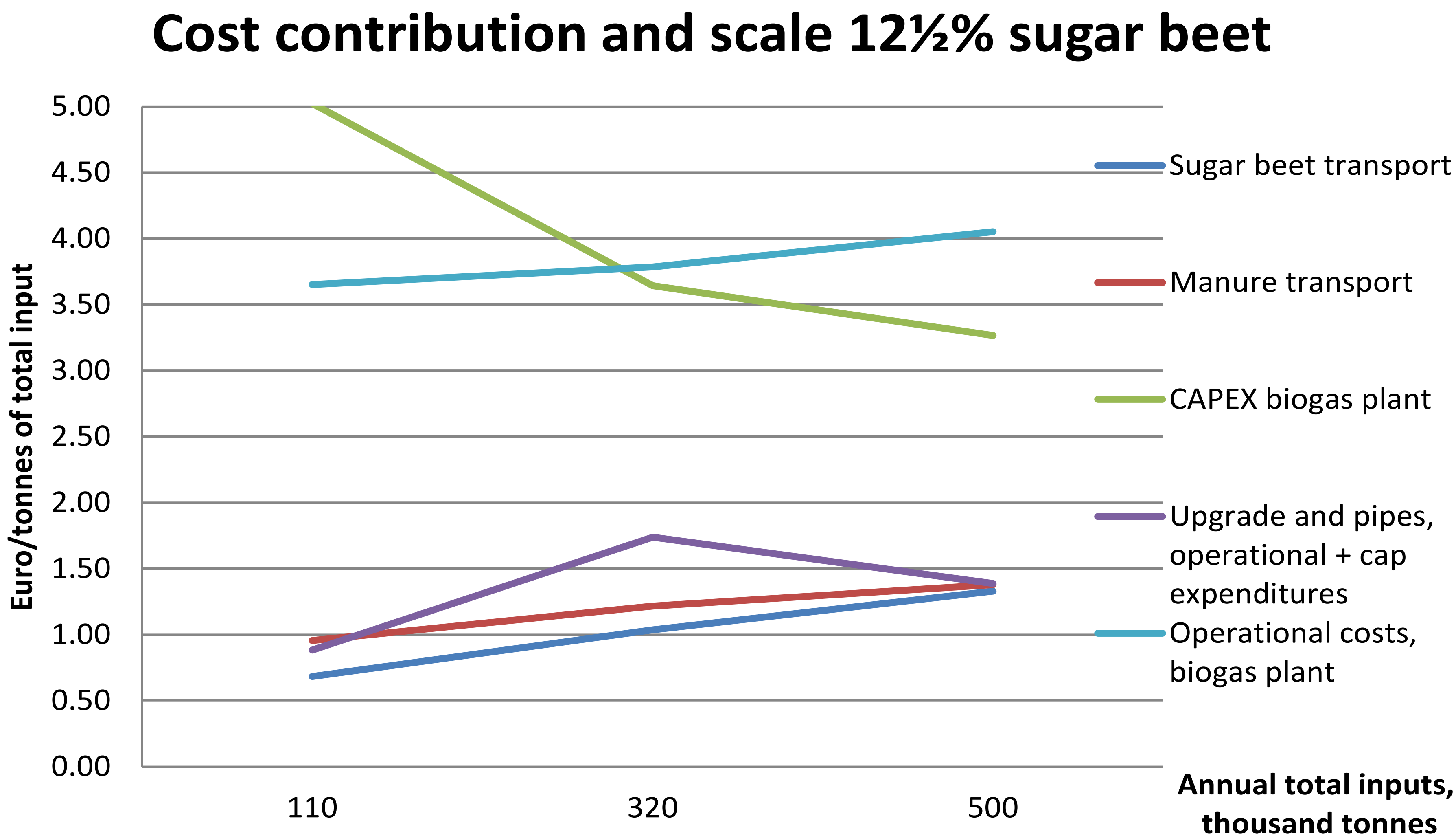
- Scale of biogas plant
  - economies of scale - capex expected





- Scale of upgrading facility and costs
  - storage cost
  - small scale no upgrade
  - large scale upgrade opex and capex

Trade off between rising operational and transport costs against reduced capital costs



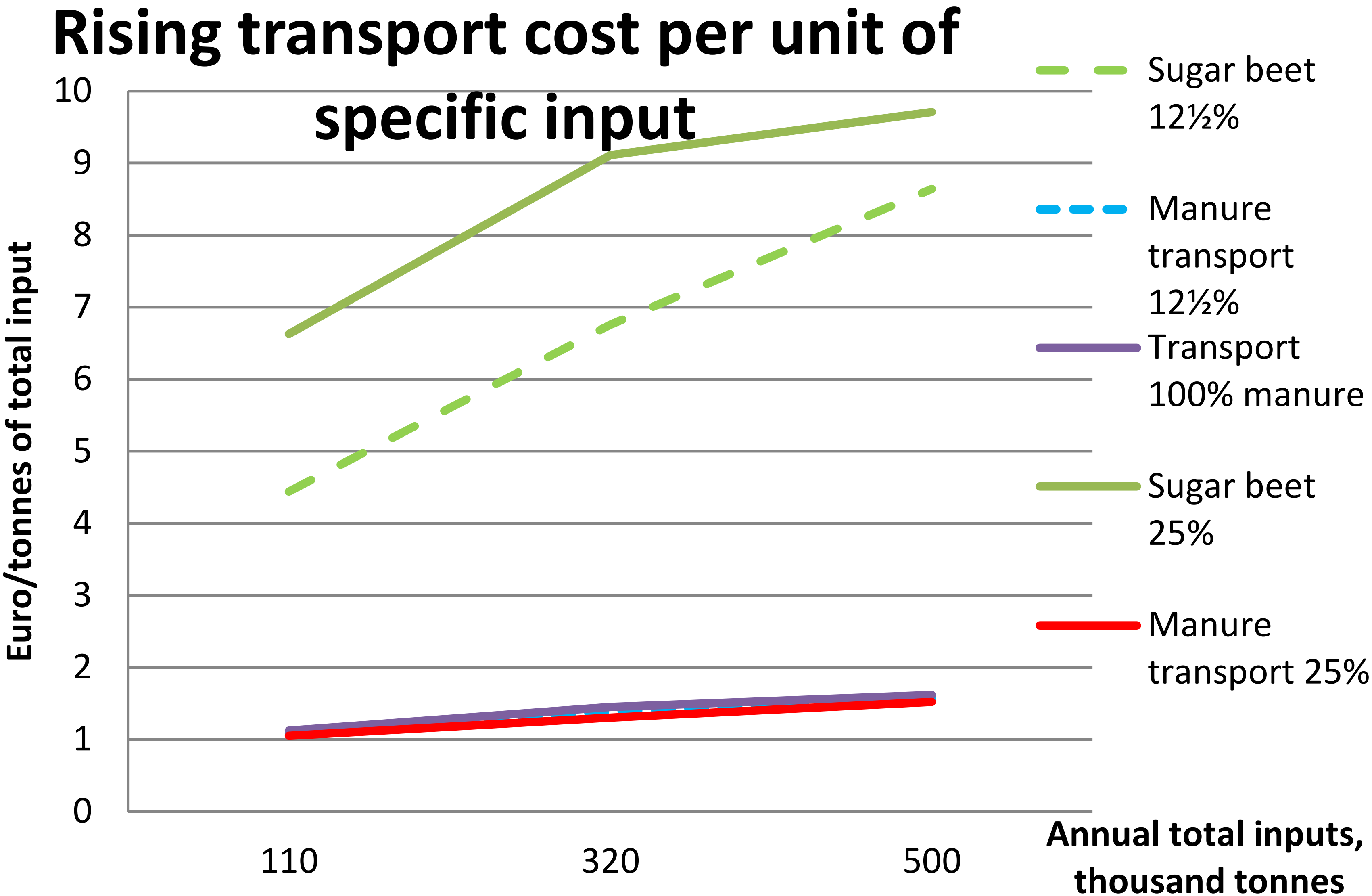
Transport costs: Tree scales of plant size and 3 cases of sugar beet inputs

- **Cost consist of transport time and loading**
  - Loading costs independent of scale but much higher for beet
  - Transport time only dependent on distance (50 km/h)
  - Capacity of beet carrier slightly lower than for manure but hourly costs also lower

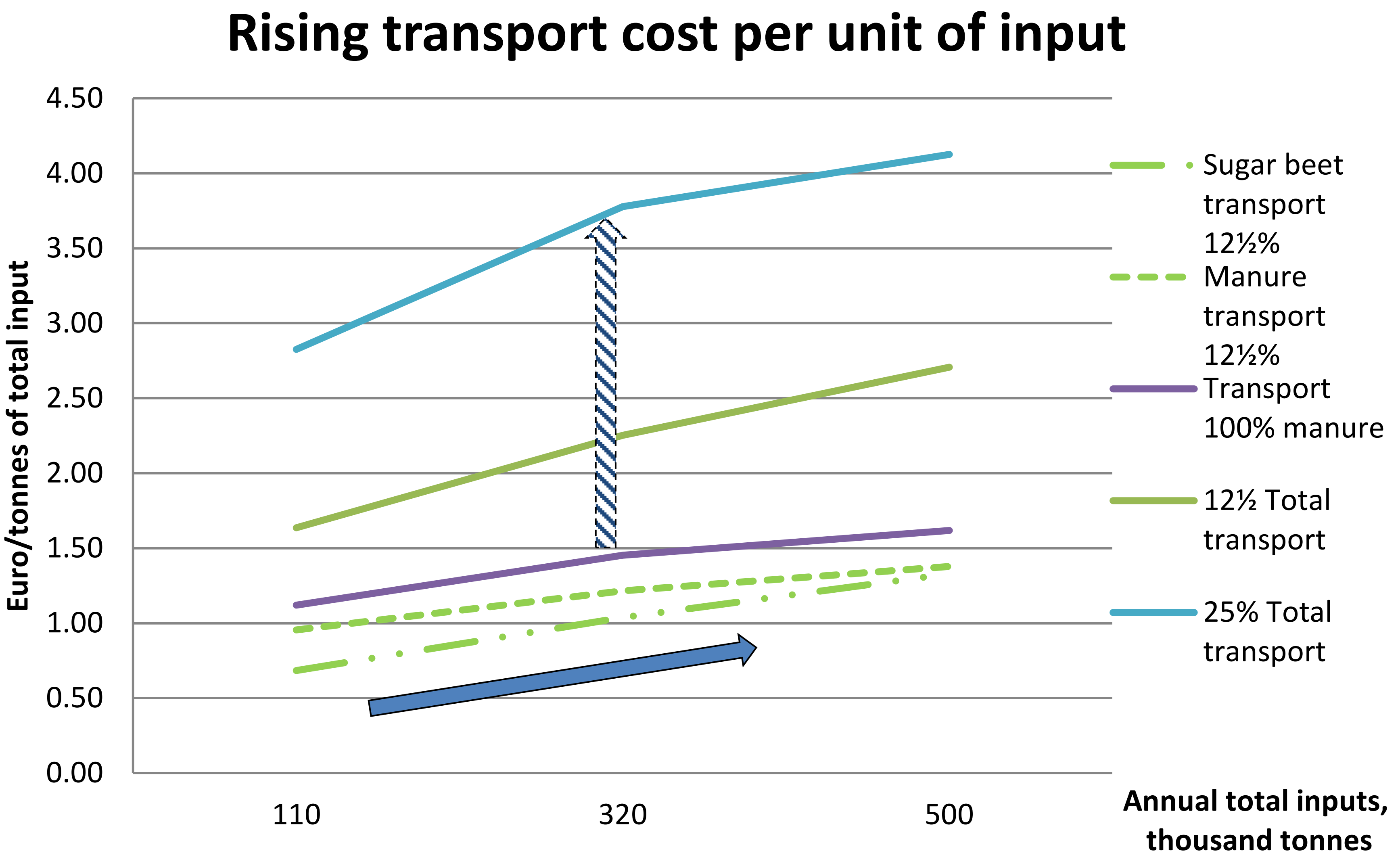
- **Scaling up the plant size**
  - Per unit cost increase for all 3 cases because average transport distance increase: from 6 km to 10 km for manure 100%; from 23 km to 61 km for beet in the 12½% case; and from 43 km to 71 km in the 25% case

- **Increasing the share of beet**
  - With increased beet share the unit cost increase a lot - *since the unit cost for beet transport is much higher than for manure*
  - For high beet share the unit cost also increase faster with larger plant size - *because the effect of inceased transport distance is more pronounced for beet* (especially from 110-320kt)

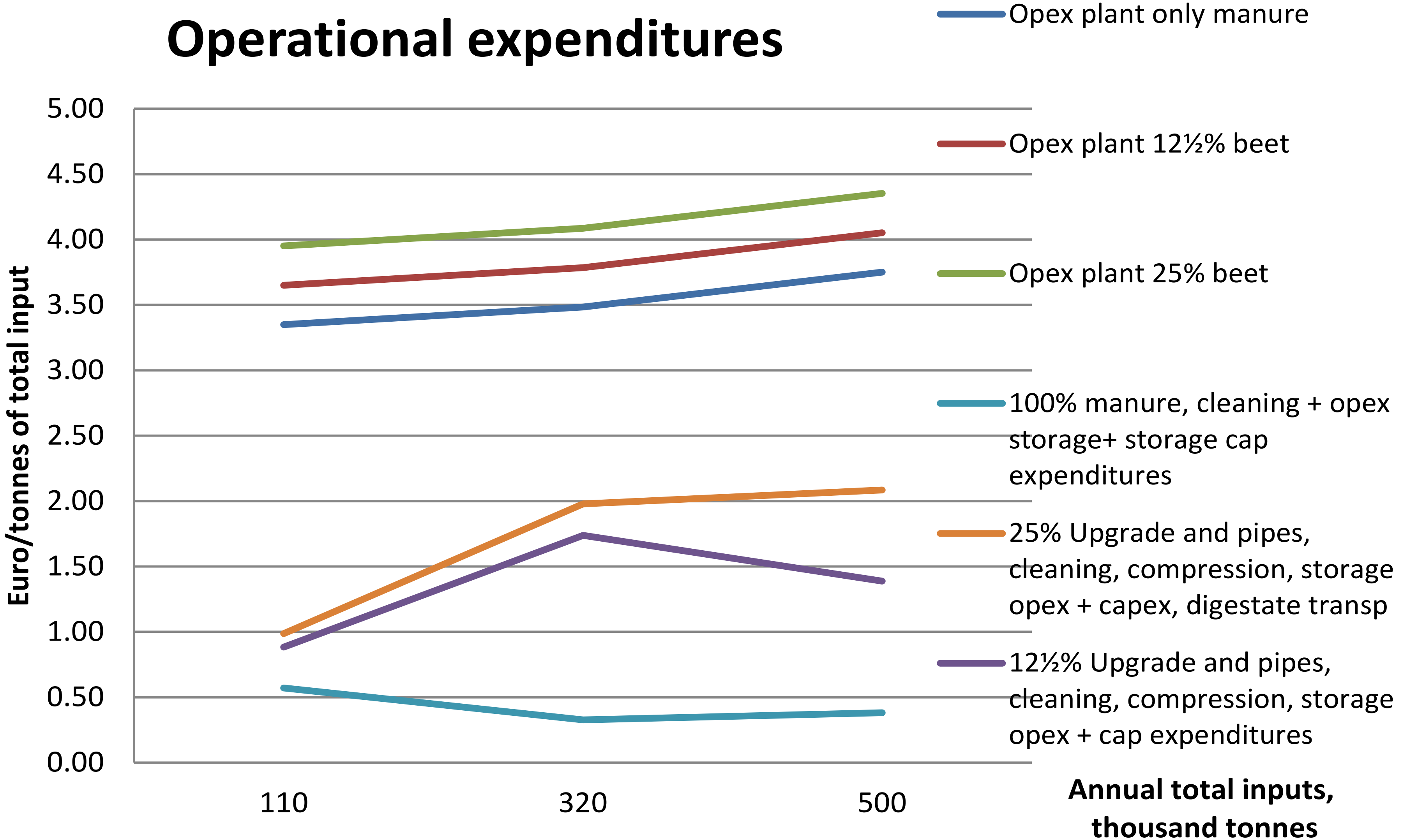
Tree scales of plant size and 3 cases of sugar beet inputs



Tree scales of plant size and 3 cases of sugar beet inputs



Operational expenditures and scale effects



Operational expenditures and scale effects

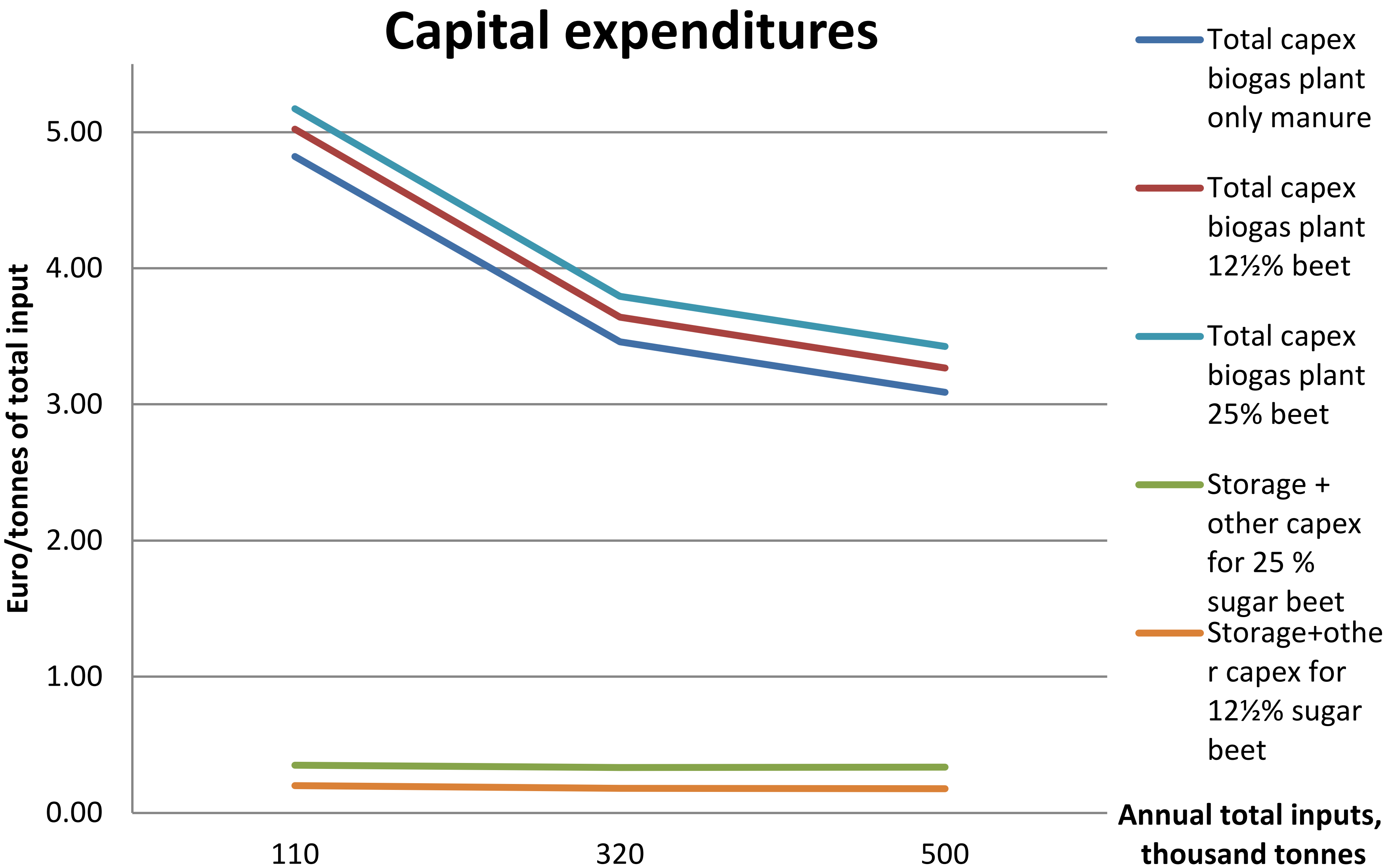
- **Operational costs constitute an important part of total costs**
  - includes wages and salary (also for handling of inputs - transport)
  - includes other material inputs than input to biogas reactor
  - includes process heat and electricty

- **Scaling up the plant size**
  - Scale effects for opex at plant are slightly negative as they increase the unit costs (this deserves more attention/check)

- **Increasing the share of sugar beet**
  - only increases the plant unit costs proportionally for all the plant sizes

- **Scaling up plant size involves additional opex at output level**
  - cleaning of gas, storage very little for pure manure
  - cleaing, upgrade and compression (losses) increase when scale shifts to upgrade for natural gas grid
  - shift involve negative scale effect - but from 320 to 500kt positive scale effect for 12½% sugar beet (due to capex of upgrade facility)

Capital expenditures and economies of scale



Capital expenditures show large economies of scale effects

- **Plant size and capex**
  - Economies of scale primarily achieved for this cost component
  - Largest effect from 110 - 320kt size
  - This scale effect outweigh the negative scale effects from transport costs and the slightly negative effect from opex

- **Increasing the share of sugar beet**
  - adds a proportional cost per unit due to investment in storage and pretreatment/handling equipment
  - no cost advantages or disadvantages of scale in this investment (could be further investigated)

Sensitivity and main parameters

- **Transport costs**
  - Concentration of input resources in general - farm structure and economic conditions
  - Sugar beet will be cultivated closer to plant in time
- **Input costs**
  - Price of manure - uncertainty high and regulation dependent (environmental, animal restrictions)
  - Price of sugar beet - dependent on alternative use (biofuel) and cost of alternatives (for cattle etc.) - world market links
- **Output**
  - Volume - uncertainty of given process should be low? at annual output level
  - Price of gas - for upgraded quantity the uncertainty in this 1/3 of revenue is high
  - Price support - if granted/approved it is stable
  - Price digestate etc. - high uncertainty

Scale effect in total

All costs, Euro/Tonnes			
Ratio\Scale	**110**	**320**	**500**
0/100	15.89	14.75	14.87
12½/87½	20.69	20.91	20.91
25/75	25.90	26.60	26.95

The cost advantage from capex declining is outweighed by rising operational and transport costs

Scale effect conclusion

- Cost reducing effect in scaling biogas plant size 110 00 to 500 00 tonnes (capex per input unit is reduced 35%, 0/100 mix)
- Negative scaling effect for transport costs (increase 45% for manure and 96% for sugar beet)
- Net effect (trade-off) result in equal costs per unit of the 320 000 t case and the 500 000 t case:
  - the benefit of scaling to 500 000 t (biogas plant capex + upgrade plant capex) is outweighed by the increase in transport costs

Positive scale effects are only dominating the net result for the pure manure case

Overall economic results

Net-income, Euro/Tonnes			
Ratio\Scale	**110**	**320**	**500**
0/100	-0.42	0.72	0.78
12½/87½	3.99	**4.23**	**4.23**
25/75	-4.34	-4.68	-5.03

Table 1 Net annual result per tonnes of inputs

The case with the highest profit is the 12½ % sugar beet case with a capacity of 500000 tonnes even though there are no particular scale effect here

Logistic of Biogas Production

PARTNER I DLBR

Logistic in production of biogas

How is production, transport and storage optimized?

Many parameters need optimization and coordination

VIDENCENTRET FOR LANDBRUG

Wheat straw as an example:

Straw bale or briquette?

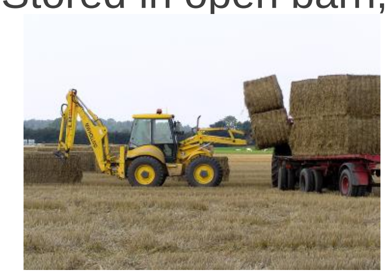
Transport in field/on road?

Loading/unloading?

Stored in open barn, closed barn, silo, container?

Density 0.2T/m^3

Ø= 7-9 cm
Density 0.5 T/m^3



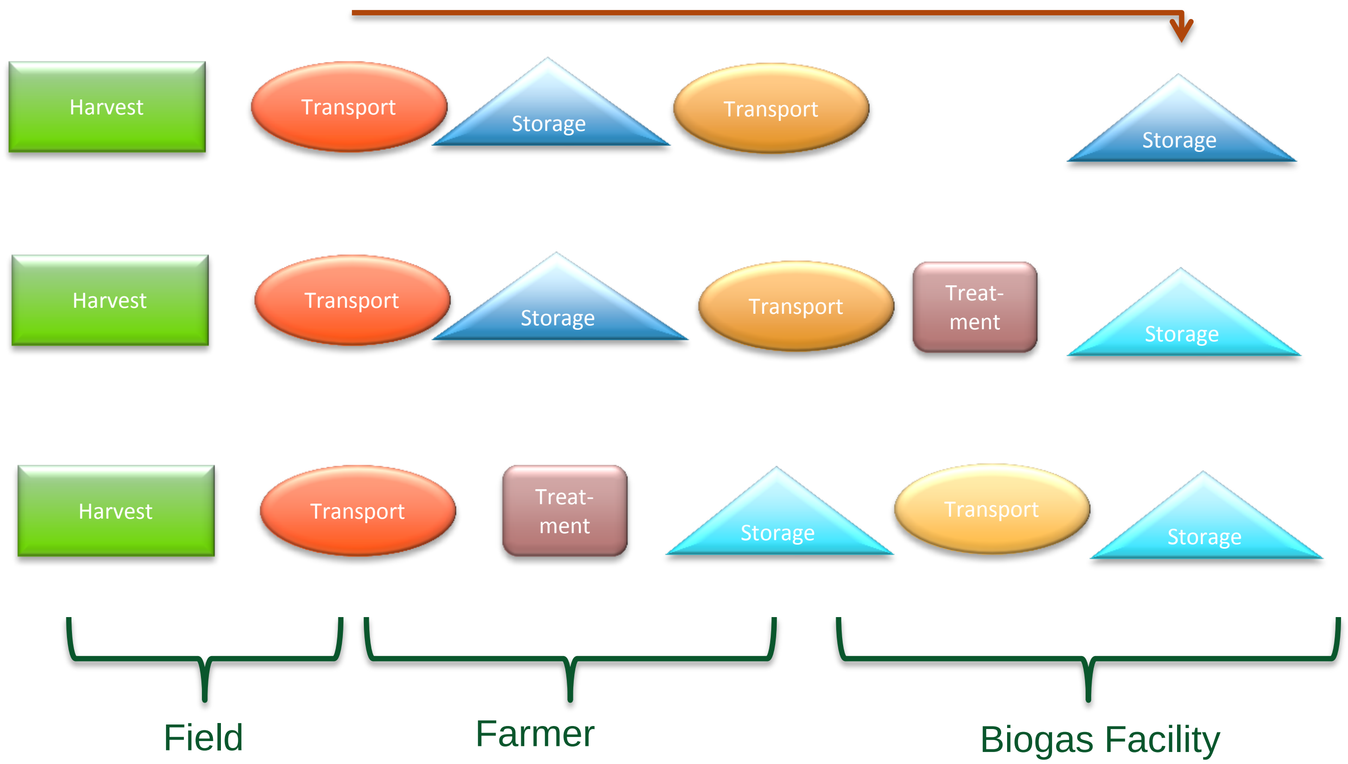
Logistic in production of biogas

How can all these parameters be optimized?

Which parameters inflict most on economy?

This calls for a model !!!

Identification of value chains



VIDENCENTRET FOR LANDBRUG

Example: Wheat straw, Data entry sheet

Entry for straw

Yield		
Yield	676	ton
Cultivated area	200	ha.
Yield per hectare	3,38	ton/ha.
Dry matter	85%	
Organic matter - VS/TS	95%	
Methane potential		
Straw	230	L CH_4/kg VS
Extruded straw	277	L CH_4/kg VS
Briquetted straw	277	L CH_4/kg VS
Field expenses		
Raking	0	kr./ton
Baling	-145	kr./ton
Distance to farmer/barn		
Distance	0,5	km
Tractor equipped with frontloader & 2 bale trailers	-650	kr./hr.
Capacity	20	bales/load
Loading rate, field	2,7	min/ton
Loading rate, stock	2,1	min/ton
Farm loading		
Tractor with frontloader		
Tractor with frontloader	-650	kr./hr.
Loading rate	2,07	min/ton

These entries are locked

- Can be changed in a separate sheet if need be

VIDENCENTRET FOR LANDBRUG

Example: Wheat straw, Data entry sheet

Entry for straw

Yield		
Yield	676	ton
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Capacity	20	bales/load
Loading rate, field	2,7	min/ton
Loading rate, stock	2,1	min/ton
Farm loading		
Tractor with frontloader		
Tractor with frontloader	-650	kr./hr.
Loading rate	2,07	min/ton

White boxes signify required user input

Example: Wheat straw, Data entry sheet

End product

Ekstruded straw ▼

Choose end product

Extruding expenses

Extruder, mixer, conveyor	-5.500.000	kr.
Capacity	10.000	ton/yr
Operation and maintainance	-99	kr./ton
Insurance	-50.000	kr./yr
Service life	10	yr

End product

Briquetted straw ▼

End product

Straw bales ▼

Farm storage

Open barn ▼

Barn, concrete floor ▼

Barn, gravel floor ▼

Barn, concrete floor, briquettes ▼

Choose type and size of storage at farm and at facility

Example: Wheat straw, Comparison sheet

Wheat straw calculator

End product:	Straw bales	
Expected costs:		
Baling and raking	-145	kr./ton
Farm storage	-349	kr./ton
Plant storage	-267	kr./ton
Transport	-211	kr./ton
Pretreatment	-	kr./ton
Cost per ton	-972	kr./ton
Total cost	**-657.402**	**kr.**
Expected income:		
Energy yield	2.185	kWh/ton
- Electricity	874	kWh/ton
- Heat	1.093	kWh/ton
Income from electricity	970	kr./ton
Income from heat	273	kr./ton
Income per ton	1.243	kr./ton
Total income	**840.447**	**kr.**
Difference, kr	**183.045**	**kr.**

Decentral briquetting

End product	Briquetted straw	
Expected costs:		
Baling and raking	-145	kr./ton
Farm storage	-42	kr./ton
Plant storage	-356	kr./ton
Transport	-181	kr./ton
Pretreatment	-1.001	kr./ton
Cost per ton	-1.725	kr./ton
Total cost	**-1.166.294**	**kr.**
Expected income:		
Energy yield	2.632	kWh/ton
- Electricity	1.053	kWh/ton
- Heat	1.316	kWh/ton
Income from electricity	1.168	kr./ton
Income from heat	329	kr./ton
Income per ton	1.497	kr./ton
Total income	**1.012.191**	**kr.**
Difference, kr	**-154.103**	**kr.**

Example: Wheat straw Print sheet

Economy : Straw to Biogas

Printet		27-10-2014
Harvest		
End product	Briquetted straw	
Cultivated area	200 ha.	
Transport: Field to farmer	0,5 km with Tractor & frontloader	
Transport: Farmer to facility	60 km with Truck & trailer	
Loading equipment	Telescopic loader at farm, Tractor with frontloader at facility	
Yield		
Yield	3,38 Ton/ha.	
Dry matter	89%	
Ash	3%	
Gas potential	277 L CH4/kgVS	
Gas yield	805 m3 CH4/ha.	
Storage		
Storage needed	4225 m3 bales or 1502 m3 briquettes	
Farmer site, storage	Open barn, 5000 m3	
Facility, storage	Barn with concrete floor, 5000 m3 *Note: Storage facility used for multiple purposes*	
Pretreatment		
Briquetting		
Cost, yearly	-kr. 626.590	
Hereof, paid by straw	6 % (straw) and 80 % (other)	
Economy		
Expected costs	kr.	-542.137
Expected yield	kr.	916.298
Difference	kr.	374.162

Print sheets can be used to compare costs

Produktionsomkostninger for enggræs til biogas

Udskrevet d. 22-10-2014

Høstmetode	
Færdigt produkt	Ingen forbehandling
Transport til landmand	Dækket af høstomkostninger
Transport udover 12 km	5 km med Traktor med halmvogn
Maskiner anvendt til høst	Pistemaskine
Maskiner anvendt til læsning	Skal ikke omlæsses
Udbytte	
Areal	12 ha.
Udbytte	69,6 Ton/ha.
Tørstofindhold	80%
Askeindhold	5%
Gaspotentiale	234 L CH4/KgVs
Gasudbytte	1017 m3 CH4/ha
	Bemærk: Gasudbytte afhænger af græsblanding og høsttidspunkt
Lagring	
Lagerbehov	249 stk rundballer
Valgt lagringsmetode	Baller under presenning
	Bemærk: Kun lagret på anlæg
Forbehandling	
Ikke valgt	
Økonomi	
Omkostning, landmand	-108 øre/kgTS

Forventet omkostninger	kr.	-59.685
Forventet udbytte	kr.	69.502
Difference	kr.	9.817

Produktionsomkostninger for enggræs til biogas

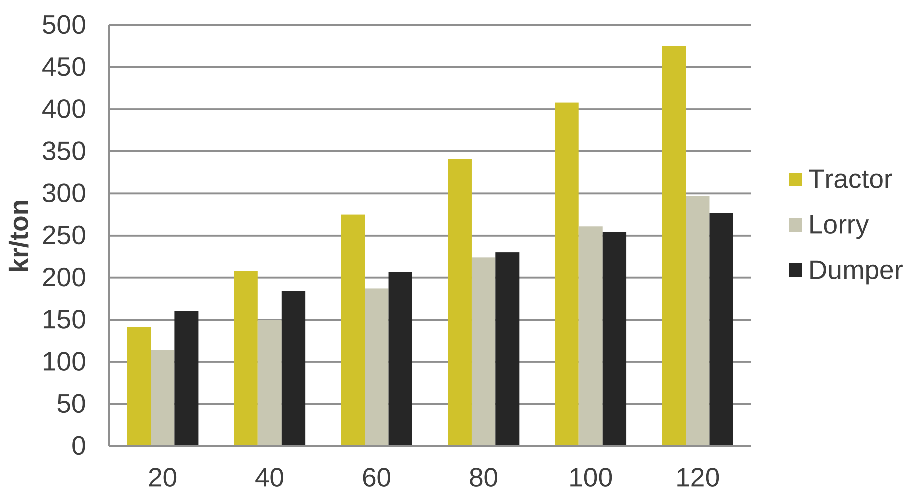
Udskrevet d. 21-10-2014

Høstmetode	
Færdigt produkt	Ingen forbehandling
Transport til landmand	Dækket af høstomkostninger
Transport udover 12 km	5 km med Traktor med halmvogn
Maskiner anvendt til høst	Pistemaskine
Maskiner anvendt til læsning	Skal ikke omlæsses
Udbytte	
Areal	12 ha.
Udbytte	69,6 Ton/ha.
Tørstofindhold	80%
Askeindhold	5%
Gaspotentiale	234 L CH4/KgVs
Gasudbytte	1017 m3 CH4/ha
	Bemærk: Gasudbytte afhænger af græsblanding og høsttidspunkt
Lagring	
Lagerbehov	249 stk rundballer
Valgt lagringsmetode	Ingen lagring/lagring i det fri
	Bemærk: Kun lagret på anlæg
Forbehandling	
Ikke valgt	
Økonomi	
Omkostning, landmand	-80 øre/kgTS

Forventet omkostninger	kr.	-44.025
Forventet udbytte	kr.	69.502
Difference	kr.	25.477

Use of model to calculate transport costs

Case: Straw is transported from the field to the farmer and further to the facility. It can be transported directly from the farmer to the facility as bales or 17 km as bales to a local briquetting station and then further to the facility. Briquettes are transported using a dumper. Cost includes transport as bales and loading/unloading of bales/briquettes.



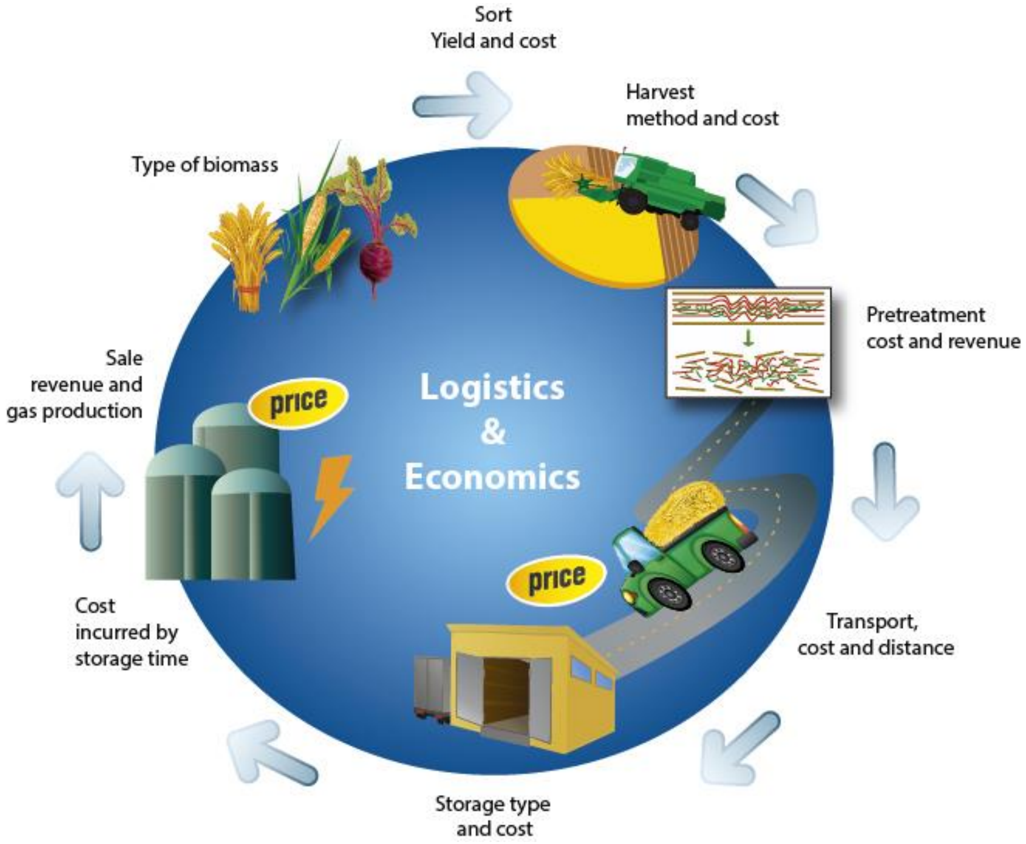
	Tractor	Lorry	Dumper
Kr./hr	550	625	650
Load	24 bales	24 bales	22 ton
Km/hr.	25	52	52

Cost calculations – questions answered by the model

- ”How is cost affected if…”
  - Another type of storage is chosen?
  - The methane potential increases?
  - The straw is pretreated?
  - Beets are produced instead of maize?
  - The distance to the facility changes?
  - Straw is briquetted locally instead of at the facility?
  - Electricity cost changes?
  - Trucks are used for transport instead of tractors?

- 50-100 parameters can be varied for each crop
- The outcomes can easily be compared

WP5: Logistics & Economics



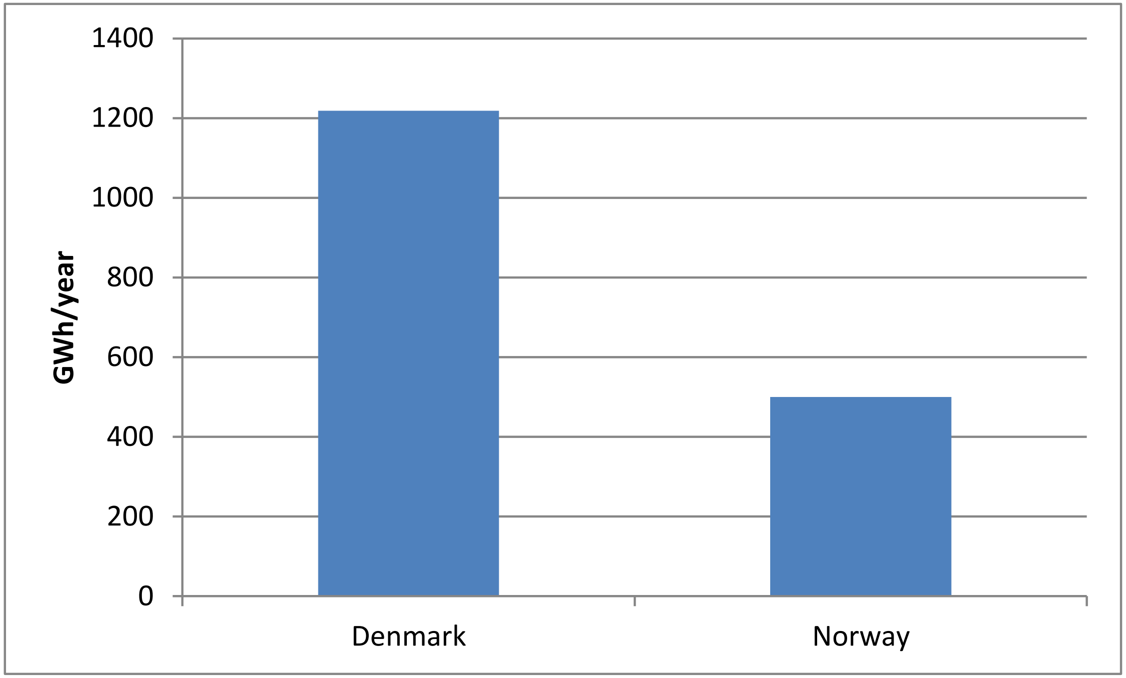
Comparative assessment of framework conditions for biogas production in Norway and Denmark

Kari-Anne Lyng, Østfoldforskning
Henrik Klinge Jacobsen, DTU

Østfoldforskning

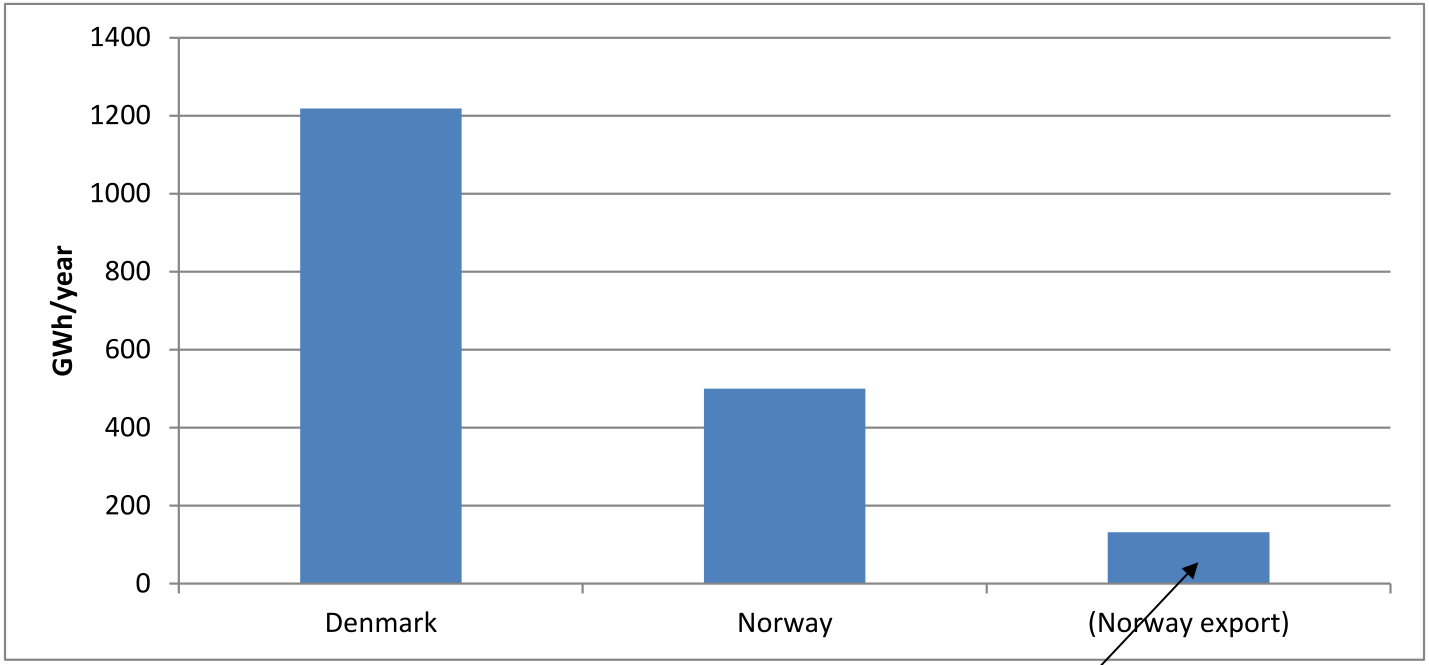
SUSTAINABLEINNOVATION

Biogas production in Norway and Denmark



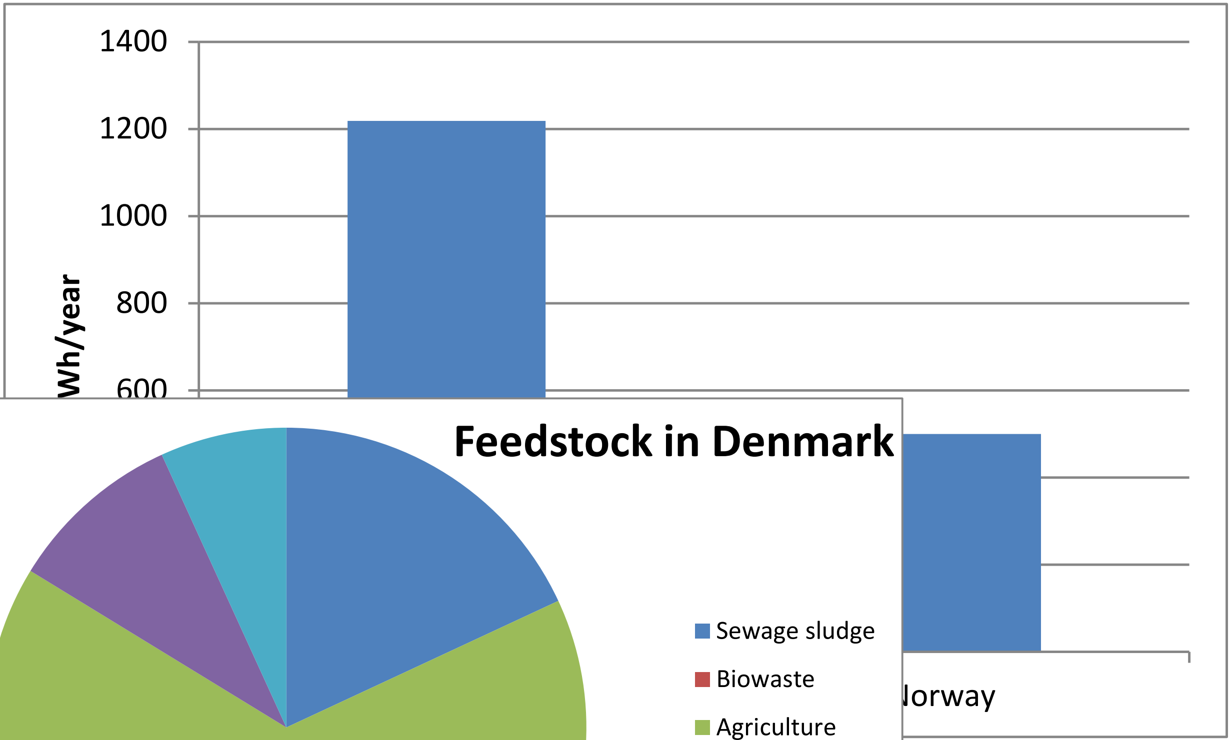
Ref: IEA task 37
2013

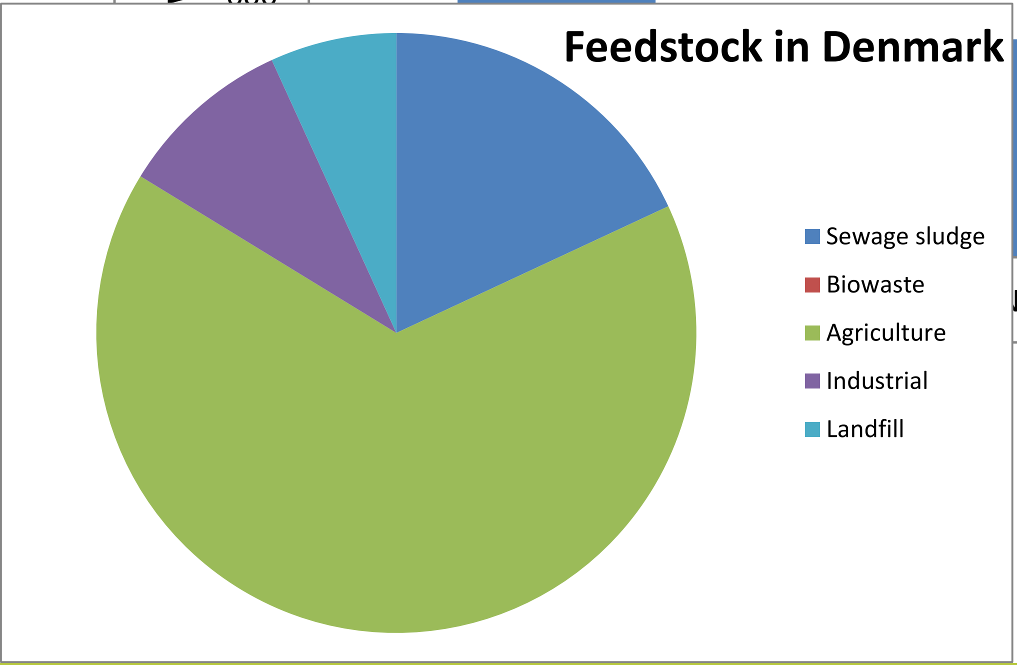
Biogas production in Norway and Denmark



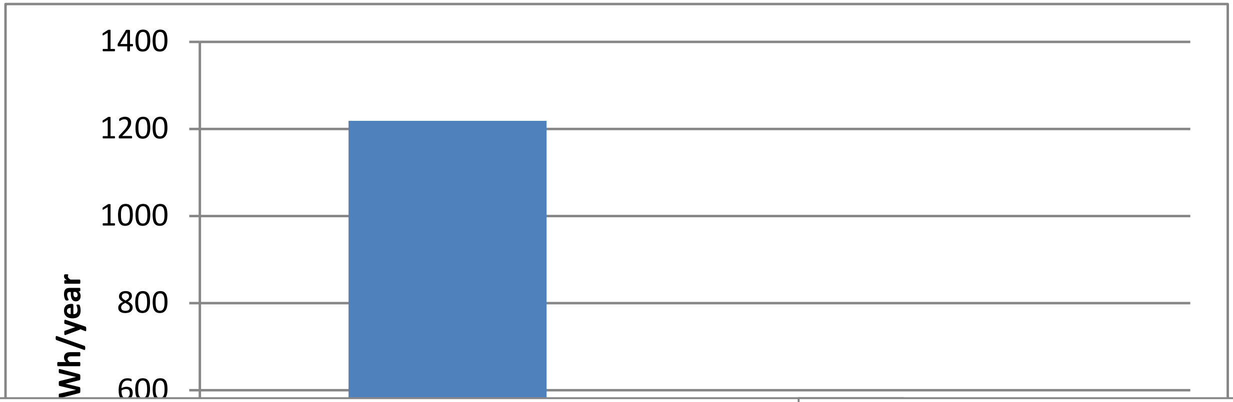
Export of organic waste

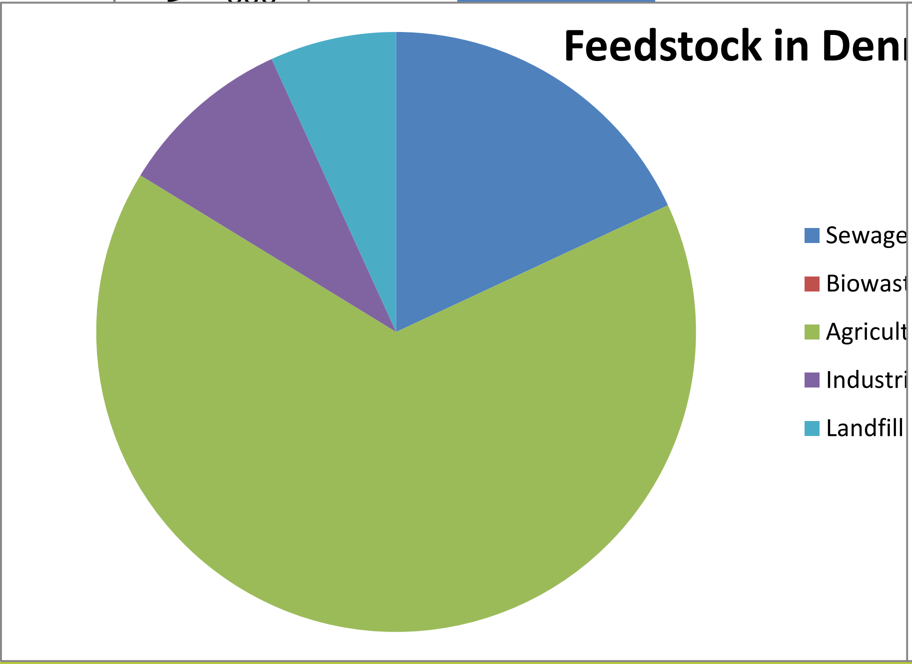
Biogas production in Norway and Denmark

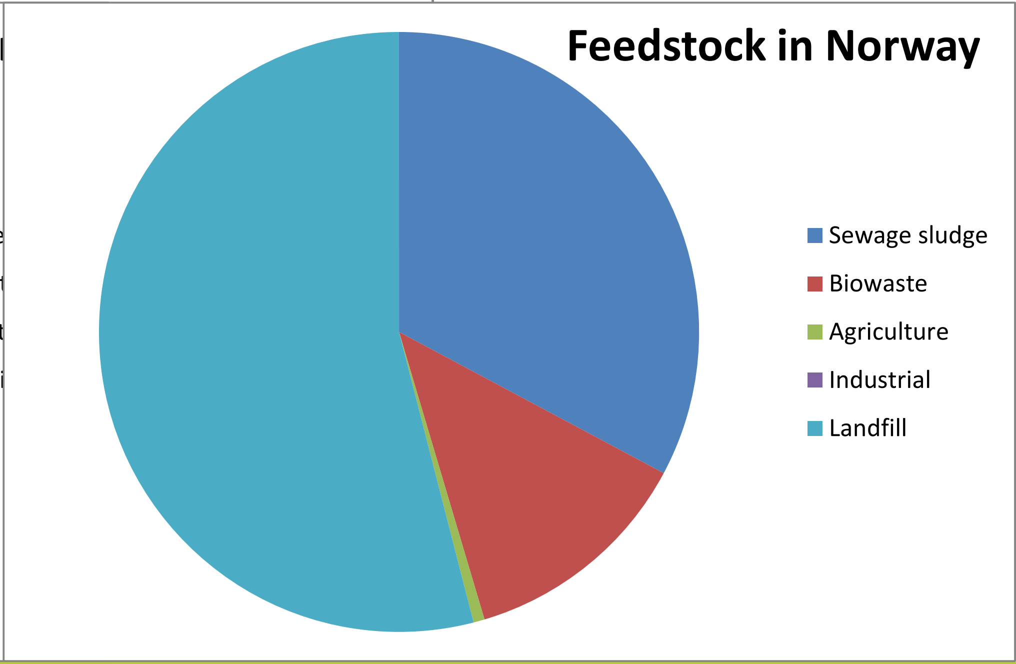




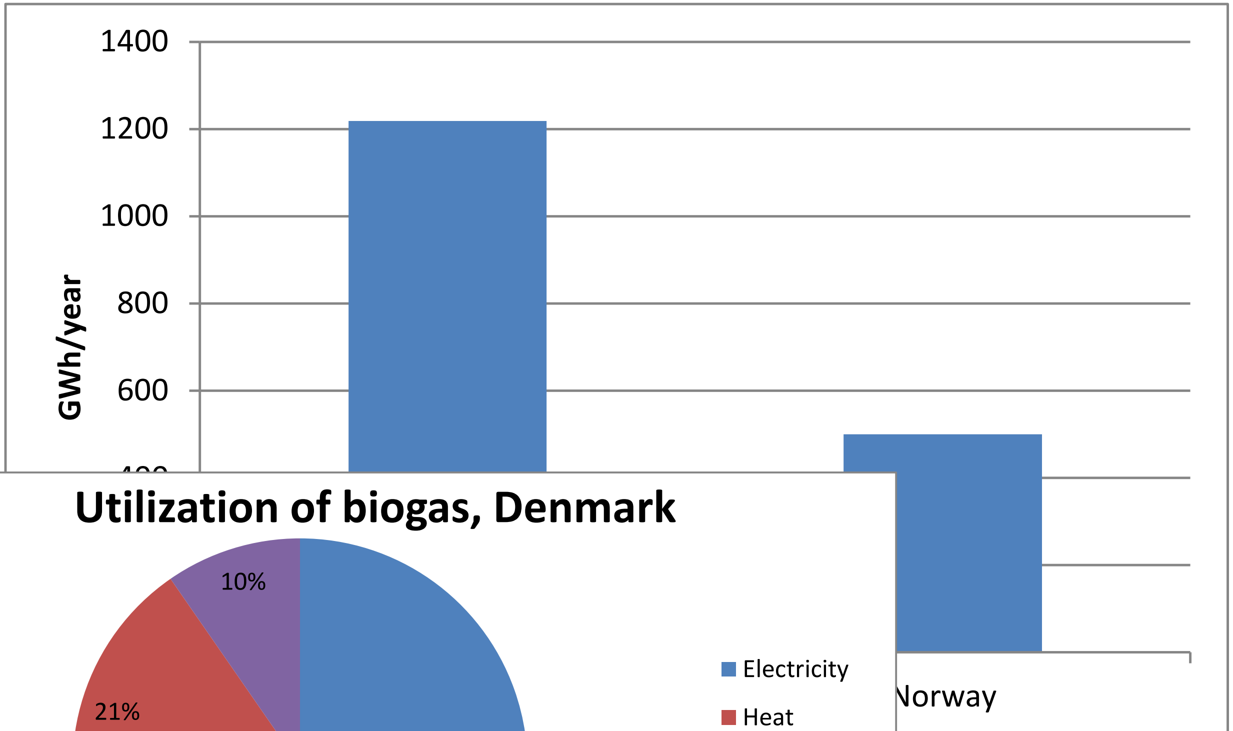
Biogas production in Norway and Denmark

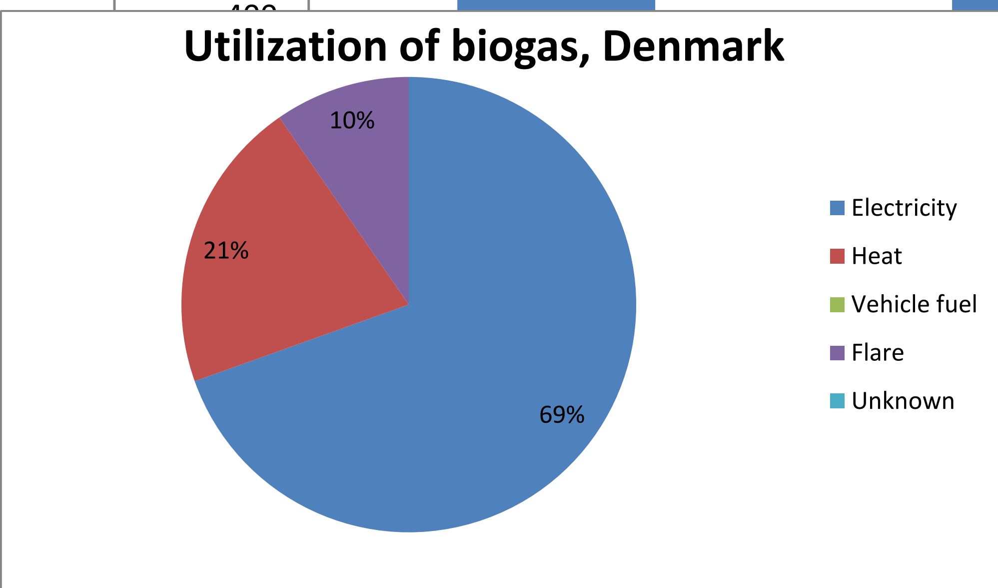




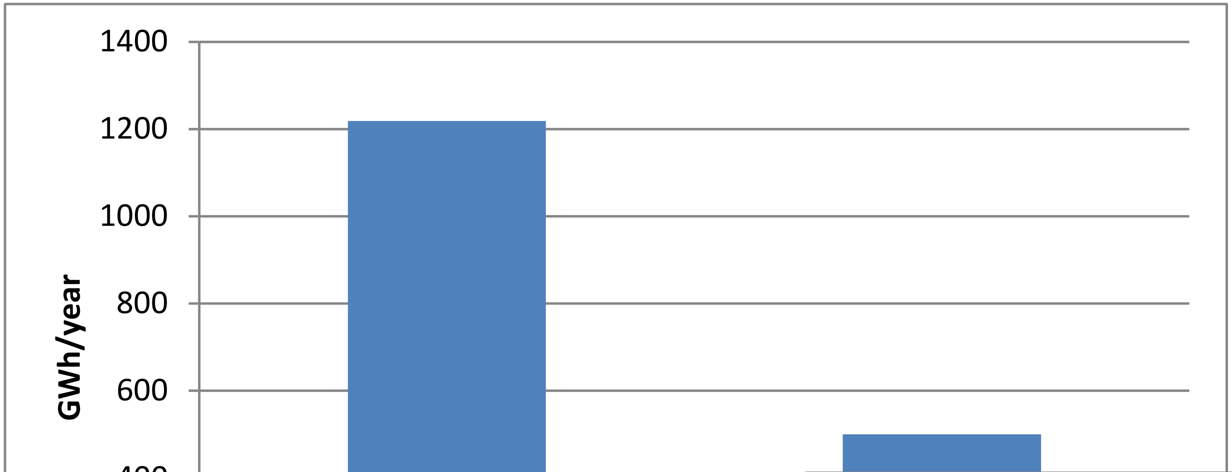


Utilization of biogas

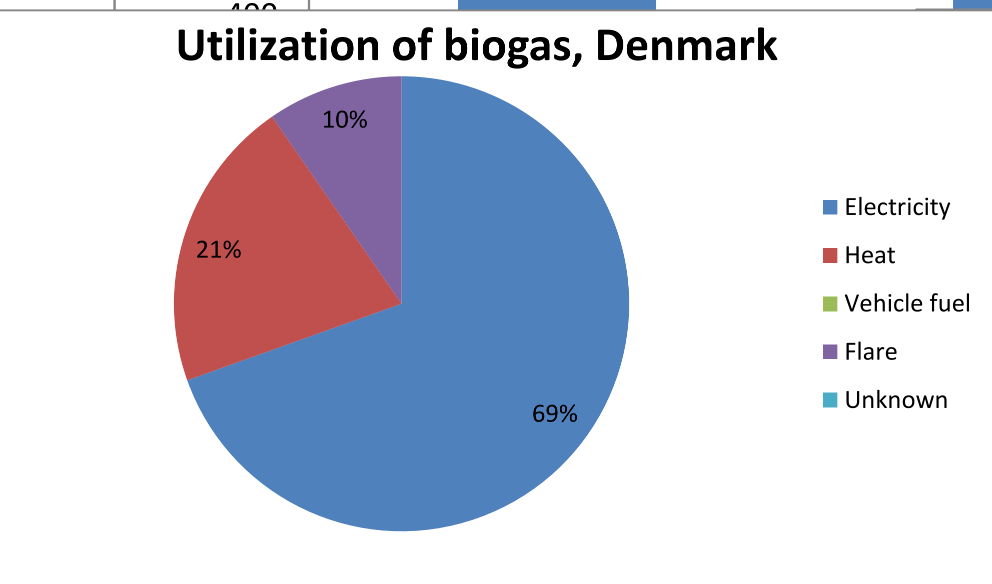


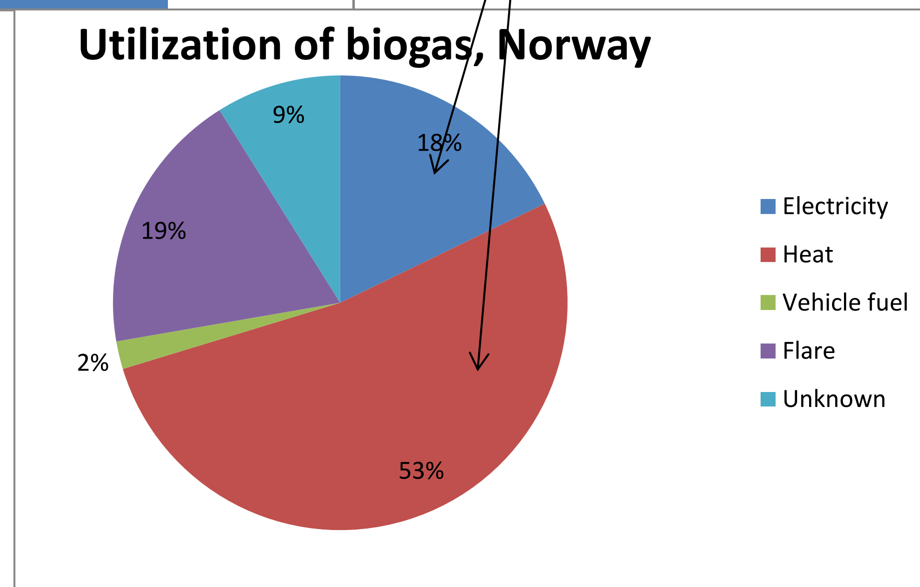


Utilization of biogas



Approximately 60 % of the biogas is used at the production plants





Utilization of digestate

No statistics found

General impression:

- Denmark: Fertilizer

(restrictions on sewage sludge)

- Norway: Normally dewatered and composted

  New plants: Fertilizer

Framework conditions

- Demography (logistics) and population density

Norway: 13 inhabitants/km^2

Denmark: 128 inhabitants/km^2

- Farm sizes

Average livestock units per farm

Norway: Small farms: 23 Large farms: 61

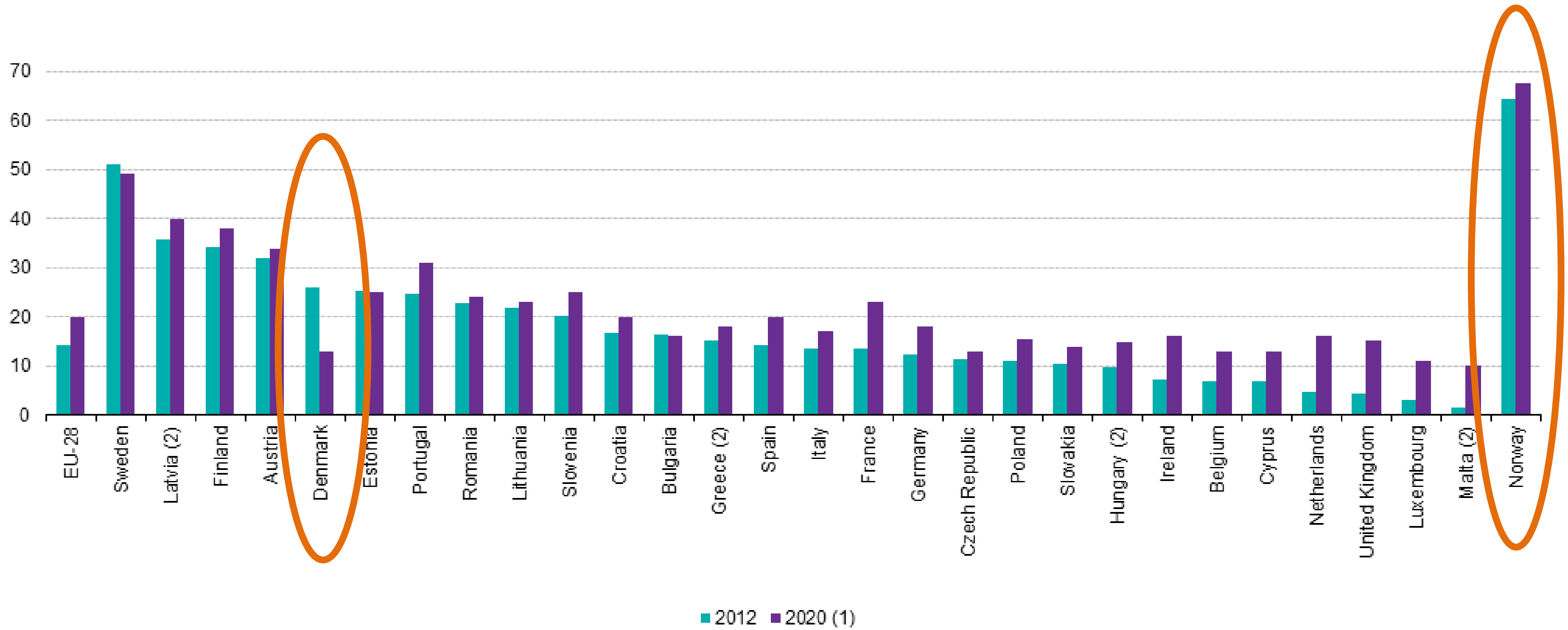
Denmark: Small farms: 86 Large farms:681

- Organic waste

Norway: about 2/3 of inhabitants have source separation of organic waste

Denmark: ?

Share of renewables in gross final energy consumption, 2012 and 2020 (%)

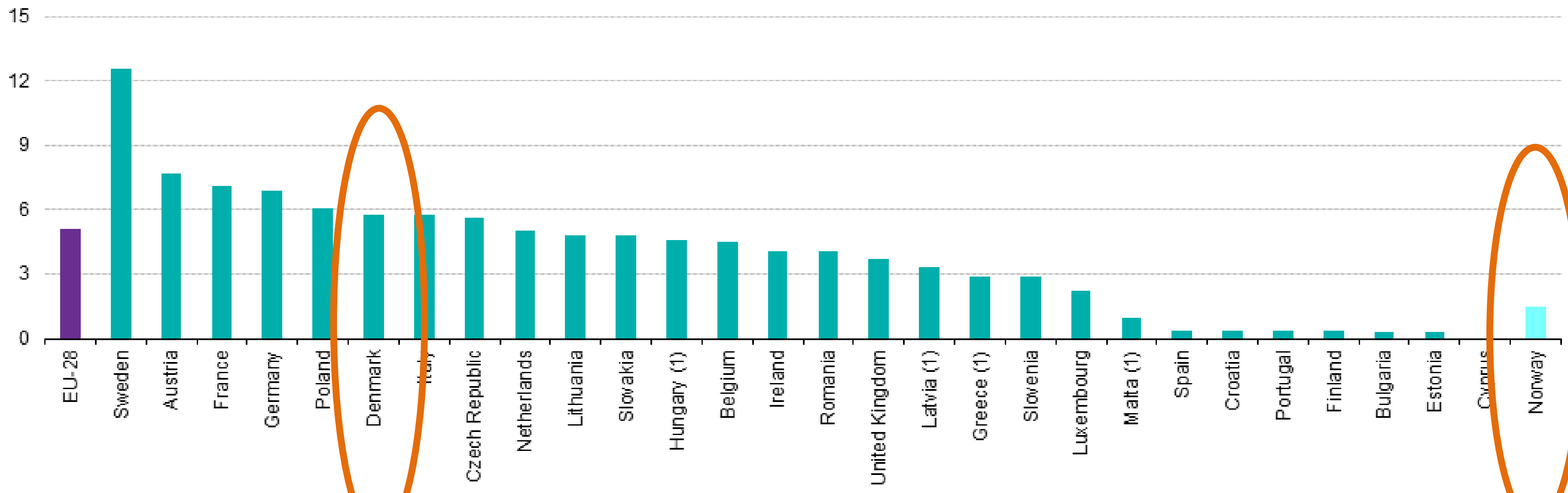


([1]) Legally binding targets for 2020.

([2]) 2012: estimate.

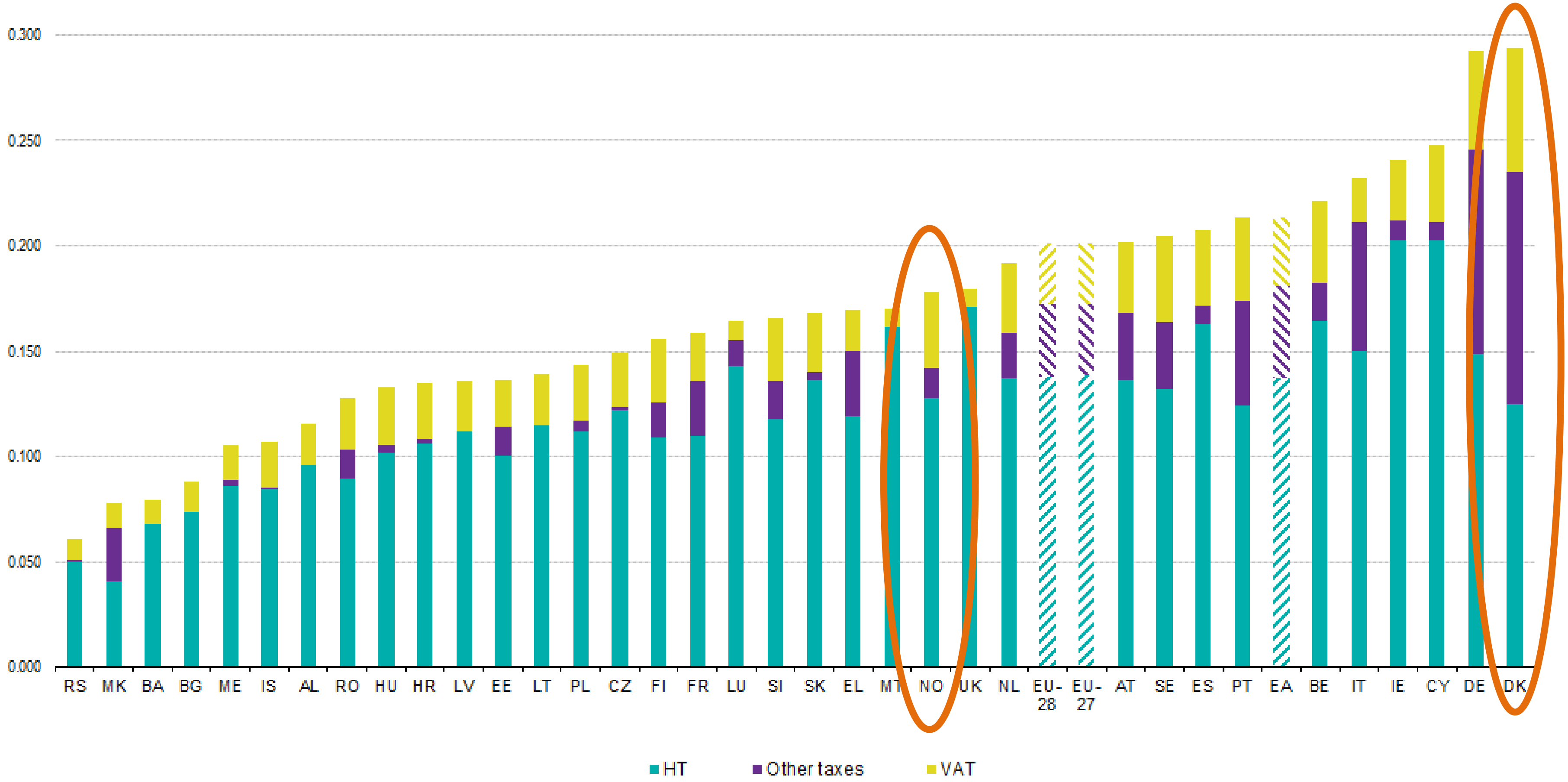
Source: Eurostat (online data code: t2020_31)

Share of renewable fuels for transport



([1]) Estimate.
Source: Eurostat (online data code: tsdcc340)

Electricity prices for households consumers 2013



Ref:Eurostat

Transport fuel prices

Financing the biogas support in DK

- Support to biogas for CHP is provided as support for the electricity output, which is financed via the PSO payments of all electricity consumers - *main driver*
- Support to upgraded biogas will be financed via PSO payments of all natural gas consumers - *main driver*
- Investment support for manure based biogas plants is financed by the government budget (only temporary *main driver*)

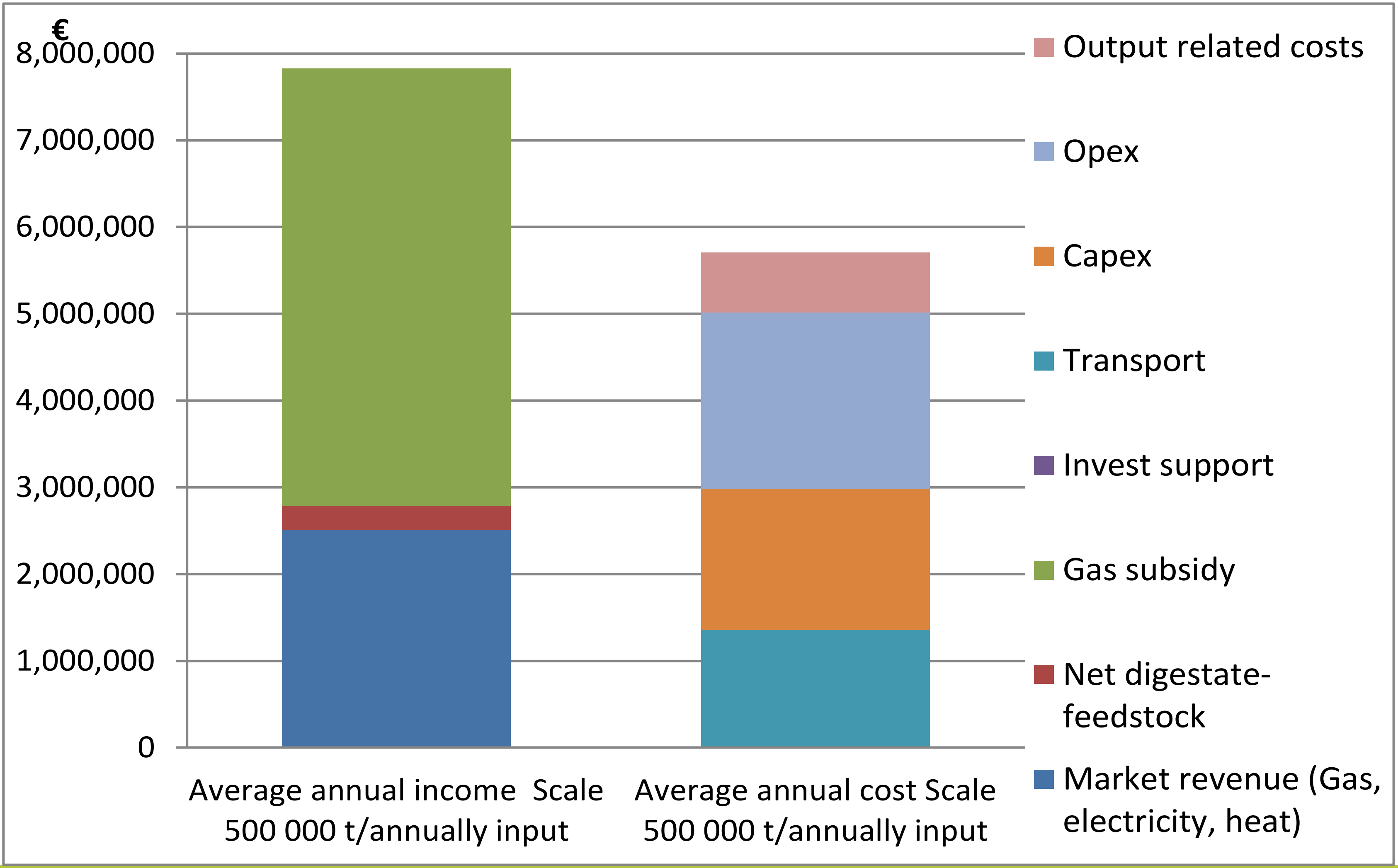
- Indirect support is provided through the regulation of farmers input use and manure treatment (manure, fertilizer, nitrogen, phosphor) - *minor effect*

Regulatory incentives in Norway

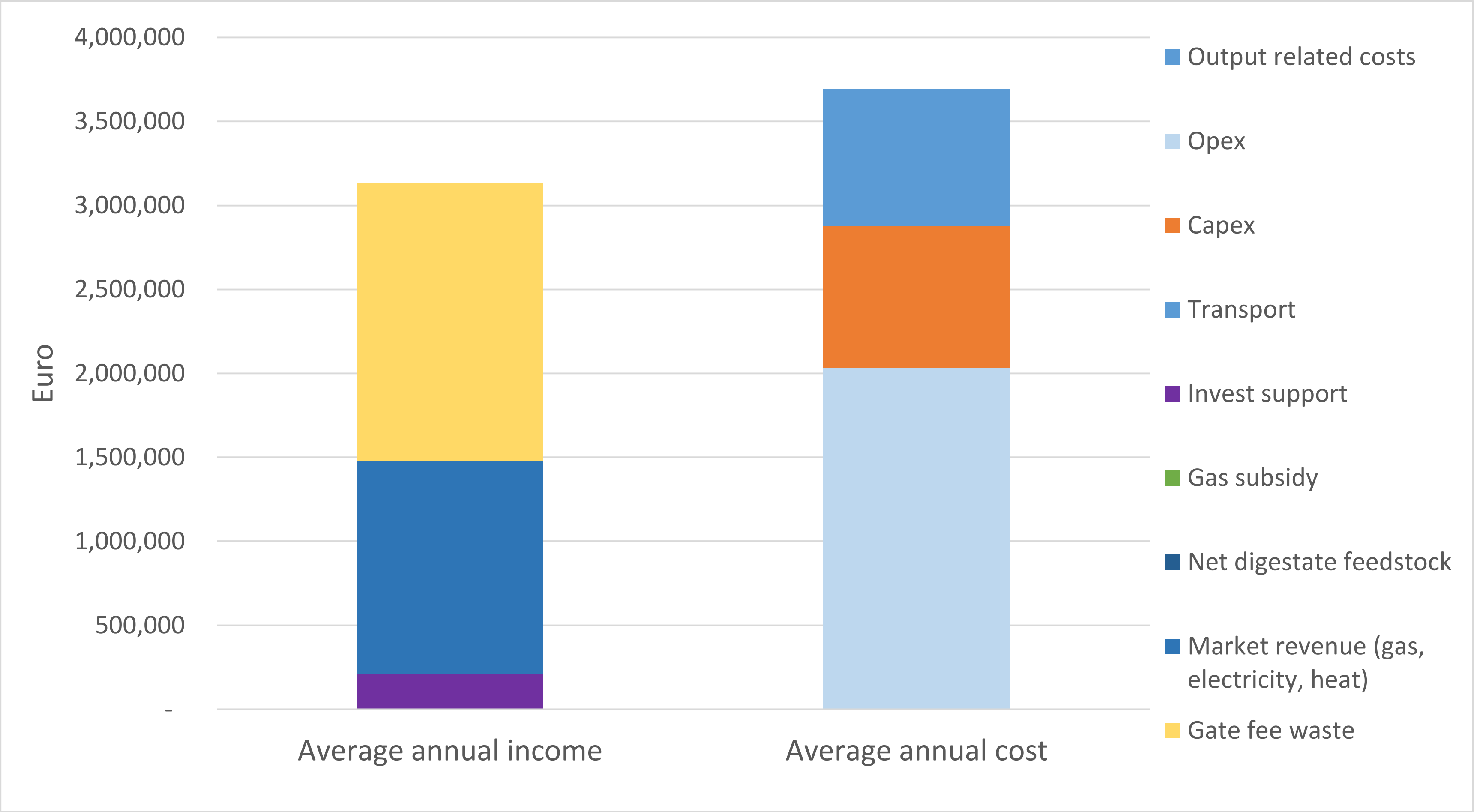
- Banned landfilling of biodegradables from 2009.
- Investment support for biogas plants
- Tax exemption for transport purposes

- Local initiatives: Østfold County tender for bus transport: Biogas as fuel

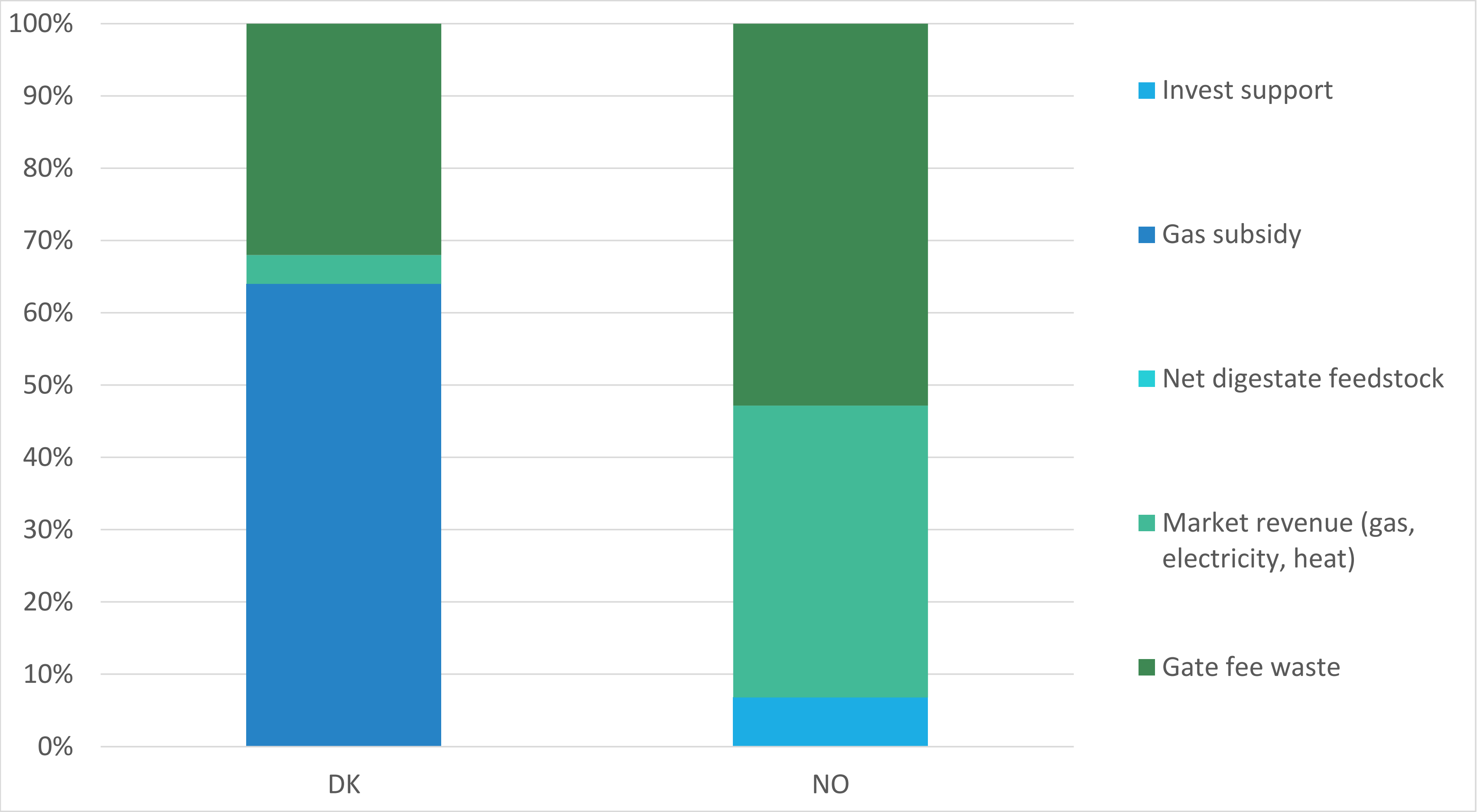
Large scale biogas plant in DK based on manure and upgrading biogas to grid (BioChain case)



Large scale biogas plant in NO (organic waste) – preliminary results



Revenue composition in DK (BioChain case, new support) and Norway



Comparison on the drivers for biogas development in Norway and DK

- Biogas development in DK is driven by the high support level for upgraded biogas to natural gas grid
- The risk involved in CHP based projects are higher even though support is at similar level as for upgrade
- For a limited amount of time the additional investment subsidy (manure) triggered the fast expansion

Biogas in Denmark and Norway

	Denmark	Norway
Drivers	Replacement of fossil energy carriers Distribution of phosphorus	Waste (water) treatment
Typical plants	Farm based plants	Central plants
Main substrates	Manure	Food waste, sewage sludge
Use of biogas	Elecricity/heat Natural gas grid	Transport (new plants) Heat (existing plants)
Use of digestate	Fertilizer	Dewatering and composting

Value chain models for effective biogas production and utilization

– Short presentation of the BioValueChain project

BioChain/BioValueChain joint workshop Viborg 28.10 2014

Ole Jørgen Hanssen
ojh@ostfoldforskning.no

Purpose of biogas model

- Documentation of net GWP as well as other environmental impacts (benefits and emissions) and economy (costs and income)
  - Through the value chain of biogas production
  - In a region, for a specific biogas plant or for treatment of a certain amount of waste/manure

- Simulate the effect of different solutions such as:
    - Size of new plants (amount and type substrate)
    - Analyze consequenses of localisation alternatives (transport distances)
    - Different utilizations of biogas and biosubstrate

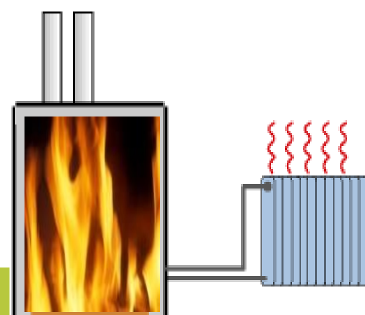
Included waste types and treatment methods

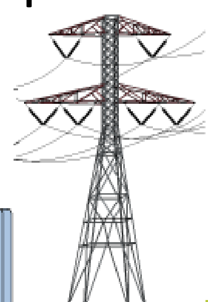
Papp, papir og drikkekartong | Metall-emballasje | Plast | Glassemballasje | Våtorganisk avfall

Del av restavfallet

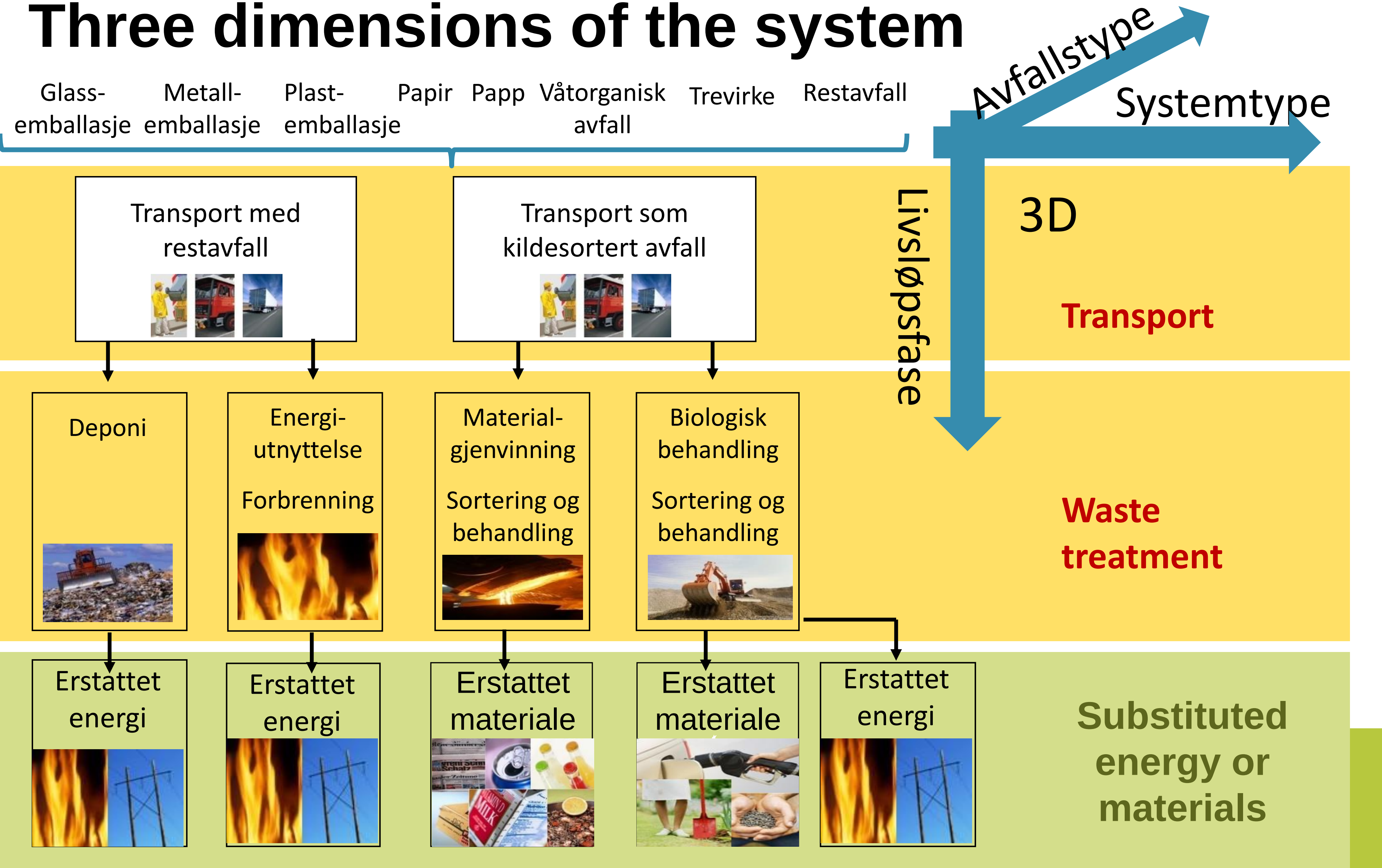
Kildesortert avfall

Deponi | Energiutnytting Noreg | Energiutnytting eksport | Material-gjenvinning | Biologisk behandling





Three dimensions of the system



Environmental impact model

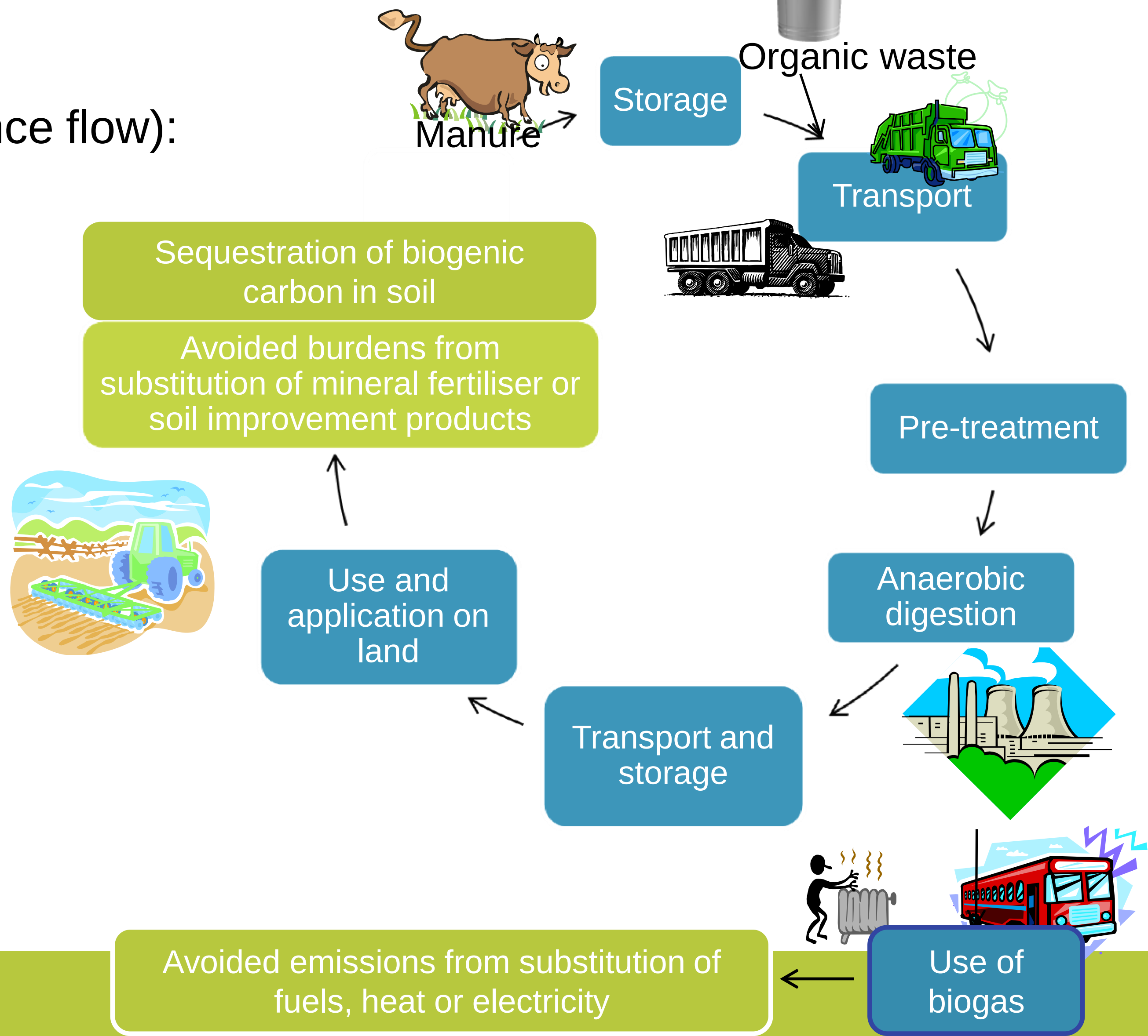
Functional unit (reference flow):
Amount of substrate
(1 tonne of DM)

+ Direct emissions from biomass
+ Indirect emissions

- Avoided burdens

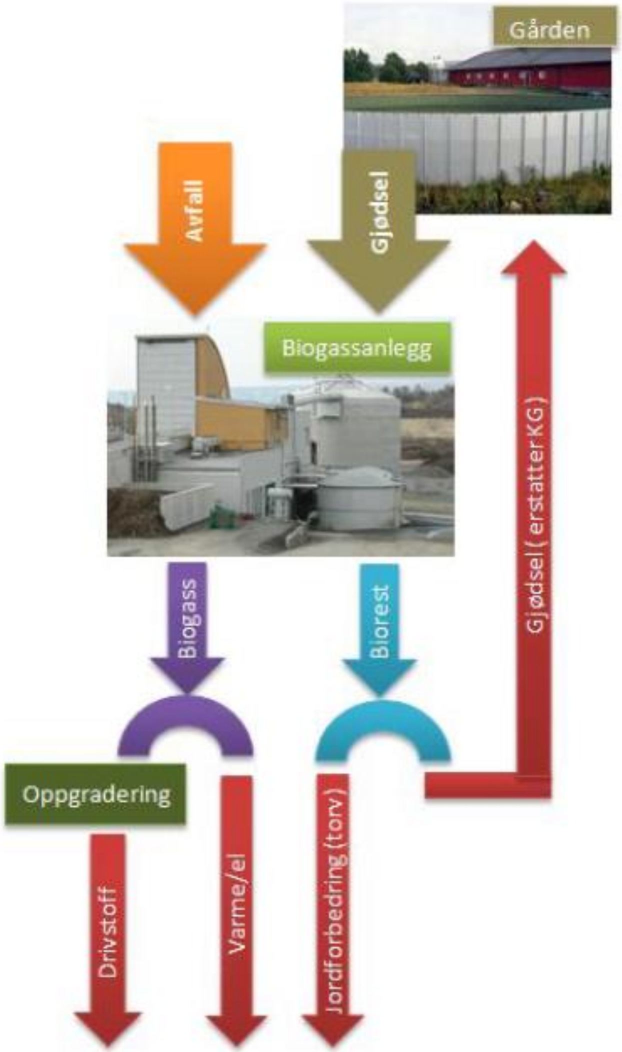
= **Net environmental impact**

Current practice for LCA of waste management systems



Economic model

- Life Cycle Costing (LCC):
  - All costs associated with the investment throughout the service life.
  - Investment costs (minus investment support), plus operating costs adjusted for interests every year.
- Annual costs:
  - Yearly capital costs (investment costs distributed per year)
  - Annual operating costs
  - Annual transport costs
  - Includes annual depreciation and interest costs



Historical development of the biogas models

FoU-

E6 som Biogassveg
Frstad Biogass
→ **Potensial-studie biogass**
Enova
→ **VRI Østfold Gjenvinning Østfold Biogass-nettverk**
→ **Biogass Østfold 2015 Regionalt utvikl.prosj.**
→ **Nasjonal biogass-strategi**

Modell

Klimaregnskap Avfall I og II
Avfall Norge
→ **Regionale avfalls-studiar i i Noreg (18 kommunar)**
→ **DISBiogass**
Tel-Tek/HiT Oslofjord-Fondet
→ **Verdikjede-modell biogass for avfall og gjødsel Fase I**
→ **Verdikjede-modell biogass for avfall og gjødsel Fase II**

Finansiert av SLF i samarbeid med FMLA i Østfold og Vestfold, Østfold/Vestfold bondelag. Utviklet saman med Bioforsk og UMB.

Matavfall til deponi, forbrenning og kompostering

Fem livsløpsfasar
- Deponi, energiutnytting og materialgjenvinning (+ kompostering og biogassproduksjon) av:
- Glassemballasje, metallemballasje, papir, plastemballasje, treavfall, våtorganisk avfall og restavfall.

Matavfall til biogassproduksjon

Ny og meir detaljert modell (10 livsløpsfasar)
- Biogassproduksjon, med/utan avvatning.
- Matavfall, storfegjødsel og svinegjødsel
- Kjøring av case for Vestfold og Østfold.
- Har også laga økonomimodell.
- Utvider til fleire miljøparametrar (hausten 2012).

Objectives for BioValueChain

The main objective of the project is to design effective biogas value chains, and to describe how Norwegian and EU governmental regulations affect relevant actors in the value chain. This objective will be fulfilled through the following specific sub goals:

- Compare Norwegian and Danish biogas value chains, and analyse and describe the effectiveness of the systems with respect to environmental, resource and economic cost benefits assessments
- Analyse and describe how governmental politics, regulations, instruments and incentive programs influences on economic and environmental effectiveness of the biogas value chains in Norway and Denmark, and how EU regulations and politics influences on the national politics
- Analyse if and how small farm-based biogas plants can be implemented in combination with larger industrial biogas plants and utilize local manure and resources with economic benefits
- Develop and update value chain models for biogas production and use through cooperation and joint research with the Danish BioChain project.

Arbeidspakker i prosjektet

I. *Further development of the models with improved data, and necessary development to incorporate Danish conditions in the models*

II. *Analyses and comparisons of effectiveness and efficiency of Norwegian and Danish value chains for biogas*.

III. *Analyse effects of politics and regulations from Danish, Norwegian and EU authorities on the efficiency and effectiveness of biogas value chains in Norway and Denmark.*

IV. *Analyse if and how smaller biogas plants based on manure and locally distributed substrates can be incorporated in systems with large industrial biogas plants*.

V. *Educate one PhD candidate in value chain effectiveness in collaboration with the Danish BioChain project.*

Partners in the BioValueChain project

Contributors

- Norwegian Agricultural Authority (SLF)
- Norwegian Research Council
- Avfall Norge
- The Norwegian Farmers Union (Bondelaget)
- Cambi
- NHO Mat og Drikke
- Agricultural department, Østfold and Vestfold County (Fylkesmannens landbruksavdeling)

Research collaboration between:

- Østfoldforskning
- NMBU
- Bioforsk
- Telemark University College
- TelTek
- RebioKonsult

- DTU Management engineering
- University of Southern Denmark

Thank you for listening!

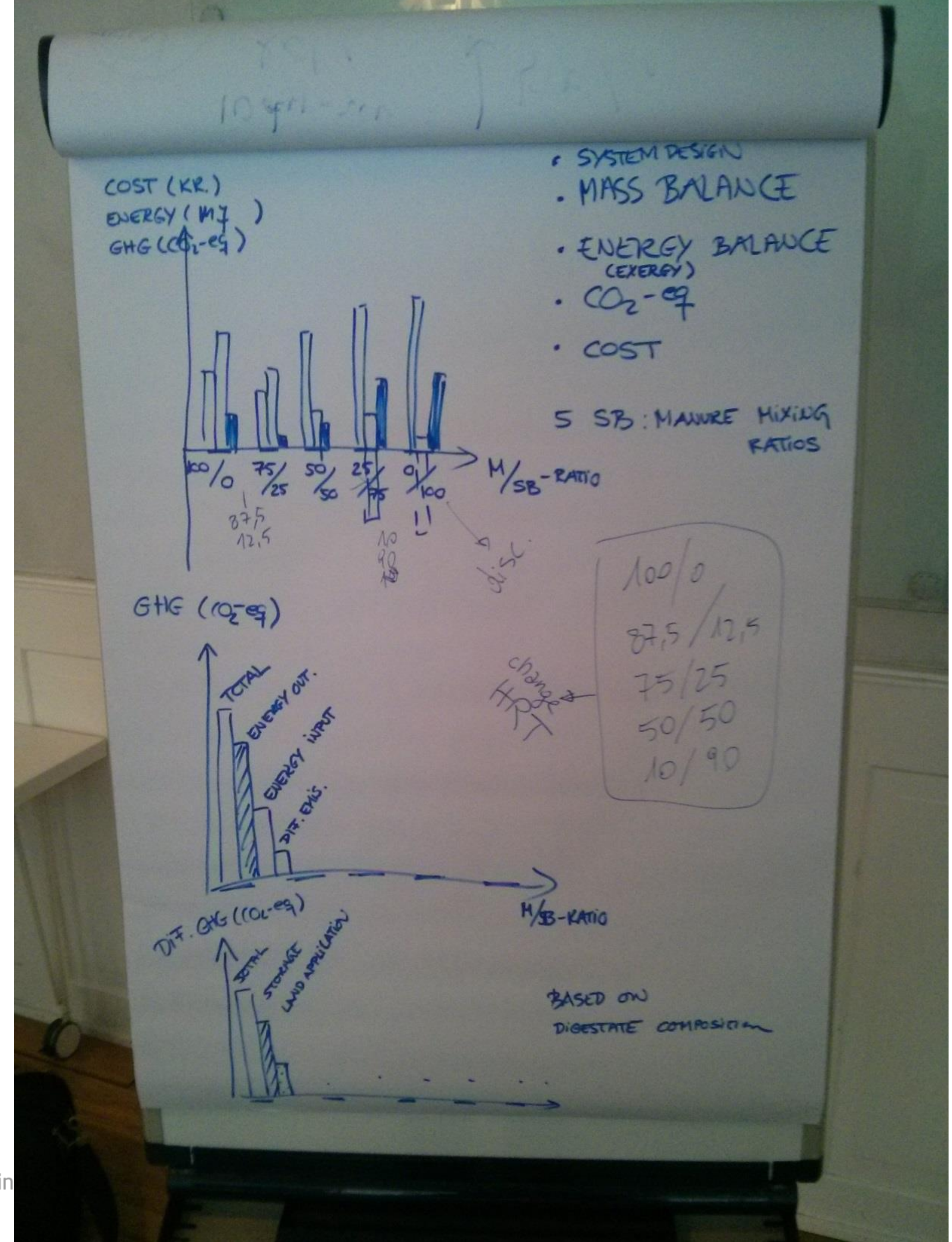
E-post: ojh@ostfoldforskning.no

A dynamic model for integrated optimization of Biogas Production – A case study on Sugar Beet Biomass

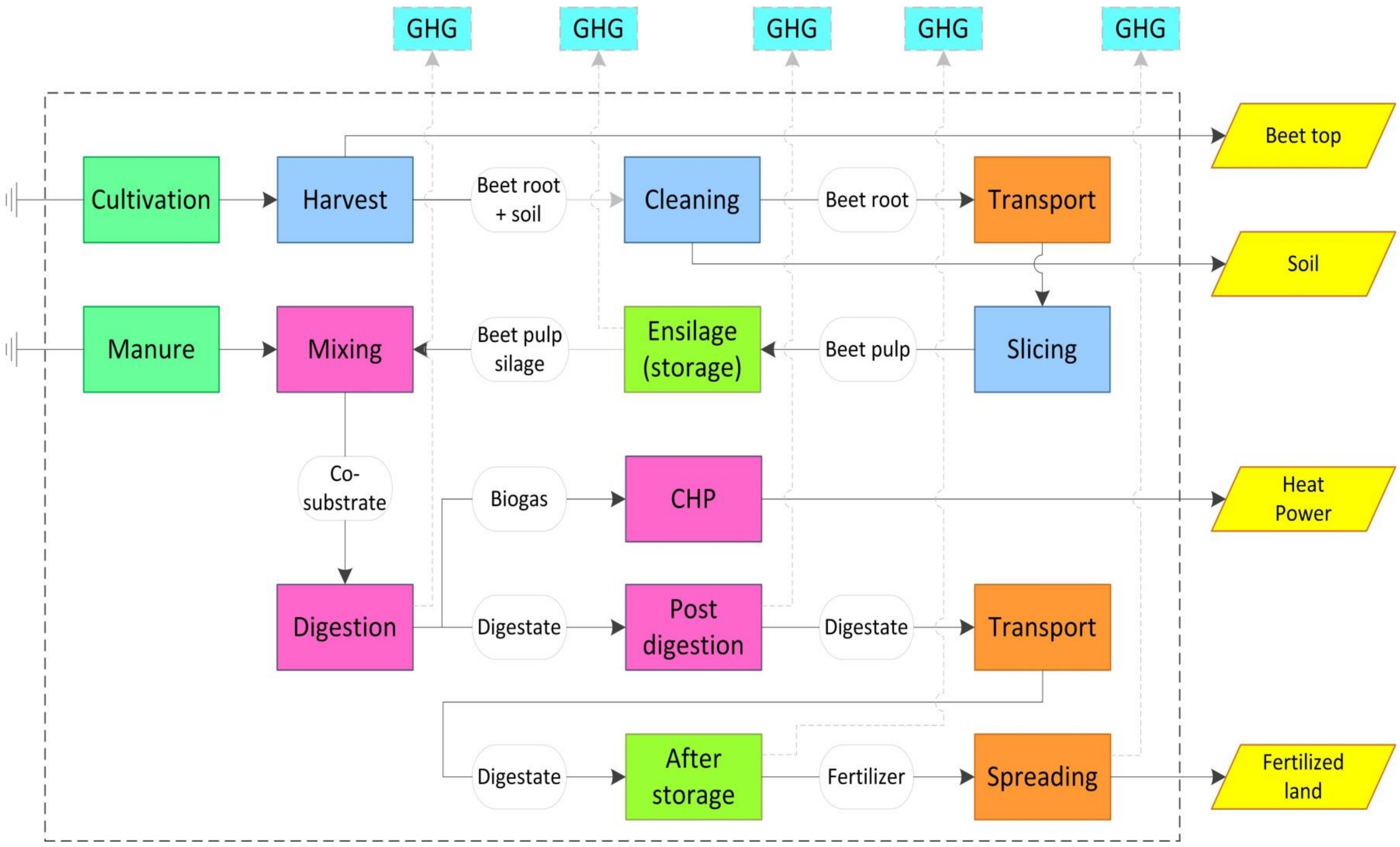
Alessio Boldrin, Khagendra Raj Baral, Temesgen Fitamo, Ali Heidarzadeh Vazifehkhoran, Ida Græsted Jensen, Ida Kjærgaard, Kari-Anne Lyng, Quan Van Nguyen, Lise Skovsgaard Nielsen, Jin Mi Triolo

Objectives

- Integrate:
  - Mass
  - Energy
  - GHG
  - Economy
- Test different ratios of pig slurry (PD) and sugar beet (SB)
- Test the influence of scale
- (effect of HRT)


COST (KR.)
ENERGY (MJ)
GHG (CO_2-eq)
• SYSTEM DESIGN
• MASS BALANCE
• ENERGY BALANCE (EXERGY)
• CO_2-eq
• COST
5 SB : MANURE MIXING RATIOS
100/0
75/25
50/50
25/75
0/100
M/SB-RATIO
87,5 12,5
disc.
100/0
87,5/12,5
75/25
50/50
10/90
change HRT
GHG (CO_2-eq)
TOTAL
ENERGY OUT.
ENERGY INPUT
DIF. EMIS.
M/SB-RATIO
DIF. GHG (CO_2-eq)
TOTAL
STORAGE
LAND APPLICATION
BASED ON DIGESTATE COMPOSITION

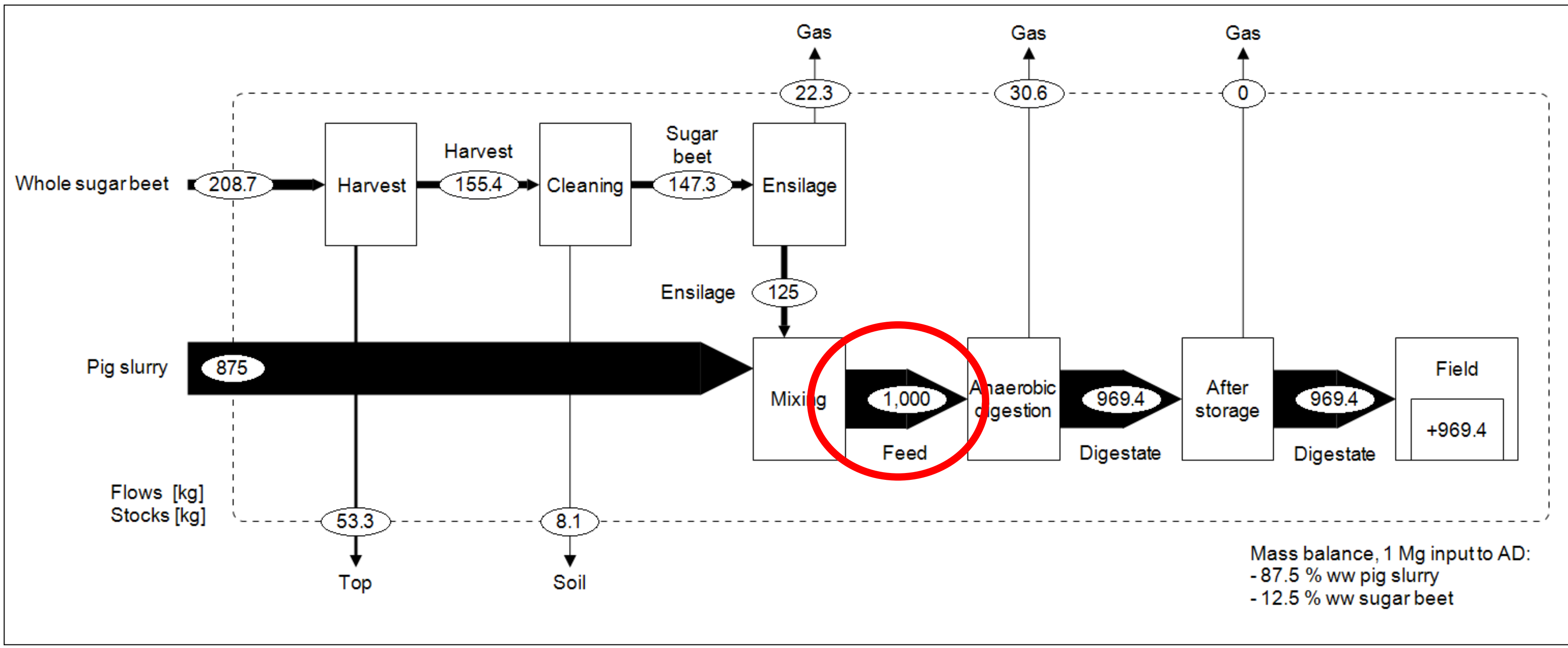
The biogas chain



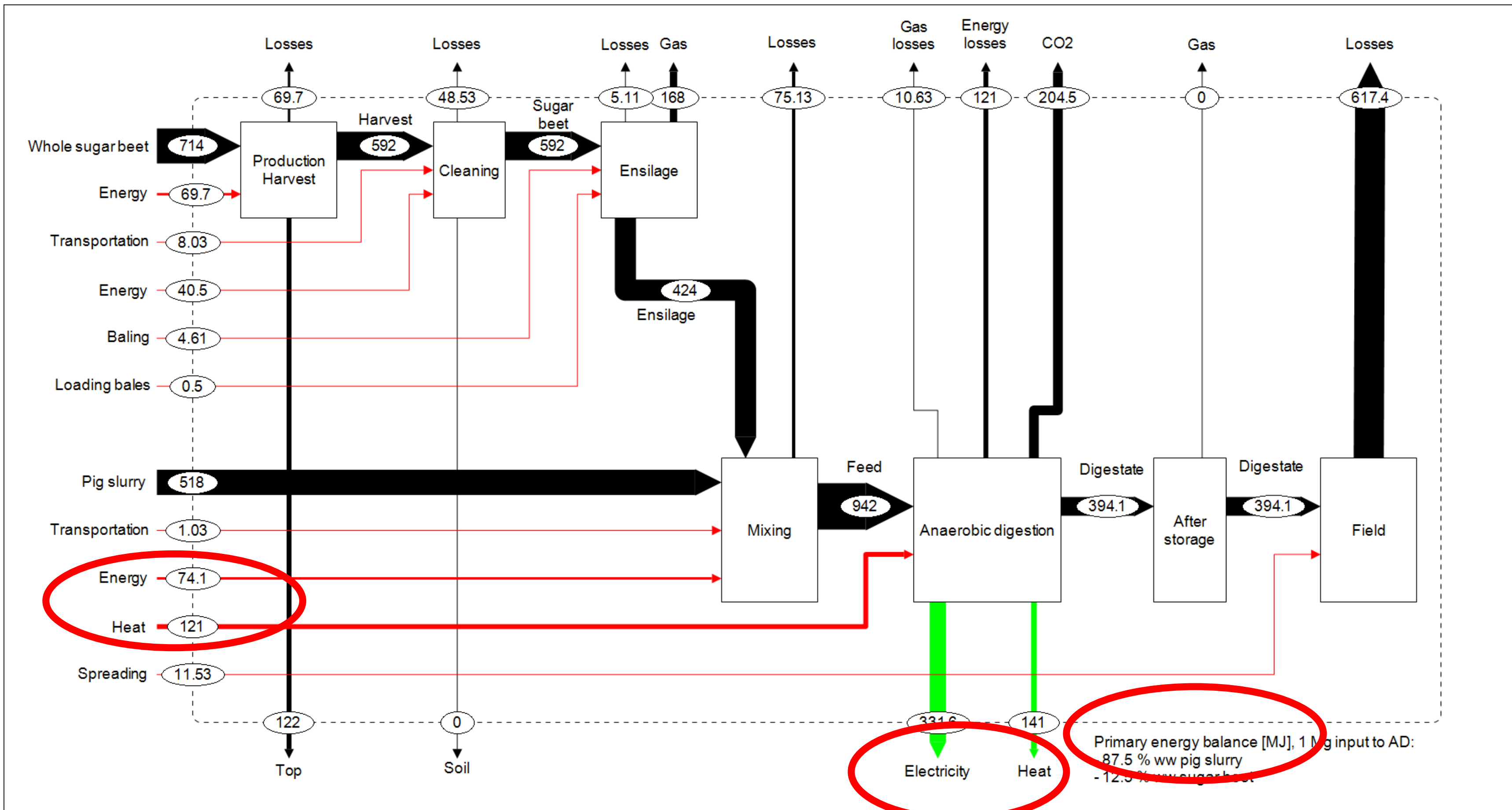
Approach

- Mass balance
  - Lab experiments
    - biogas production
    - VS degradattion
    - 2 pools: degradable/non-degradable
- GHG balance
  - Incubation tests
  - Emission factors
- Energy balance
  - Gross calorific value: 18.56 MJ/kg_{VS}
  - Primary energy
  - Cumulative Energy Demand (CED)
- Economy balance

Example of mass balance

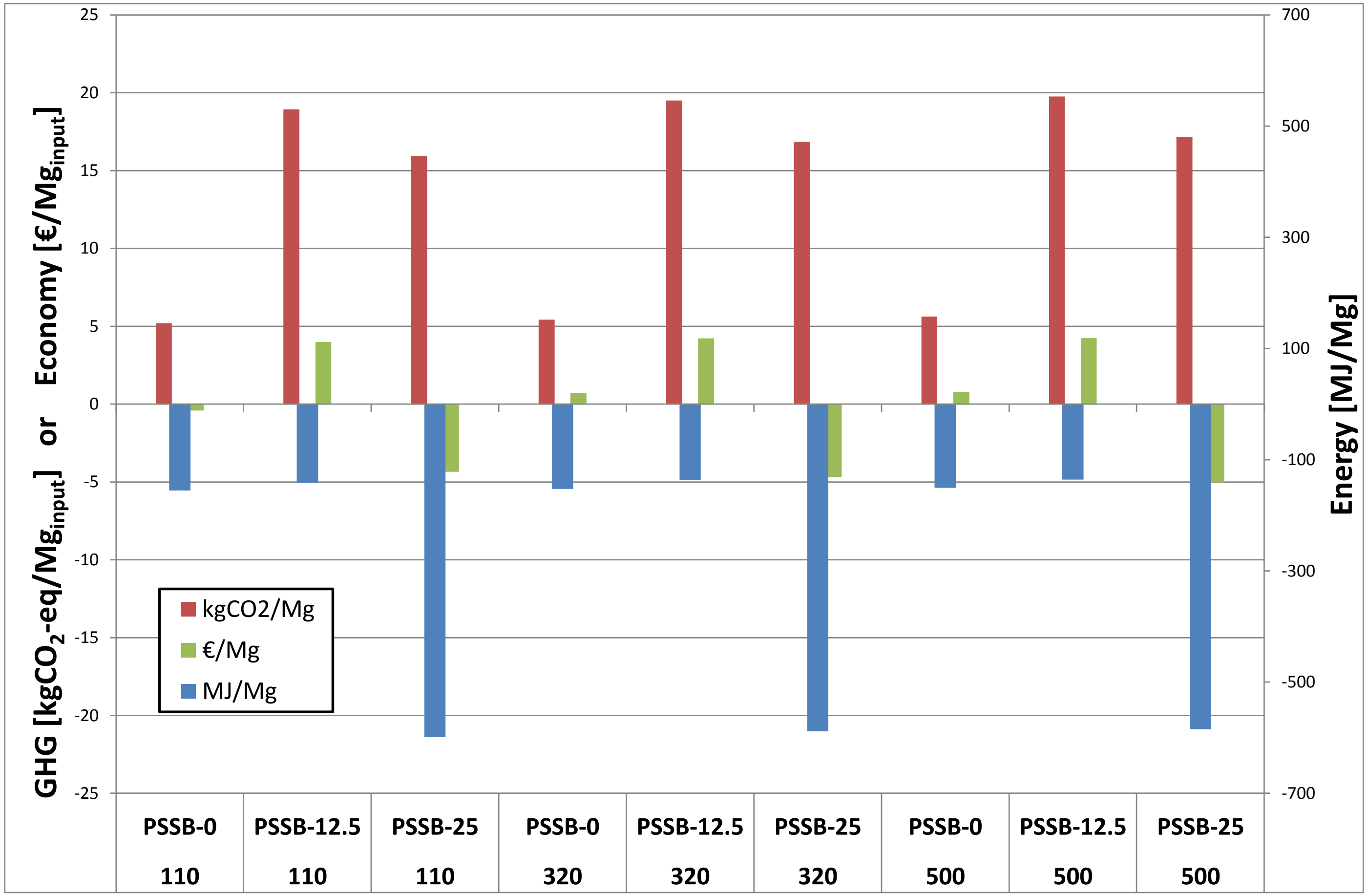


Example of energy balance

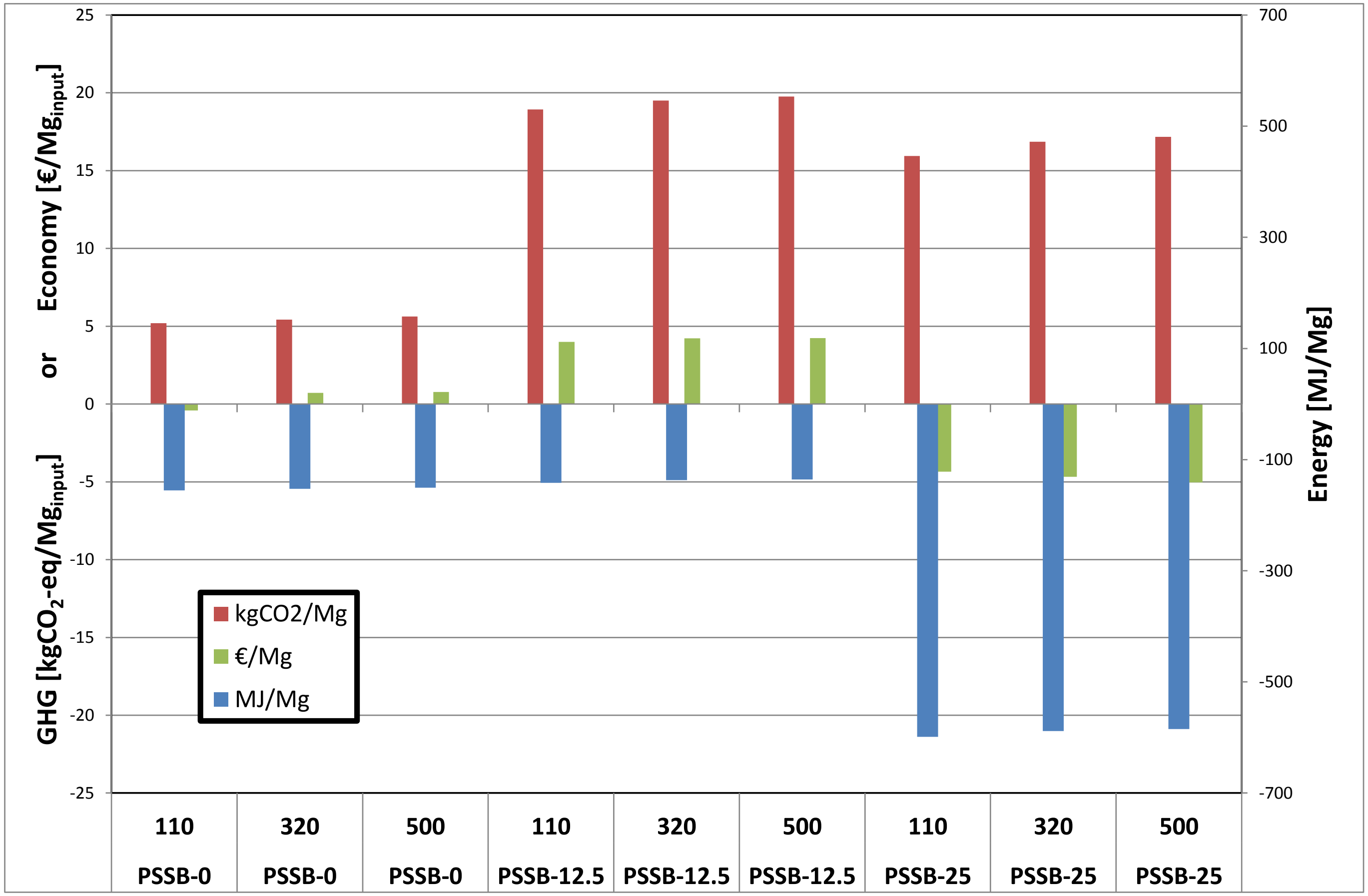


DTU Environment
Department of Environmental Engineering

Effect of mix



Effect of scale



Highlights

- Non linear effect
  - Inhibition at 25% SB
- Energy → energy production
- GHG:
  - Sugar beet production
  - Energy production
  - N2O from field
- Economy
  - Transportation
  - Energy production
  - SB supply
- Transportation
  - not very relevant for energy and GHG
  - Important for economy

Tuning the details

- Mismatch:
  - VS degraded, CH4 produced, gross calorific value of sugar beet
  - Modelling of storage is missing
- Inclusion/exclusion of biomass-energy in the calculation
- N_2O from N leaching
- Deeper analysis of results → disaggregate
- Title: ” A dynamic model for integrated optimization of Biogas Production – A case study on Sugar Beet Biomass”

- Knowledge transfer

Thank you

Potential errors in the quantitative evaluation of dry matter and methane potentials in biogas production

Jin Mi Triolo

jmt@kbm.sdu.dk

BioChain workshop, Foulum, October 2014

Biogas potentials
COD-based or VS-based

- Waste water : COD based biogas potentials
  (CH_4 NL/kg COD)
- Animal manure, solid and semi solid biowaste : VS based biogas potentials (CH_4 NL/kg VS)

$CH_4 + 2O_2 = CO_2 + 2H_2O$

1g COD = 4g CH_4

1g COD =350ml CH_4

	Theoretical BMP (VS based)	Theoretical BMP (COD based)	
	CH_4 NL/g VS-1	CH_4NL/COD g	g COD/g VS
VFA	0.37	0.35	1.07
protein	0.50	0.35	1.42
Carbohydrate	0.41	0.35	1.19
Lipid	1.01	0.35	2.90
Ethanol	0.73	0.35	2.09

Background

- To draw attention to the errors that can arise from using uncorrected, oven-dry-based values of dry matter

- DM and VS determined by oven drying
  - A standard method of determining the TS of biomass is oven drying at 105°C
  - Other oven temperatures, such as 60°C, 85°C or 100°C are also common.

- Well reported inaccurate values of the DM by oven drying in case of silage. (From the beginning of the 20th century)

  ⇒ Volatilization of volatile compounds during oven drying.
  - volatile fatty acids (VFAs)
  - lactic acid
  - alcohols

⇒ No or little attention to animal manure

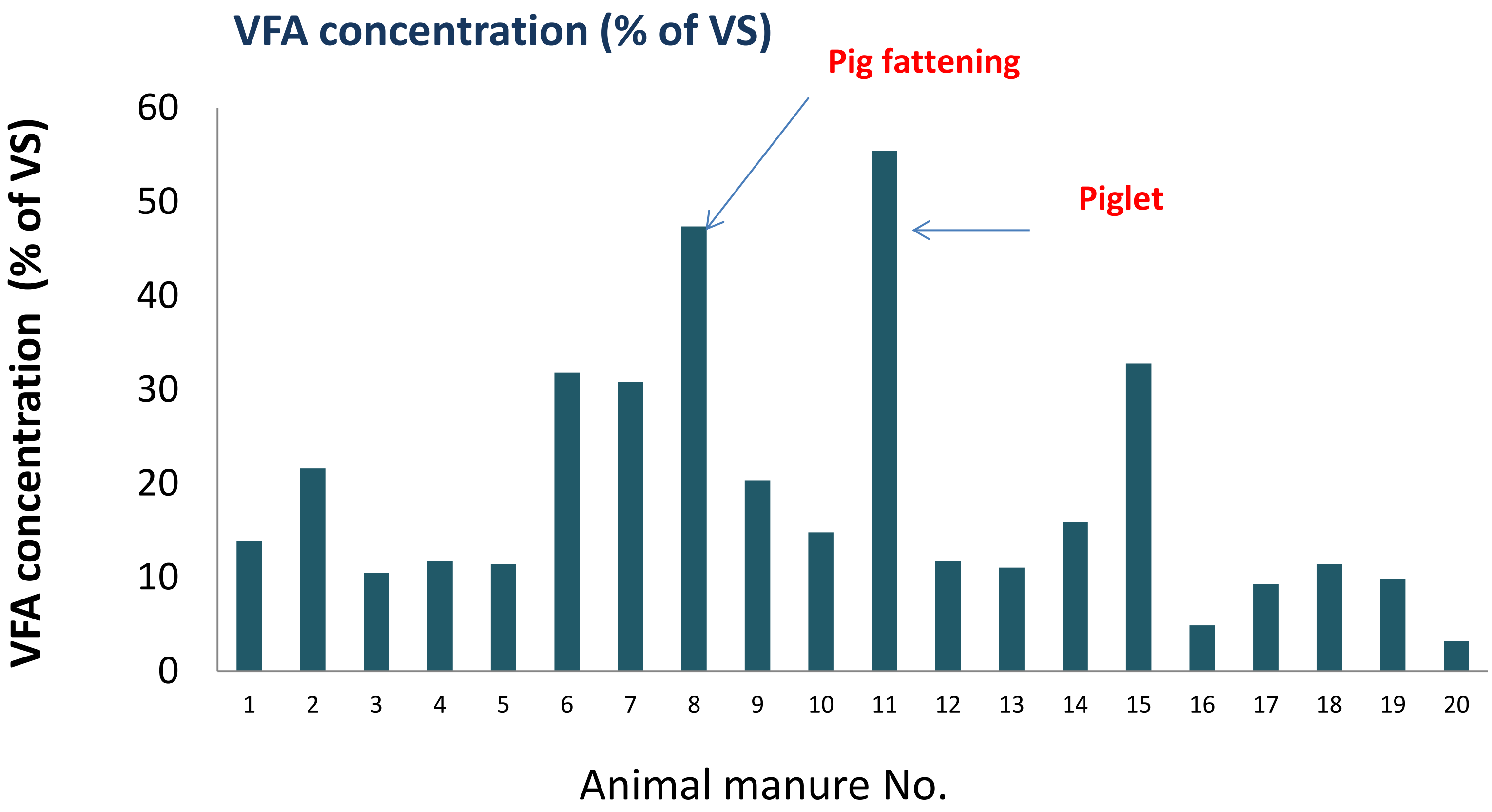
Current methods to correct errors in determination of VS in silage

- Oven drying + with corrections for the volatilization of VFAs, lactic acid, alcohols and ammonia.

- Although the limitations of using oven drying without correction for volatile compounds have been known for many years in agricultural sciences, the method is still routinely used in research related to methane production through anaerobic digestion.
- Organic compounds other than VFAs, lactic acid and alcohols will not be included. Methods, including volatilization

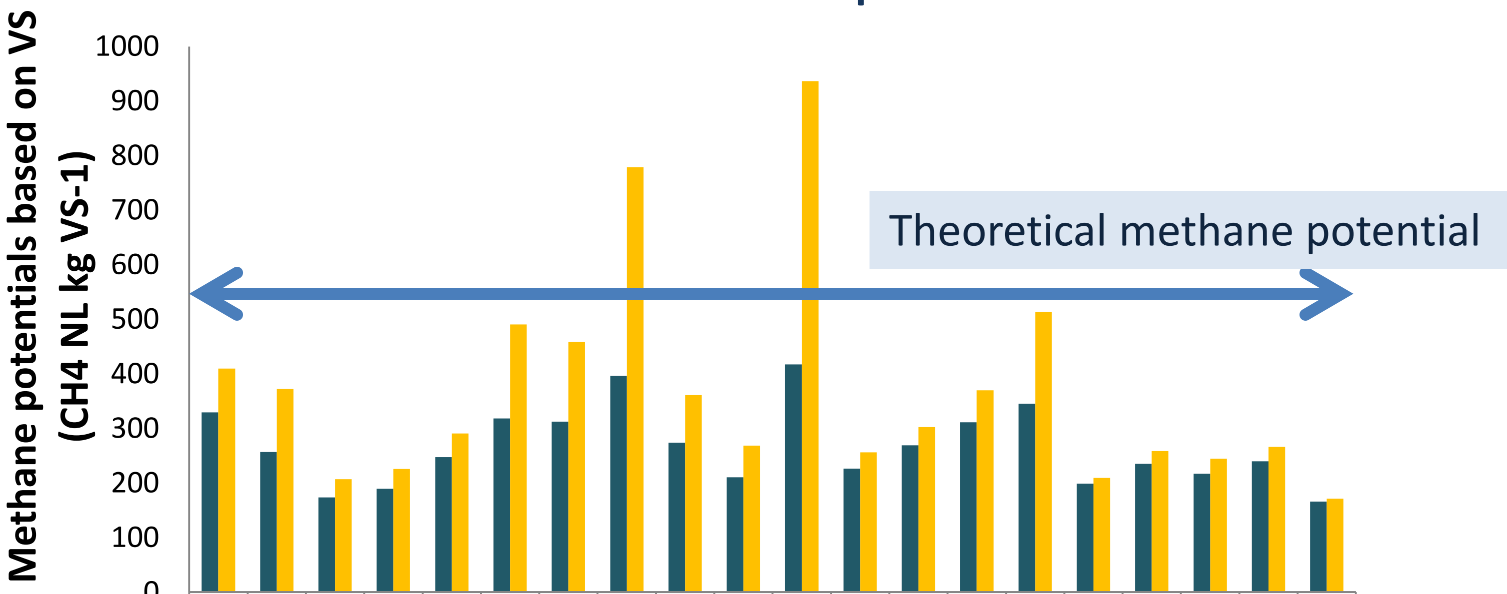
➡ The VS-based methane yields given for ensiled materials may therefore be overestimated.

VFA concentration in animal manure



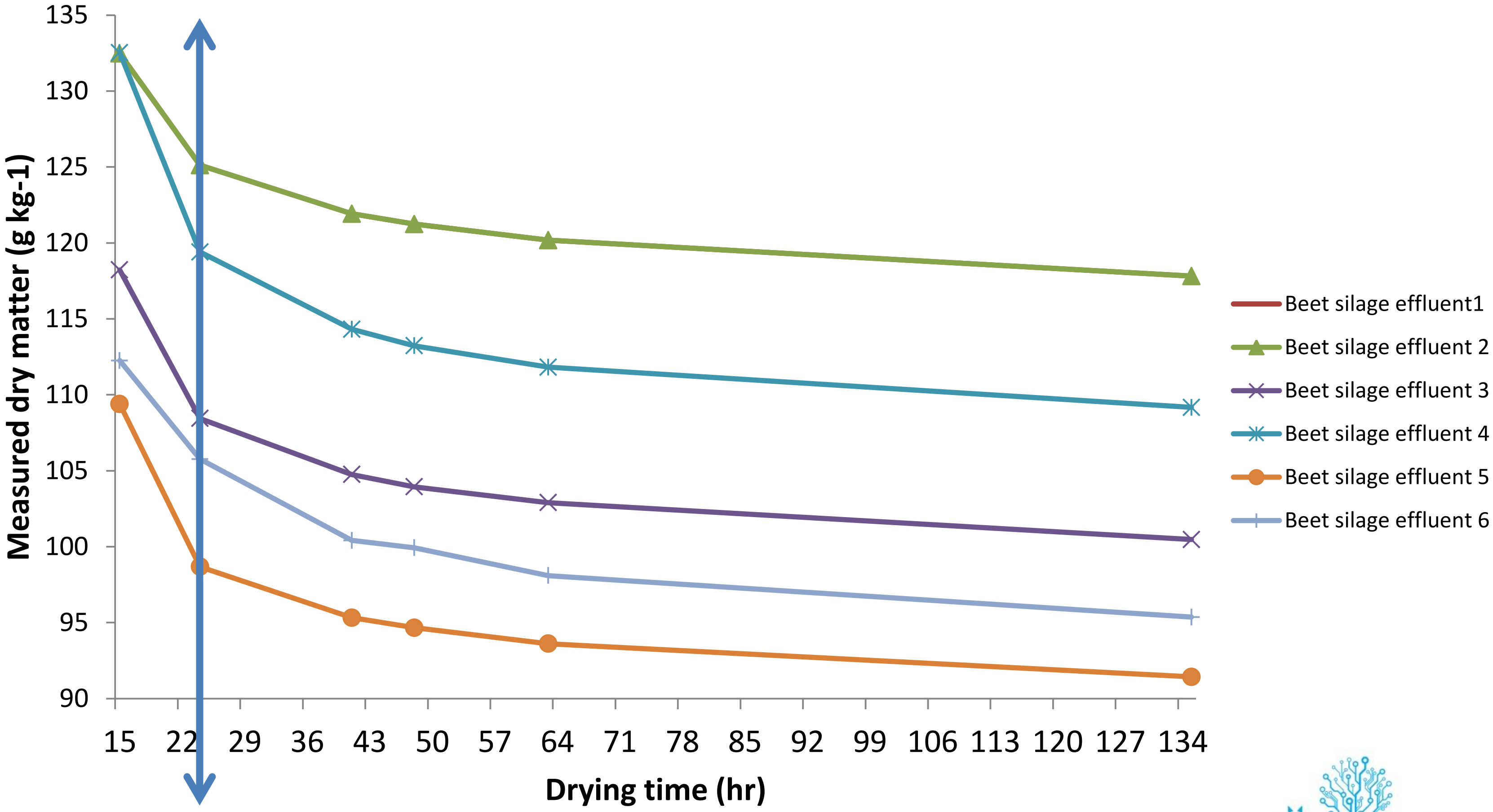
VFA concentration in animal manure

Overestimated VS based methane potentials



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
BMP After correction	329,	256,	173,	189,	247,	318,	312,	396,	273,	210,	417,	226,	269,	311,	345,	199,	235,	216,	239,	165,
BMP Before correction	410,	372,	206,	225,	290,	490,	458,	778,	361,	268,	936,	256,	302,	370,	513,	209,	258,	244,	266,	171,

Beet silage efflent :Dry matter determined by oven drying 105°C (APHA standard method)



24hr : Standard method

Dry matter determination : can not reach constant weight.

- Residues dried at 103 to 105°C may retain
  - Water of crystallization but also some
  - Mechanically occluded water.
- Removal of occluded water : marginal at this temperature, attainment of constant weight may be very slow
- APHA standard method recommands drying temperature 180°C
  - Organic matter may be lost by volatilization

Can increasing pH reduce errors?

Angelidaki et al. (2009): Suggests increasing pH and oven drying at 90 °C

Generation of water

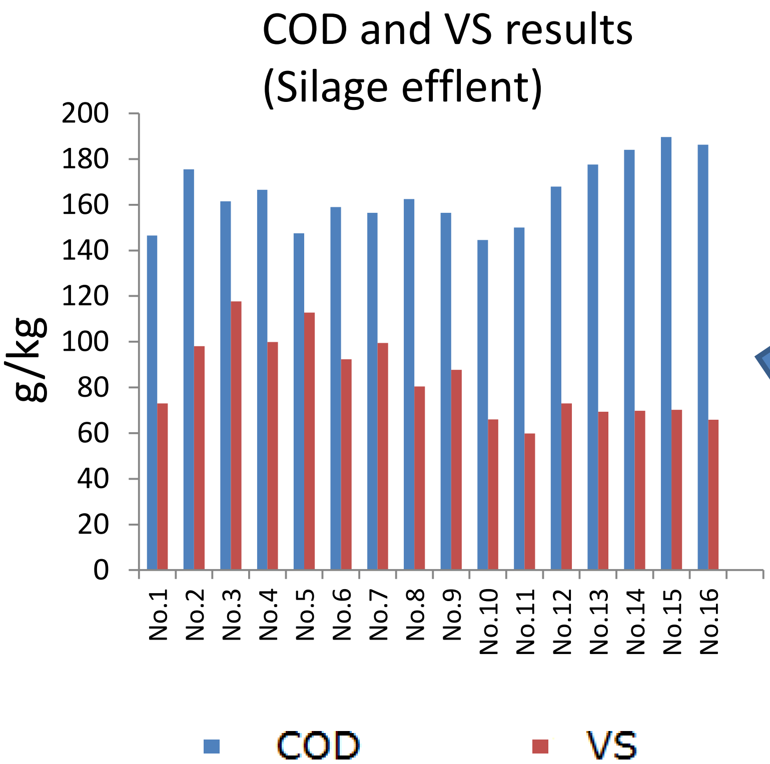
$$1\,g\,CH_3COOH + 0.67\,g\,NaOH \rightarrow 0.30\,g\,H_2O + 1.37\,g\,CH_3COONa$$

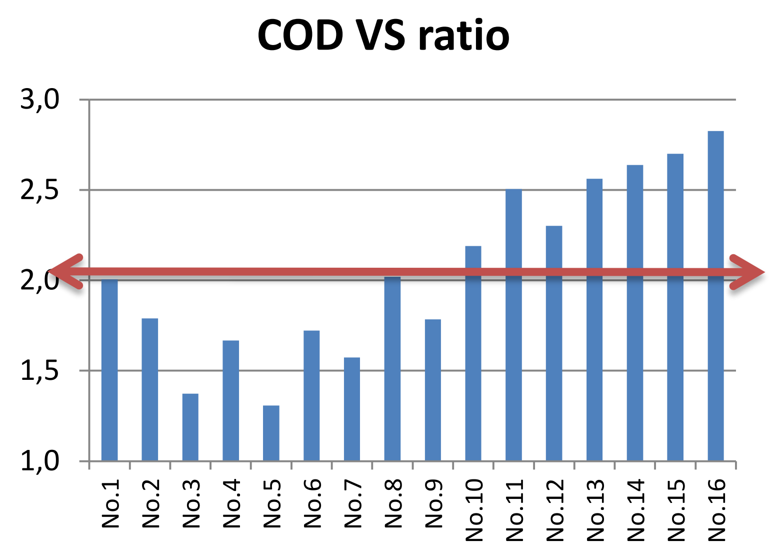
	ash g/kg	ash g/kg
	Standard method	Increasing pH
Silage 1	44,5	81,0
Silage 2	45,6	72,5
Silage 3	58,5	96,9
Silage 4	41,0	76,2
Silage 5	51,0	67,3

Sodium acetate crystal

Further problem : Volitalisation of alcohols and ammonia can not be prevented by increasing pH.

VS results from oven drying 105°C for 24hr



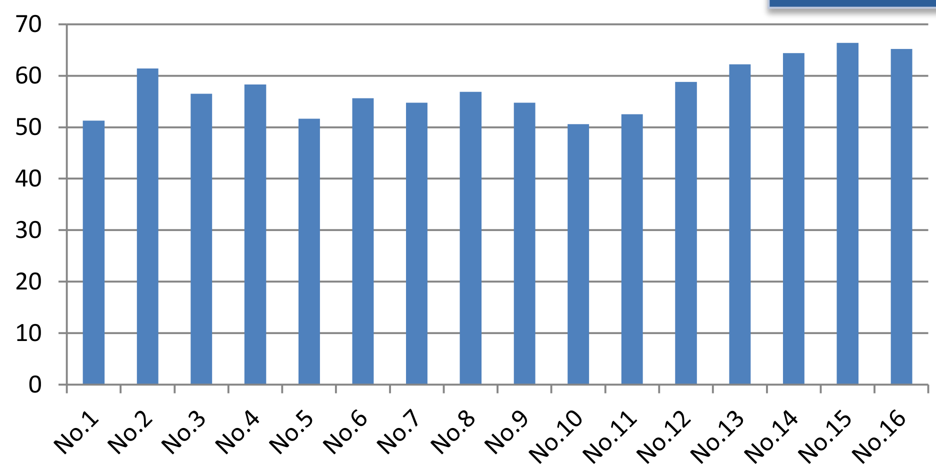


	g COD/g VS
VFA	1.07
protein	1.42
Carbohydrate	1.19
Lipid	2.90
Ethanol	2.09

We suggest COD- based methane potentials for silage biomass

	Theoretical BMP (VS based)	Theoretical BMP (COD based)	
	CH_4 NL/g VS-1	CH_4NL/COD g	g COD/g VS
VFA	0.37	0.35	1,07
protein	0.50	0.35	1,42
Carbohydrate	0.41	0.35	1,19
Lipid	1.01	0.35	2,90
Ethanol	0.73	0.35	2,09

TBMP of (CH_4 m^3/ton)



Using COD, Theoretical BMP can be assessed easily.

Effect of ensilaging on energy potentials and organic compositions of sugar beet root pulp for biogas production

Ali Heidarzadeh

The Danish Council for Strategic Research

Outline

- Background
- Ensiling and sample collection
- Physicochemical Characterization
- Biogas and methane production from sugar beet silage

Background

Source: http://www.riomay.com/renewable-technologies/biomass-energy

Types of biomasses:

- Agricultural crops and residues
- Sewage
- Municipal organic solid waste
- Animal residues
- Industrial organic waste
- Forestry crops and residues

Background

Energy Crops:

- Sugar beet
- Maize
- Sudan grass
- Millet
- White sweet clover

……..

Sugar beet as a co-substrate:

- High energy potential
- High biodegradability
- large dry matter production potential per ha field
- Readily digestible organic matters

Field study - Ensiling and Sample Collection

Types of silos:

- Open Silo
- Closed Silo

Size : $3m^3$

Harvest: November 2012

Pulping: February 2013

Ensiling: February 2013

Sampling: September 2013

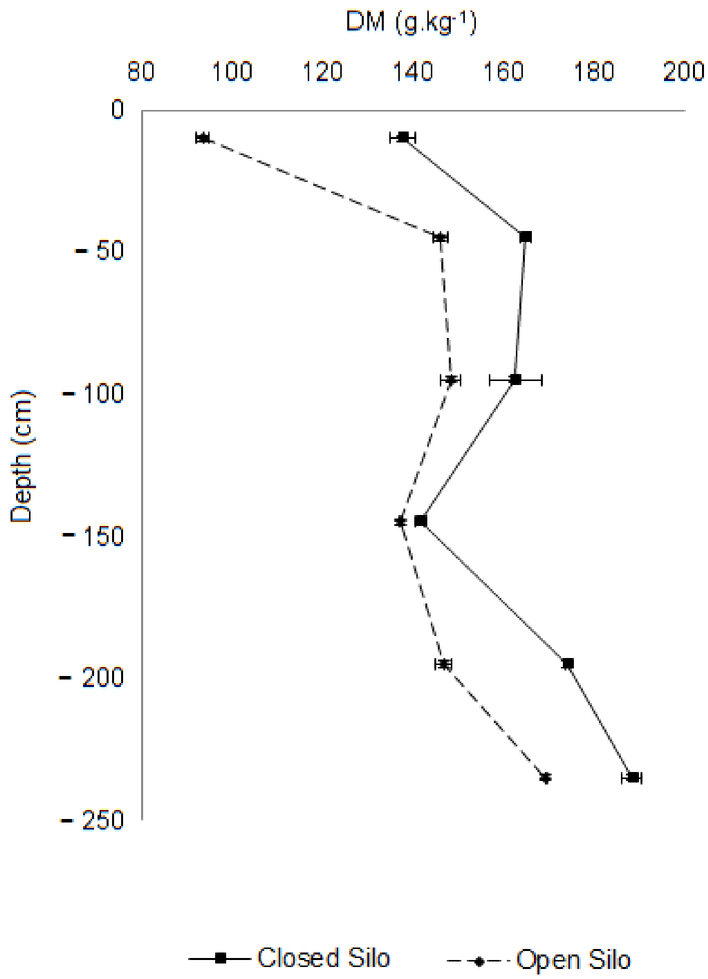
To study BMP and organic composition profile throughout silos, sample collection from six depths:

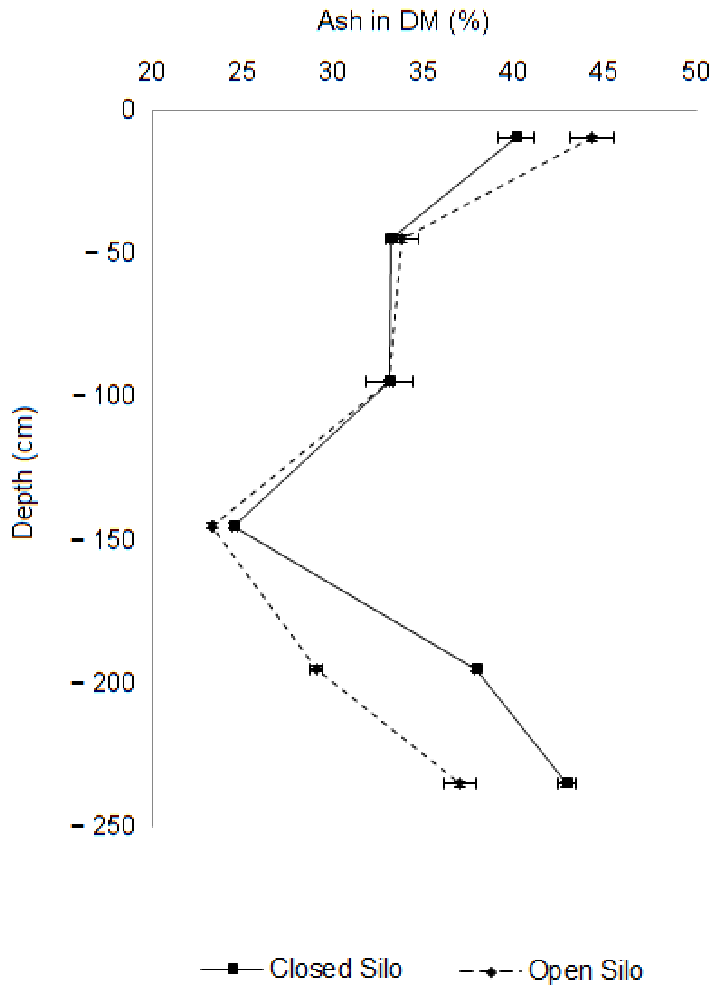
1. 0-20
2. 20-70
3. 70-120
4. 120-170
5. 170-220
6. 220-250

Physicochemical Characterization

1. Biochemical methane potentails (VDI 4630)
2. Dry matters and volatile solids
3. Total kjeldahl nitrogen
4. Volatile fatty acids
5. Ethanol
6. Lactic acid

Dry matters and ash content



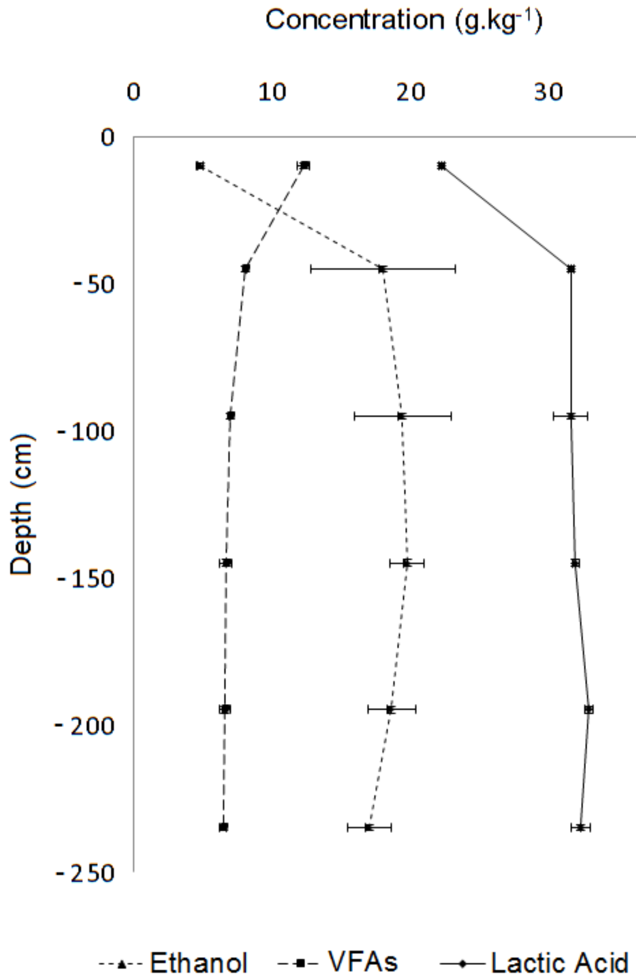


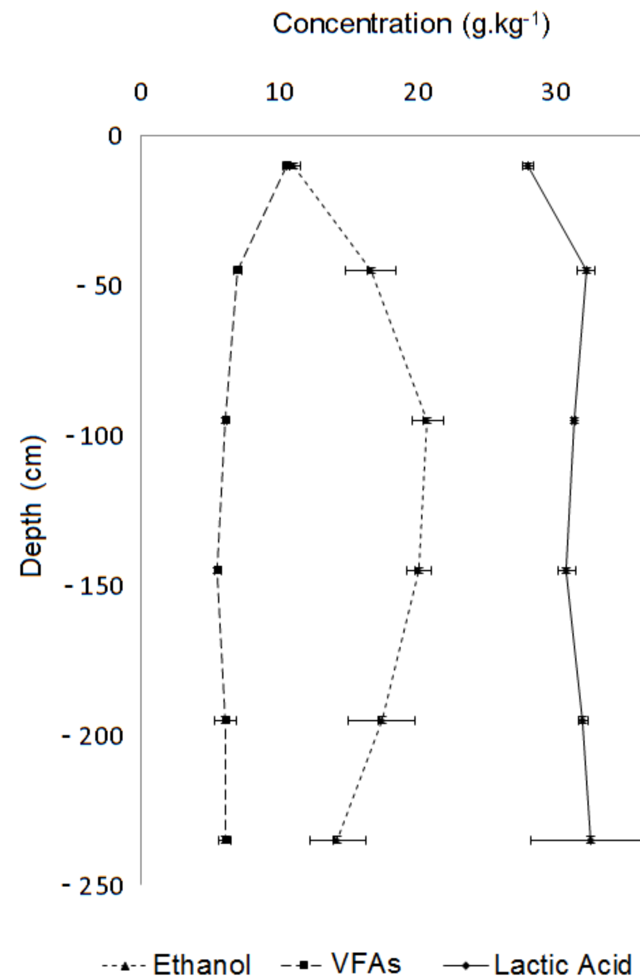
Volatile fatty acids

	Open silo								Closed silo							
Depth (cm)	AA (g/kg)	PA (g/kg)	Iso BA (g/kg)	BA (g/kg)	Iso VA (g/kg)	VA (g/kg)	Total VFAs (g/kg)	pH	AA (g/kg)	PA (g/kg)	Iso BA (g/kg)	BA (g/kg)	Iso VA (g/kg)	VA (g/kg)	Total VFAs (g/kg)	pH
0-20	9.61	0.87	0.04	1.49	0.07	0.13	12.22 (0.43)	3.7	8.10	0.62	0.11	1.49	0.07	0.10	10.49 (0.23)	3.7
20-70	7.64	0.16	0.02	0.16	0.03	0.05	8.07 (0.04)	3.6	6.38	0.15	0.02	0.24	0.03	0.15	6.97 (0.33)	3.6
70-120	6.64	0.05	0.02	0.10	0.03	0.07	6.91 (0.04)	3.6	5.77	0.05	0.02	0.10	0.03	0.14	6.12 (0.09)	3.5
120-170	6.31	0.05	0.02	0.08	0.03	0.11	6.61 (0.45)	3.6	5.25	0.06	0.02	0.05	0.03	0.13	5.54 (0.23)	3.5
170-220	6.26	0.05	0.02	0.08	0.03	0.12	6.55 (0.35)	3.6	5.75	0.05	0.04	0.09	0.03	0.16	6.12 (0.81)	3.6
220-250	6.10	0.05	0.02	0.08	0.03	0.14	6.43 (0.22)	3.7	5.62	0.06	0.02	0.15	0.03	0.17	6.05 (0.44)	3.5

AA: acetic acid
PA: propionic acid
Iso BA: isobutyric acid
BA: butyric acid
Iso VA: isovaleric acid
VA: valeric acid

Ethanol, VFAs and lactic acid concentration profile in open (left) and closed (right) silos





Corrected VS mass composition of ensiled sugar beet pulp from various depths of open silos

	Corrected VS	Crude proteins	VFAs	Ethanol	Lactic acid	Carbohydrates
Depth (cm)	(gkg^{-1} ww)	(% of VS)	(% of VS)	(% of VS)	(% of VS)	(% of VS)
0-20	69.2	16.0	17.7	6.9	32.1	26.5
20-70	122.9	7.8	6.6	14.7	25.7	44.5
70-120	125.7	8.0	5.5	15.4	25.1	45.3
120-170	131.7	7.9	5.0	15.0	24.2	47.3
170-220	129.3	5.9	5.1	14.4	25.4	48.6
220-250	130.2	6.0	4.9	13.0	24.8	50.5

Corrected VS mass composition of ensiled sugar beet pulp from various depths of closed silos

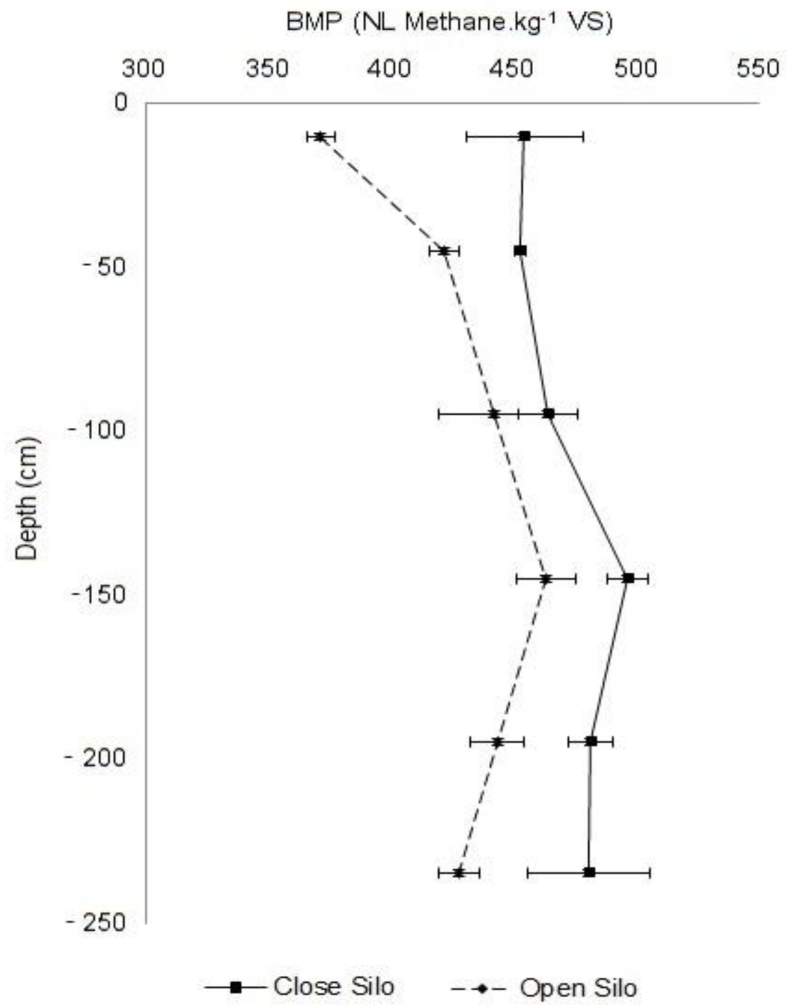
	Corrected VS	Crude proteins	VFAs	Ethanol	Lactic acid	Carbohydrates
Depth (cm)	(gkg^{-1} ww)	(% of VS)	(% of VS)	(% of VS)	(% of VS)	(% of VS)
0-20	104.1	8.2	10.1	10.6	26.8	43.6
20-70	133.8	7.4	5.2	12.4	24.0	50.2
70-120	135.7	6.9	4.5	15.3	23.0	49.5
120-170	132.5	6.3	4.2	15.2	23.2	50.5
170-220	131.7	6.9	4.6	13.2	24.2	50.3
220-250	128.0	6.8	4.7	11.1	25.4	51.1

Methane production

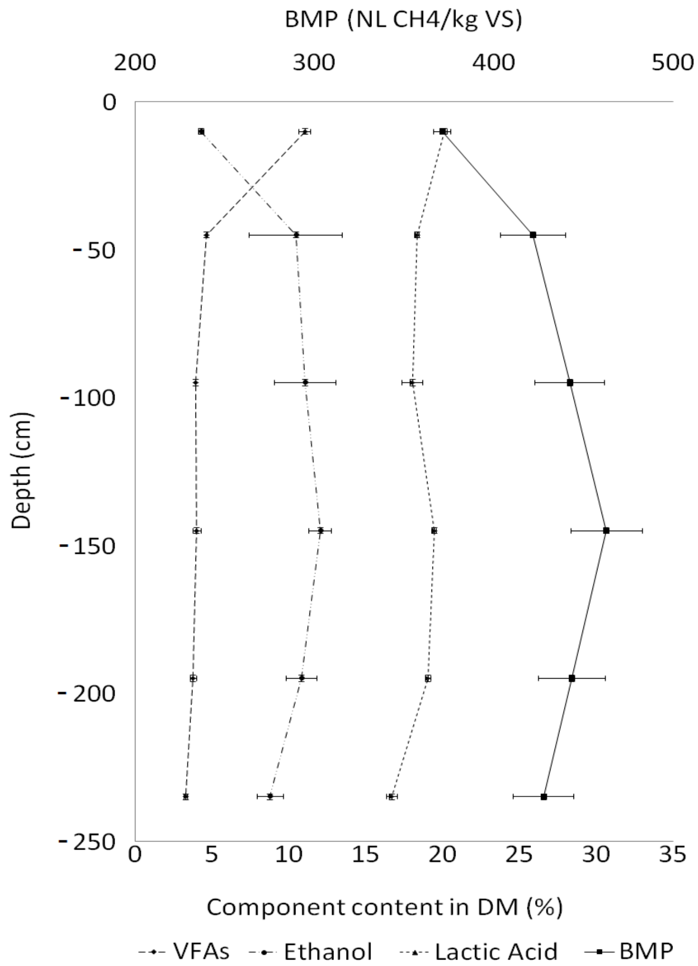
	Open Silo		Close Silo	
Depth (cm)	BMP (NL CH_4/kg VS)	BMP cor (NL CH_4/kg VS)	BMP (NL CH_4/kg VS)	BMP cor (NL CH_4/kg VS)
0-20	492.3	371.4	572.8	454.5
20-70	525.1	421.8	549.7	452.8
70-120	559.3	442.3	578.5	464.0
120-170	578.5	462.9	615.8	496.6
170-220	550.7	443.4	586.1	481.5
220-250	521.3	427.6	570.8	480.5

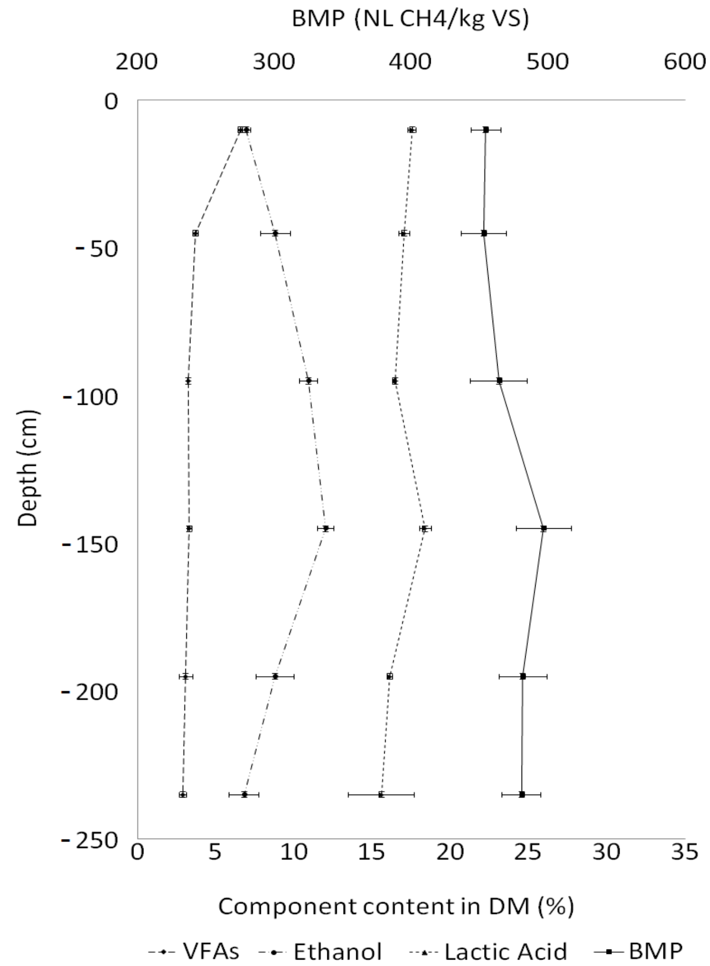
BMP cor	CH4 NL/kg VS (VS measured+VFA+alcohol)
BMP (fresh sugar beet)	342.1 CH4 NL/kg VS

Methane production

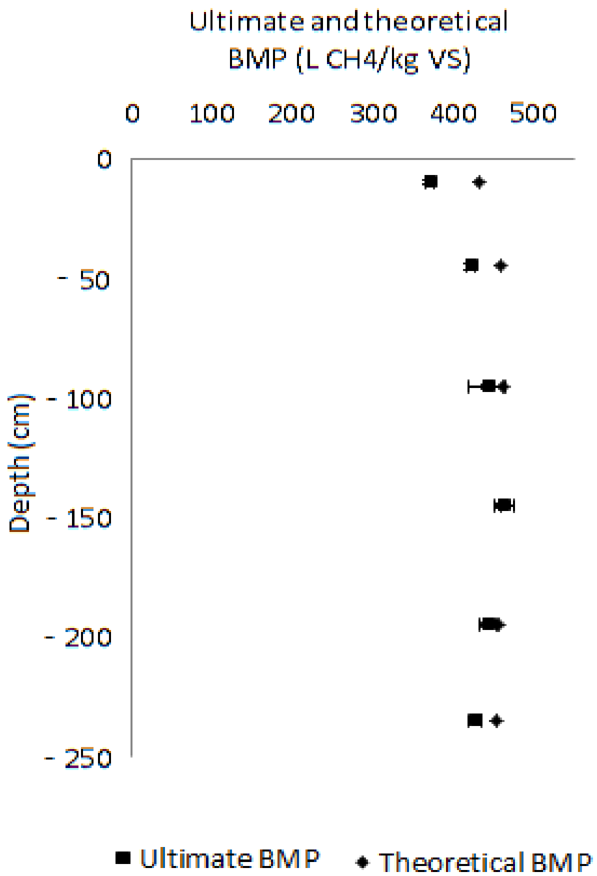


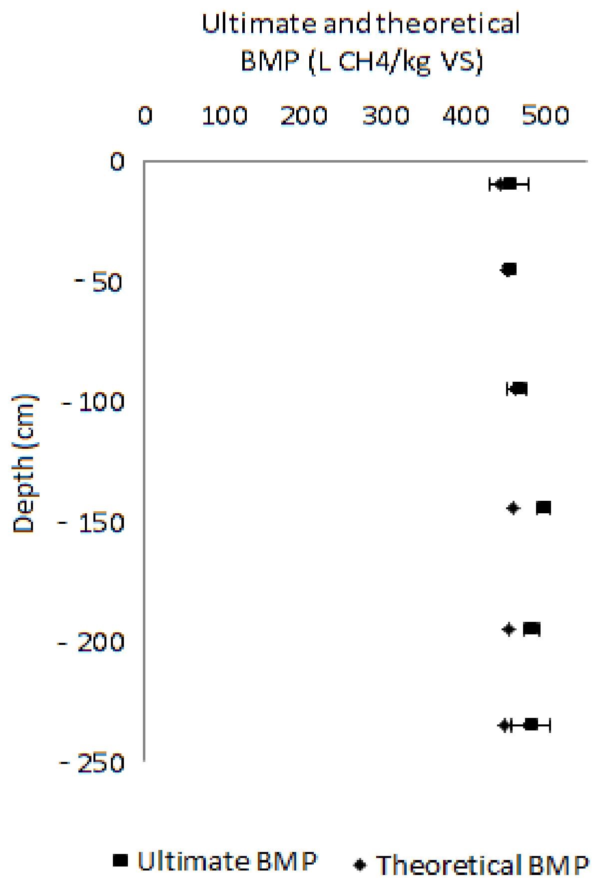
Methane production





Theoretical BMP and ultimate BMP of samples from open (left) and closed (right) silos





Conclusions

This study shows that

1. silo covering affected the biochemical composition and BMPs of ensiled sugar beet pulp
2. Closed silo has higher BMP compared to open silo
3. In both open and closed silos BMP was highest in the middle of the silos
4. The ethanol concentration and BMP showed the same trend with depth throughout the silos, reaching a maximum in the middle.
5. VFA concentration decreased from the top layer and then levelled off in the lower layers, while lactic acid concentration increased from the surface layer and then levelled out with depth.
6. This study highlighted that the energy potentials and composition of beet pulp silage were highly stratified

Thanks for your attention

Biogas yield from co-digestion affected by different retention time

Ali Heidarzadeh

The Danish Council for Strategic Research

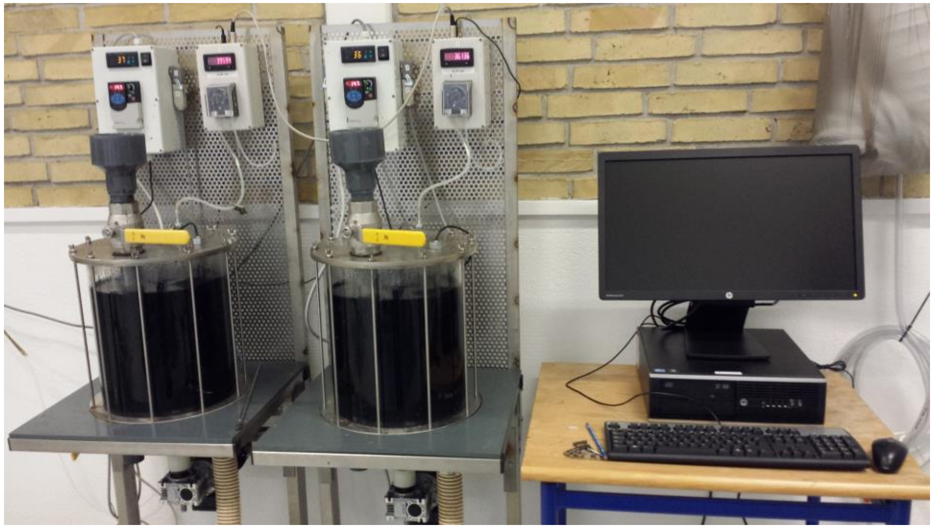
Outline

- Material and methods
- BMP test and Physicochemical Characterization
- Biogas and methane production in CSTR

Materials and methods

Materials:

- Continous reactors
- Inoculum
- Pig manure
- Food processing waste (Jaka bov)
- Brewery waste
- Slaughterhouse waste



Running CSTR:

1. Feed: Pig manure 100%, HRT=20
2. Feed: Pig manure 75%+organic waste materials 25%, HRT=20
3. Feed: Pig manure 75%+organic waste materials 25%, HRT=30
4. Feed: Pig manure 75%+organic waste materials 25%, HRT=45

Organic waste materials: Food processing waste (Jaka bov) 11.25%+Brewery waste 11.25%+Slaughterhouse waste 2.5%

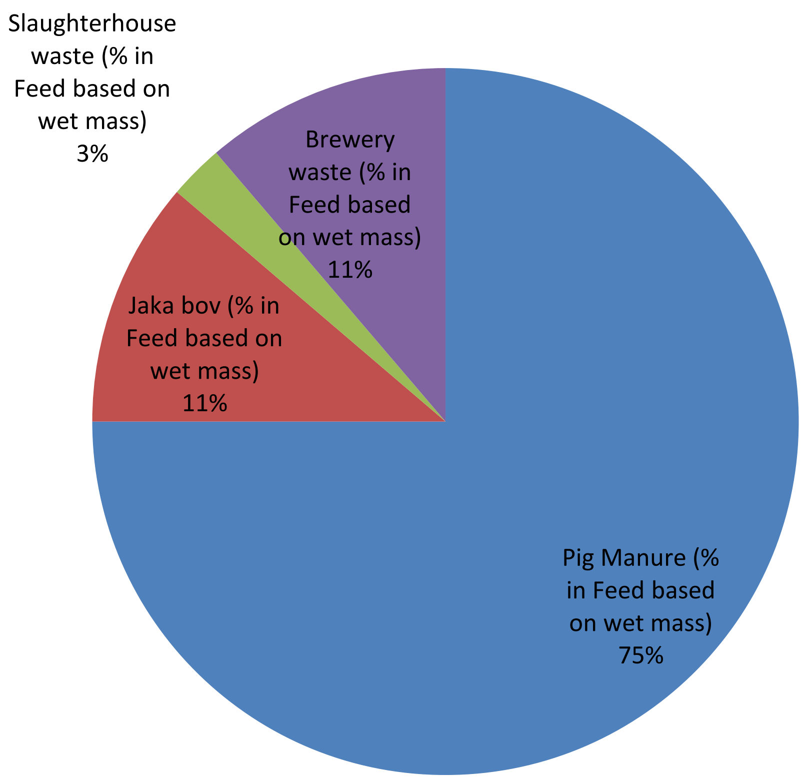
Materials and methods

1. Methane potentails (VDI 4630)
2. Dry matters and volatile solids
3. Total kjeldahl nitrogen
4. Volatile fatty acids
5. Gas concentration

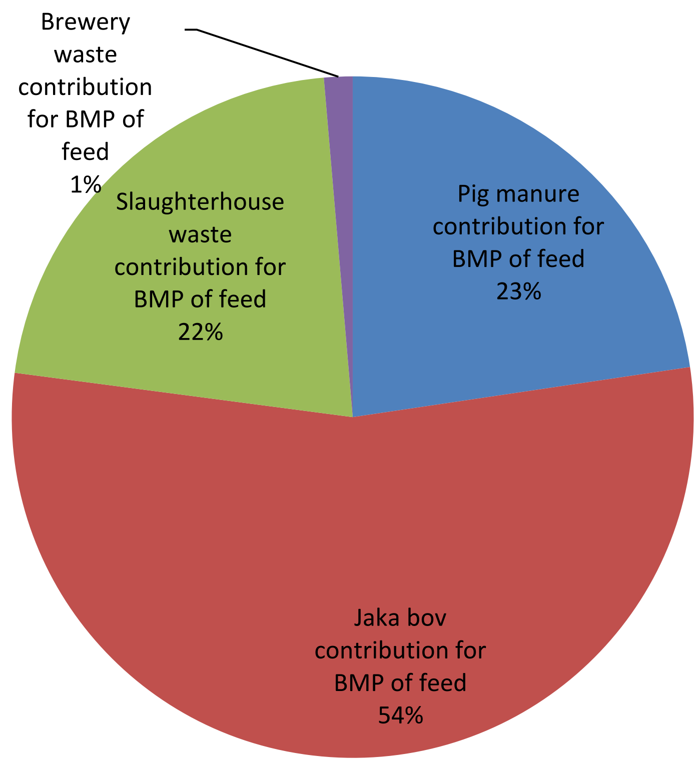
Input mass characterization

	DM (kg/tonne)	VS (kg/tonne)	TKN (kg/tonne)	TAN (kg/tonne)	VFA (kg/tonne)	BMP (Nm^3/tonne VS)	BP (Nm^3/tonne VS)
Pig manure	39.55	30.41	3.14	2.11	7.32	296.99	458.20
Jaka bov	278.71	239.08	18.82	1.68	0.00	605.24	905.69
Slaughterhouse waste	324.29	314.20	7.66	1.66	2.53	821.24	1207.74
Brewery waste	7.74	6.23	0.09	0.13	0.29	577.42	875.76
Digester feed	70.00	58.26	4.67	1.83	5.58	513.34	770.85

Input mass contributions

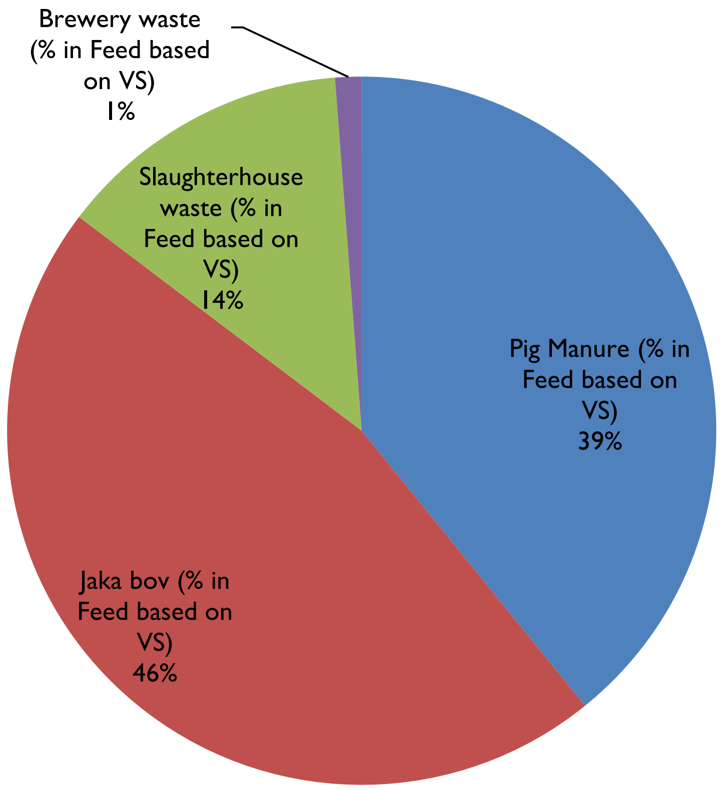


(% in Feed based on wet mass)

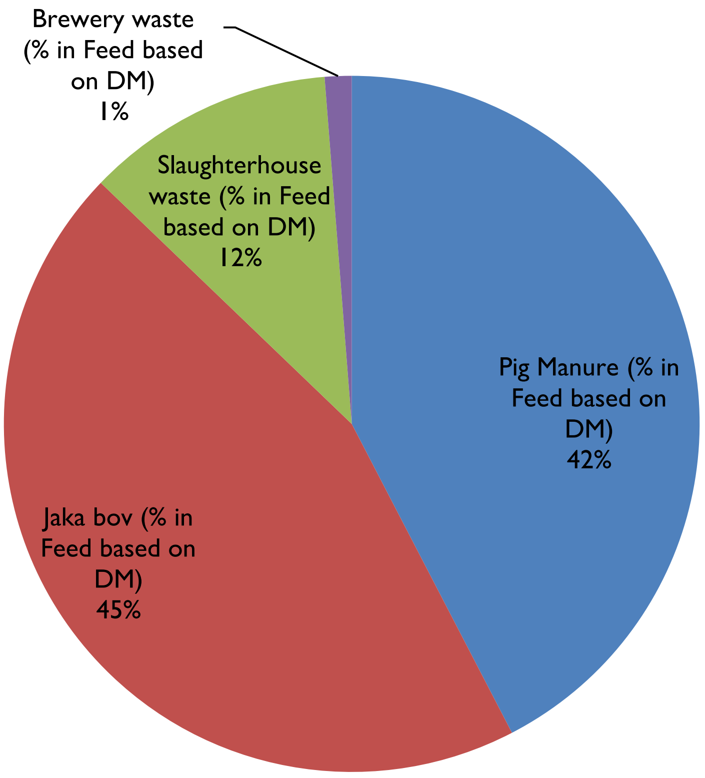


Contributions for BMP of feed

Input mass contributions



(% in Feed based on VS)



(% in Feed based on DM)

Modelling of methane production

Linear relationship between methane production and organic loading rate

$$y_{CH4} = y_{CH4}^{max} . \left(1 - \frac{OLR}{OLR^{max}}\right)$$

$$y_{CH4} = y_{CH4}^{max} . \left(1 - \frac{HRT_c}{HRT}\right)$$

$$r_{CH4} = y_{CH4}^{max} . c_0 . \left(\frac{1}{HRT} - \frac{HRT_c}{HRT^2}\right)$$

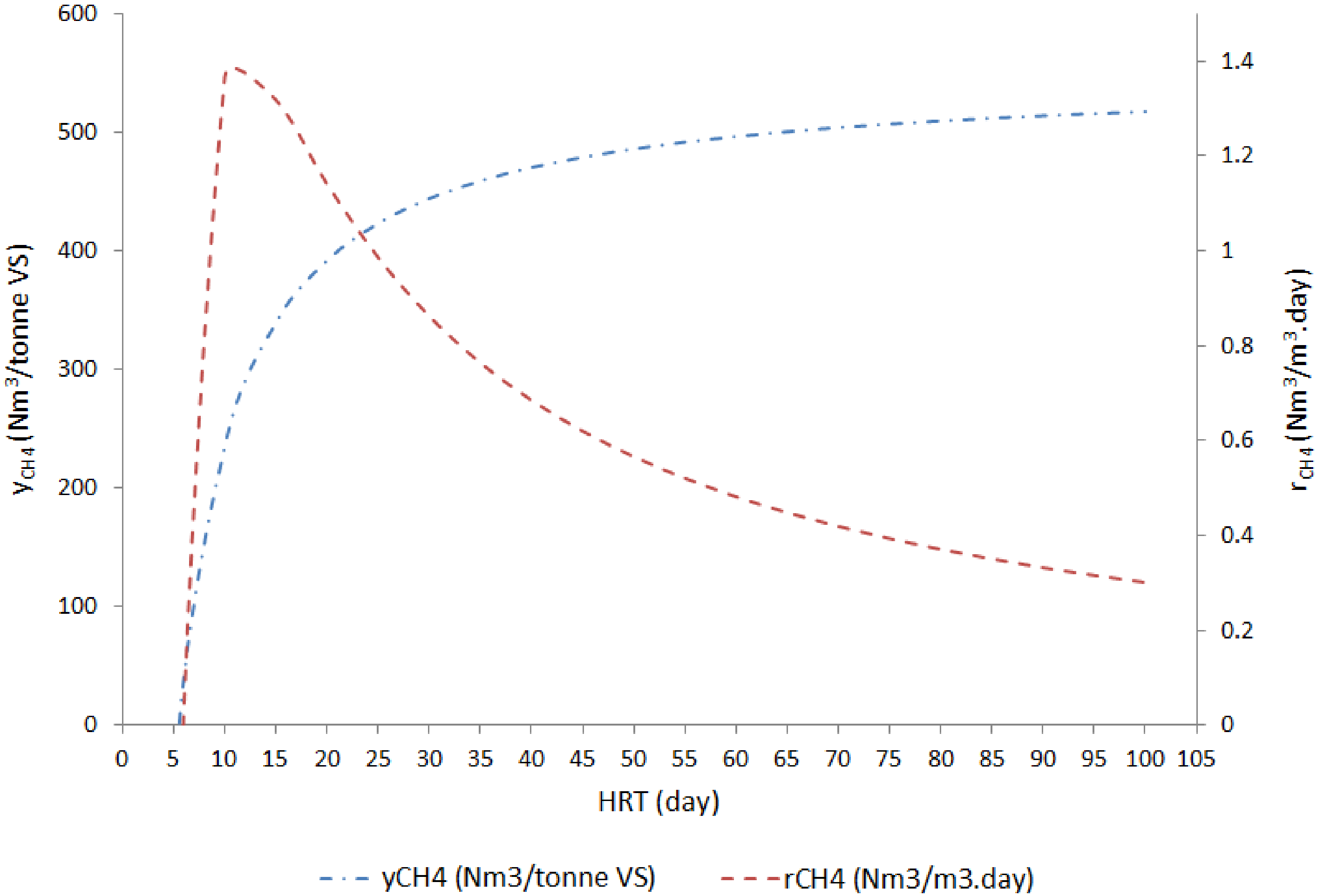
Modelling of methane production

$$y_{CH4} = 548.89\left(1 - \frac{OLR}{10.181}\right)$$

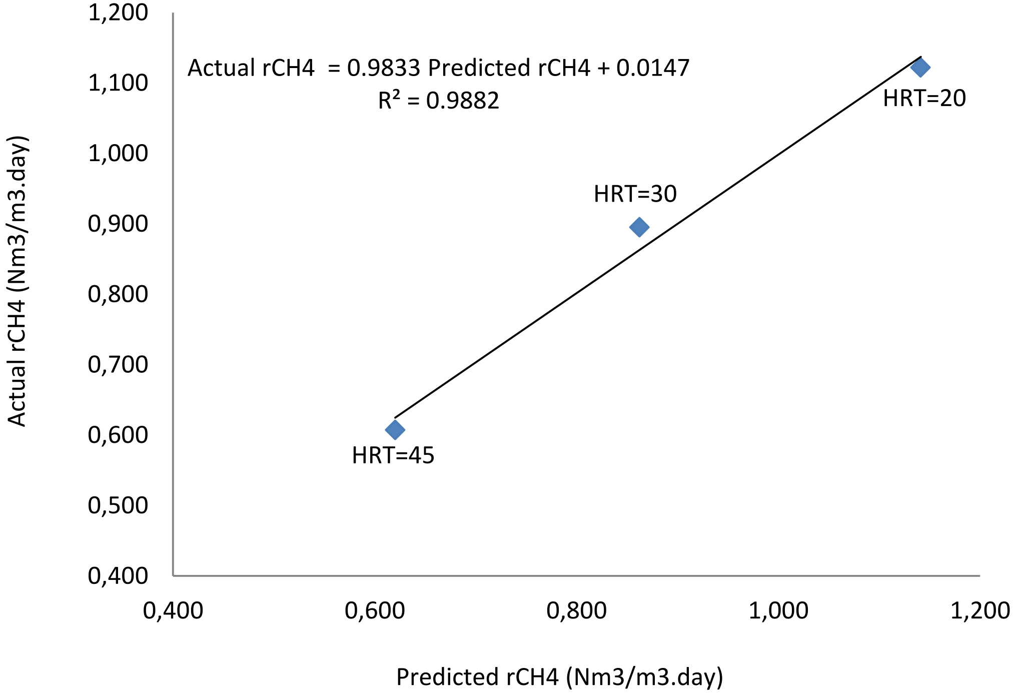
$$y_{CH4} = 548.89\left(1 - \frac{5.723}{HRT}\right)$$

$$r_{CH4} = 31.98\left(\frac{1}{HRT} - \frac{5.723}{HRT^2}\right)$$

Modelling of methane production



Predicted VS actual results



	r_{CH4} (Nm^3/m^3.day)		
HRT (day)	Predicted	Actual	SD
20	1.141	1.122	0.014
30	0.863	0.895	0.023
45	0.620	0.607	0.009

Thanks for your attention

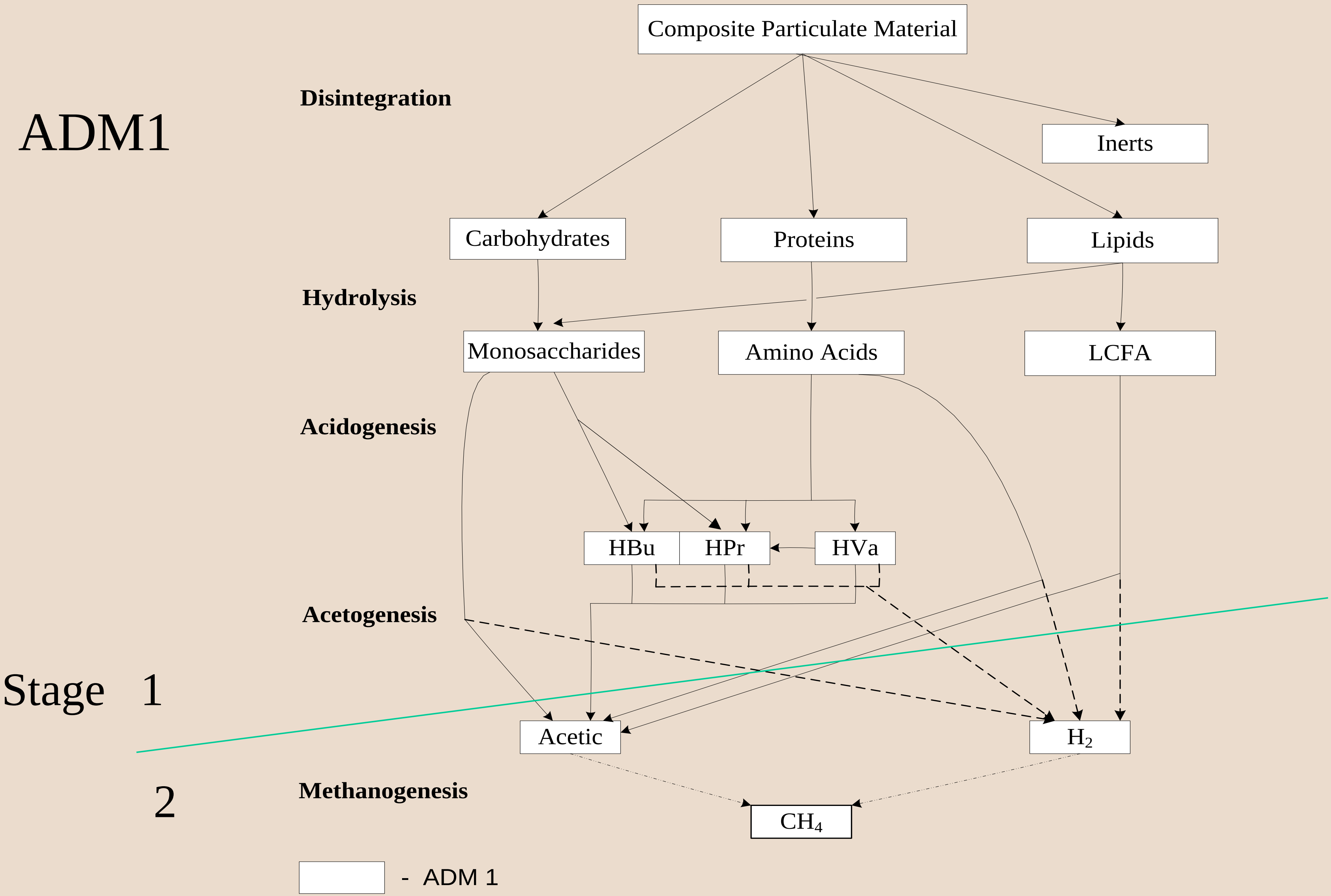
Telemark University College

Individual farm AD processes, why and how?

By

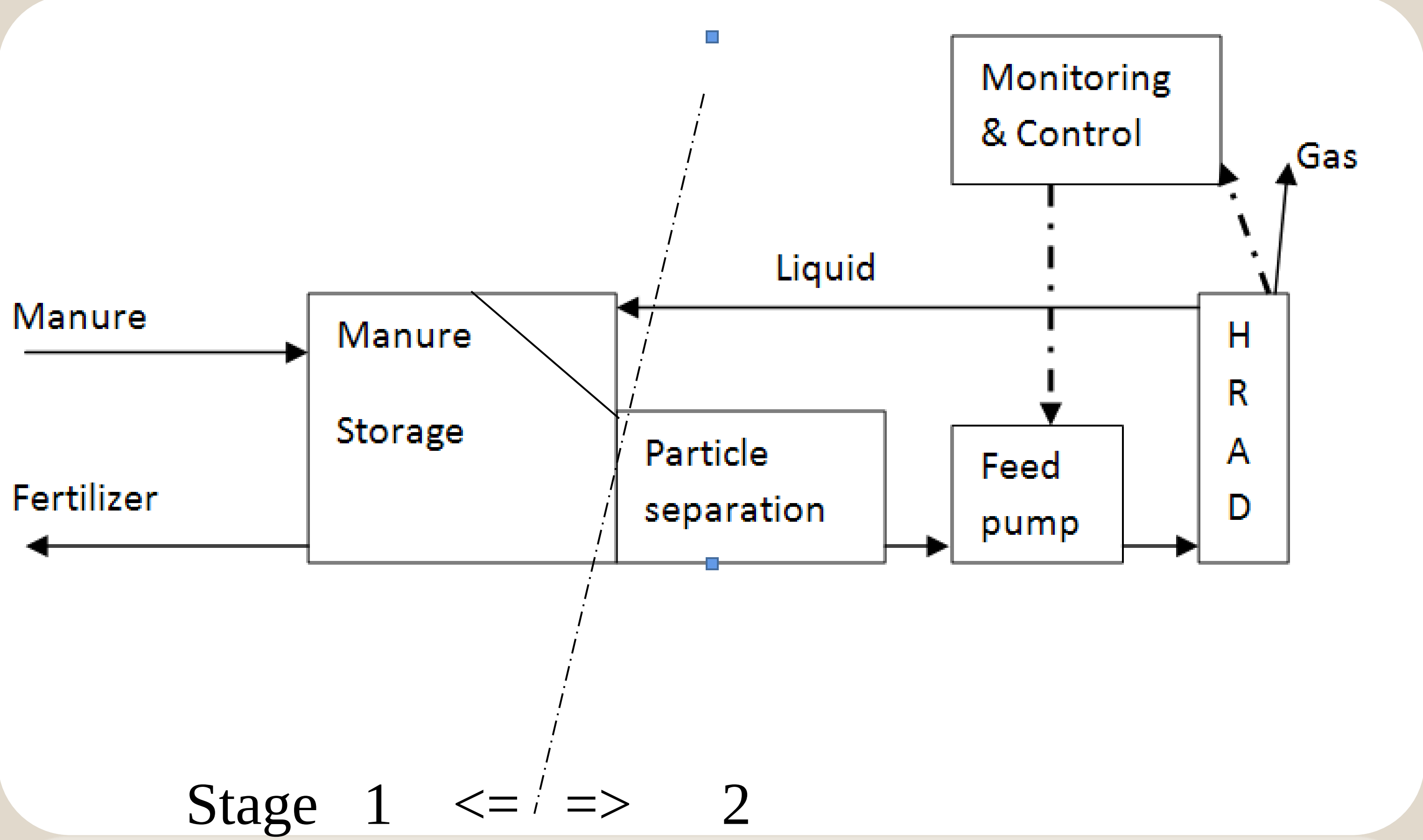
Jon Hovland, Mary Anderson-Glenna, Rune Bakke og Kari-Anne Lyng

ADM1

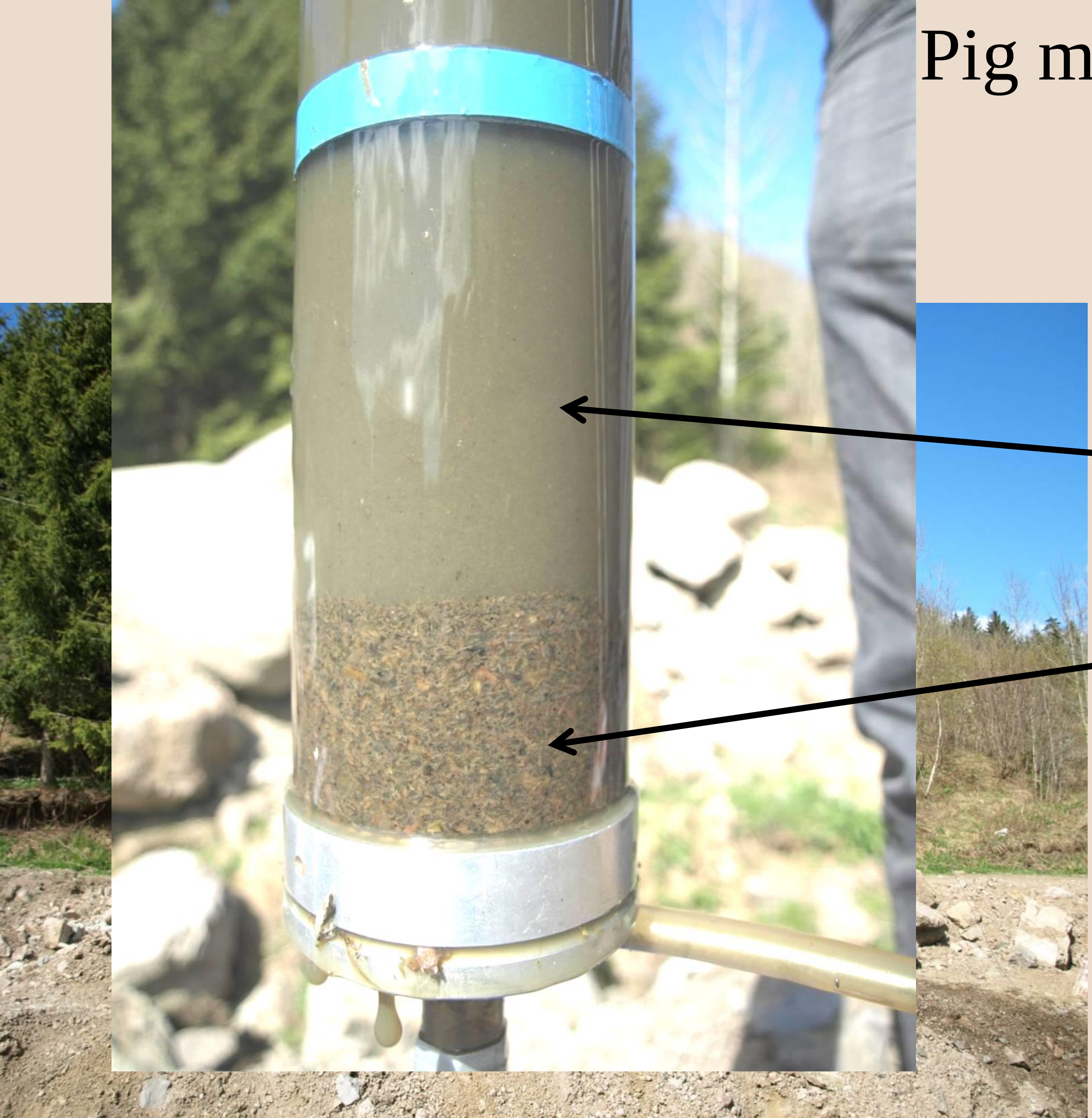


HBu – Butyric acid, HPr – Propionic acid, HVa – Valeric acid, LCFA – Long chain fatty acids

Two stage High Rate AD treatment Example manure:



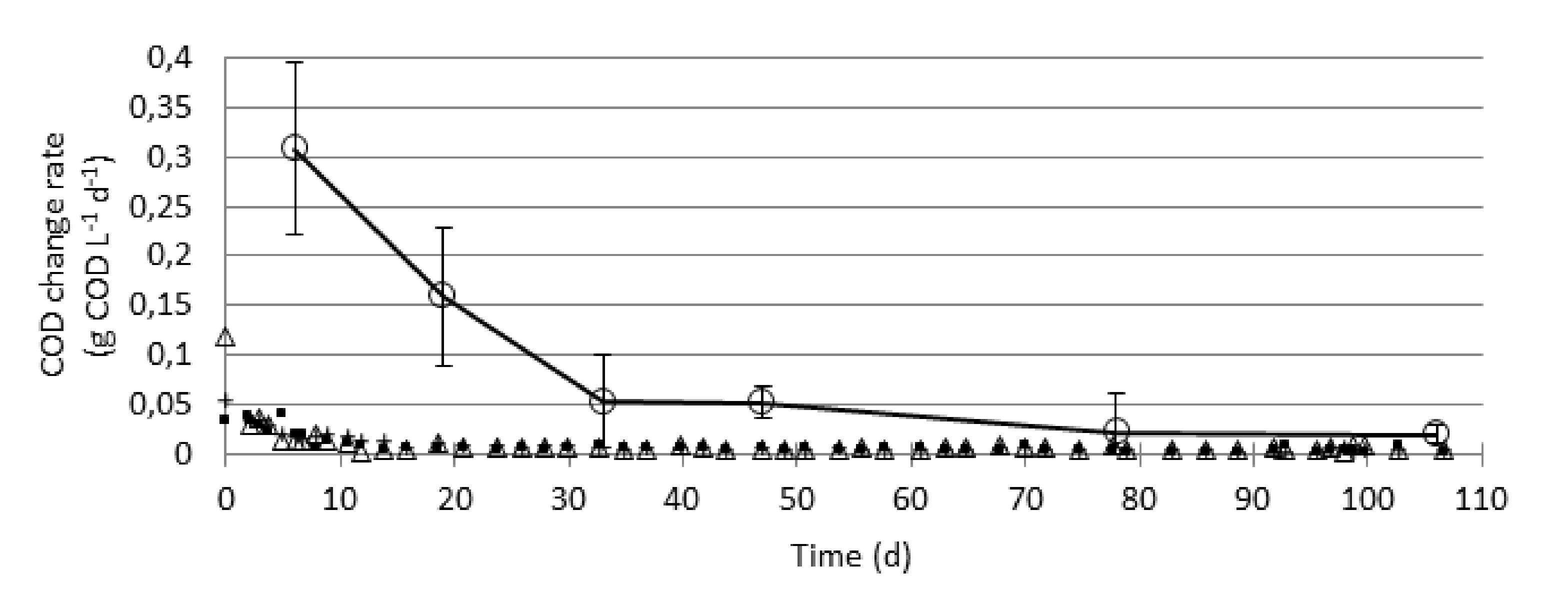
Pig manure



Suitable
UASB feed

Sediment
-Separated
by storage

Storage effects



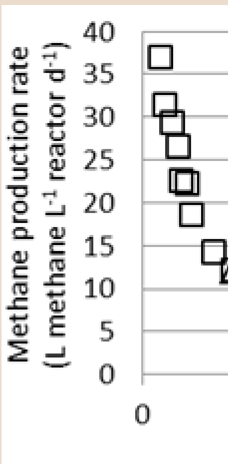
CODs (○) and Methane production during storage at 15 °C for Sows (■), Growers (Δ) and Farrow and weaners (+), and average change in CODs in the 3 manures.

UASB

(Upflow Anaerobic Sludge Blanket)
& similar High Rate AD

- SRT >> HRT
- Efficient; > 50 x trad. methods
  =>Compact => Cheap
- Diffusion limited; Low temp is ok
- Stable
- Flexible; production on demand

Hyper manure AD (Settled pig manure used as feed)



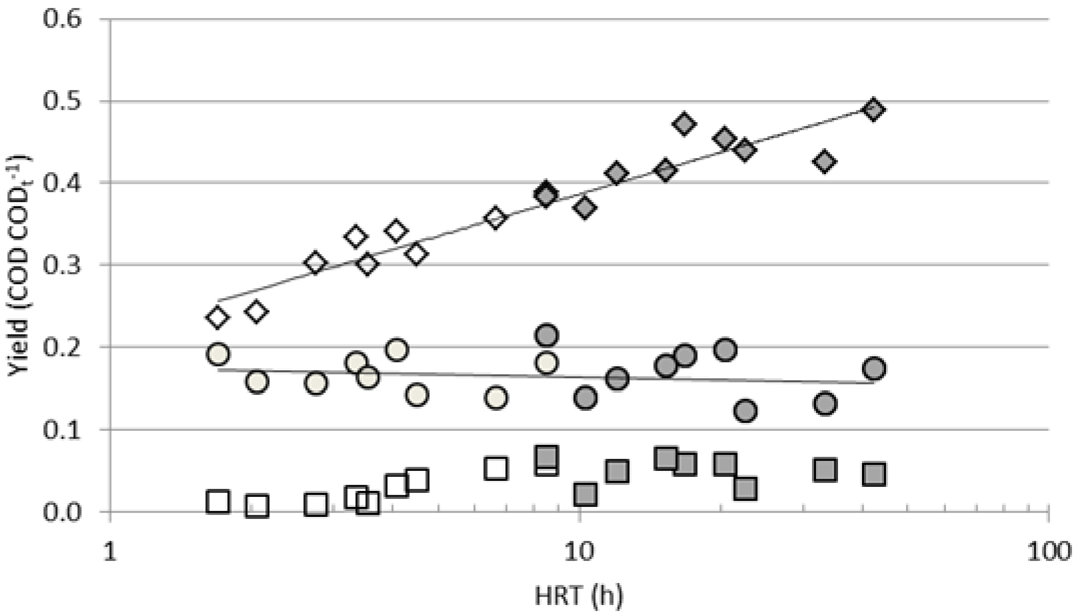
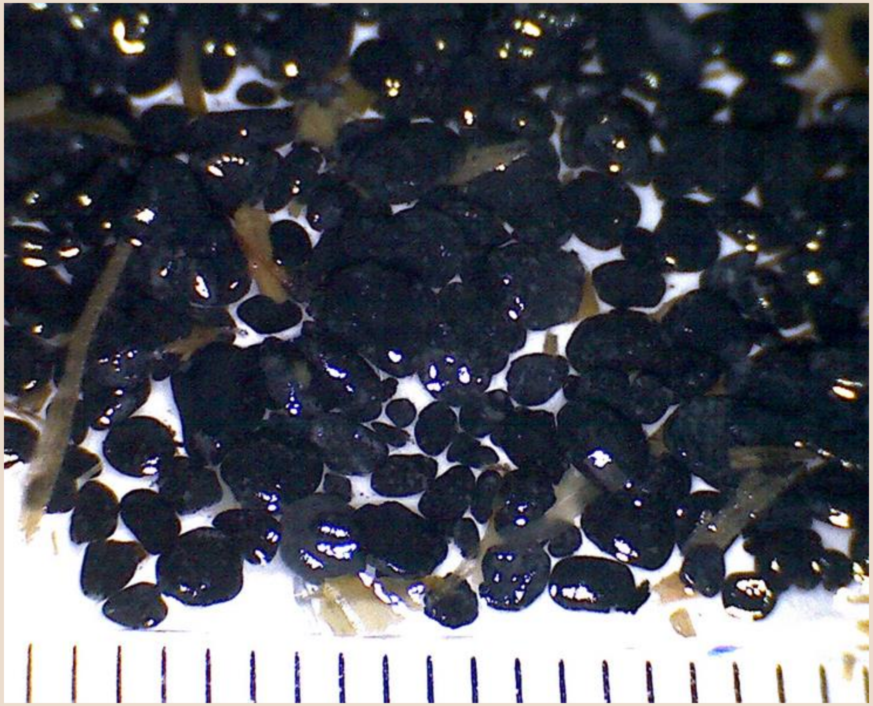


Figure 4. Produced biogas (◊), removed acetate (○) and removed propionate (□) as yield of influent COD_T. Medium rate symbols are filled and high rate symbols are unfilled.

Granuler: Naturlig, selv-genererende biologisk katalysator
(0,1 – 7 mm diameter)

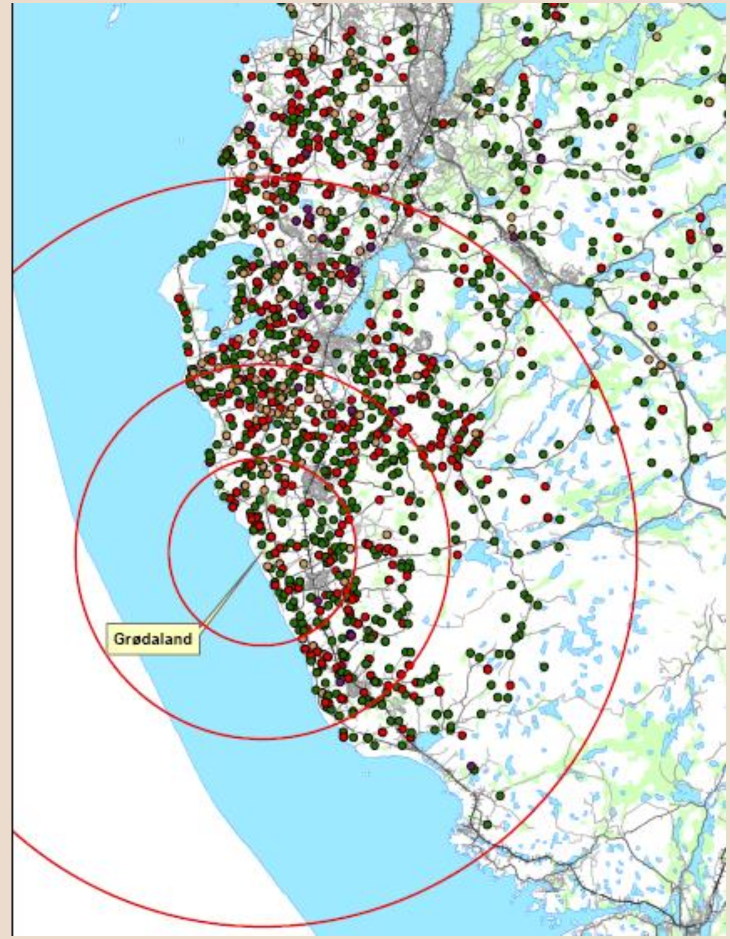
Saugbrugs
(startmateriale)



ABR på grisemøkk

Rogaland Pilot

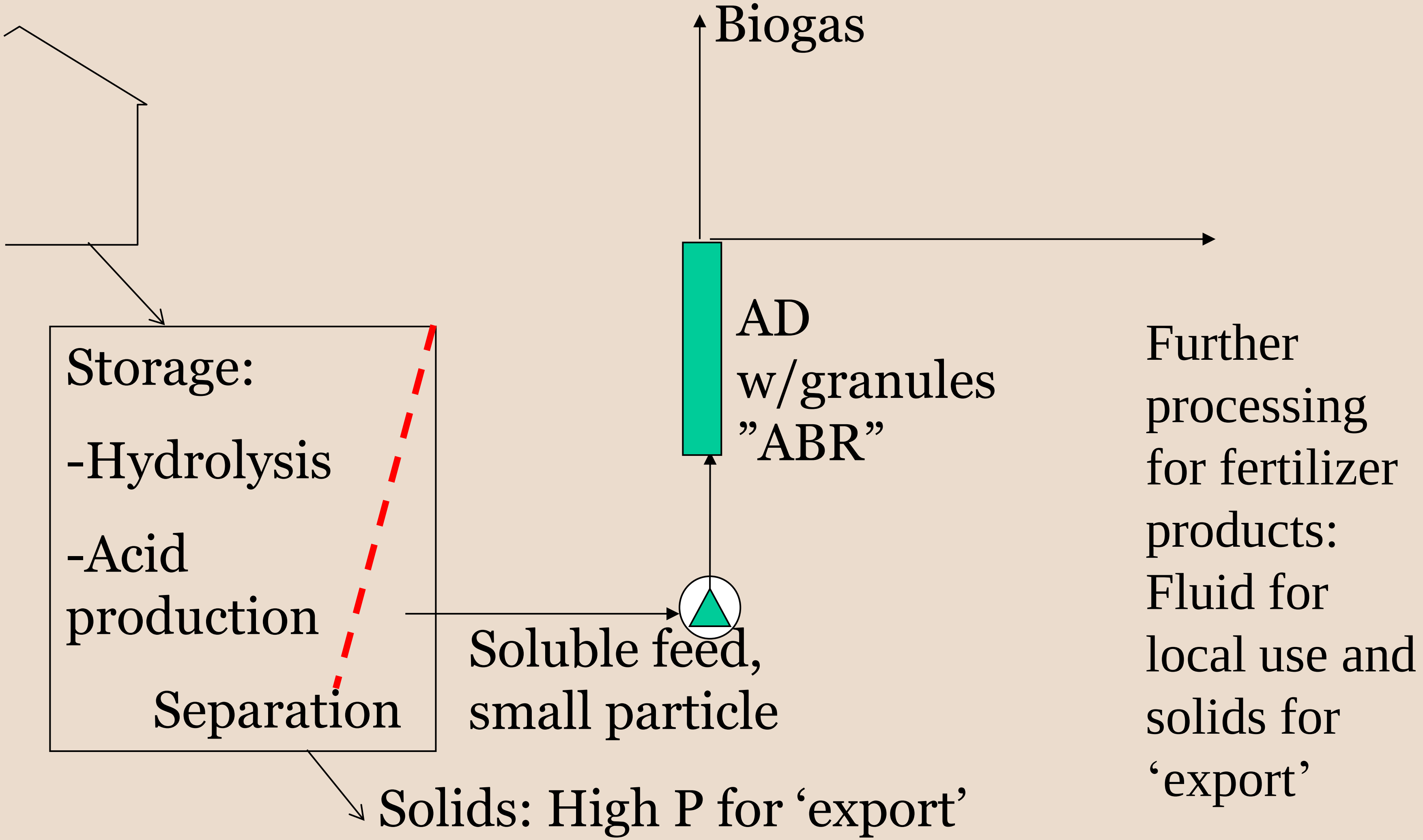
Upgrading plant



Manure sources

Biogas pipe: Green line

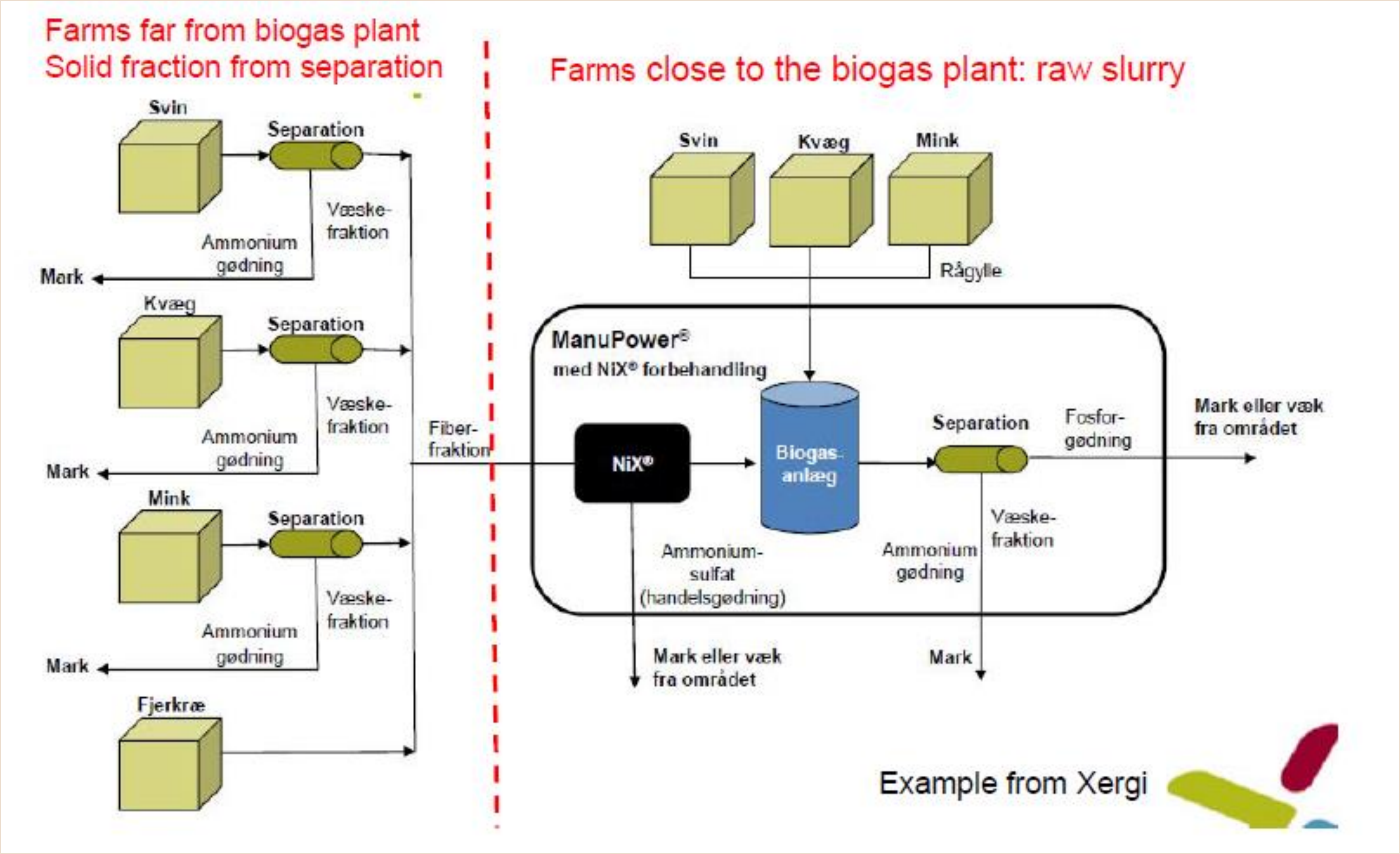
Possible connections between storage, reactor, AD and nutrients



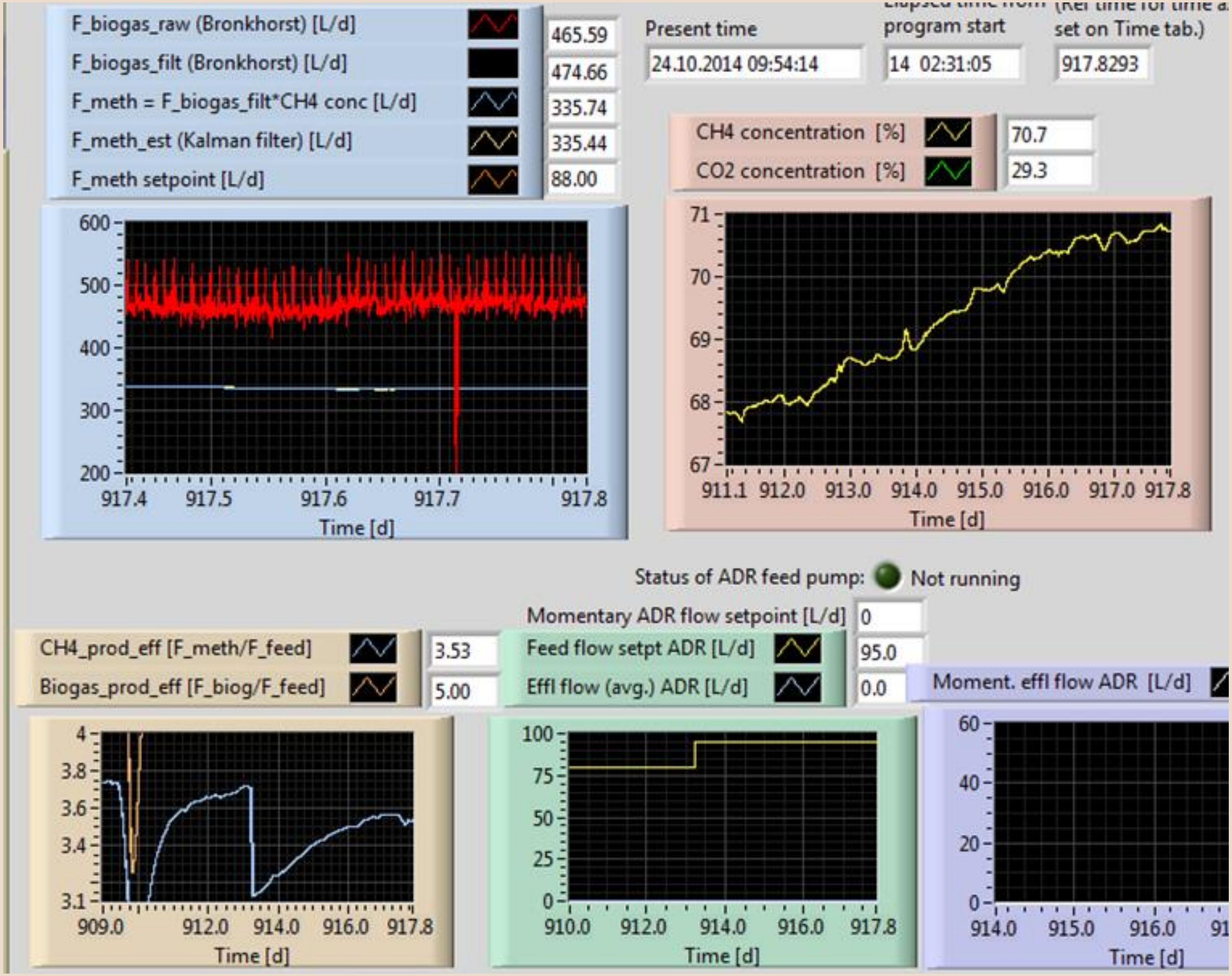
ABR 2.3 «Plug & Play»

Support slides follows

DK

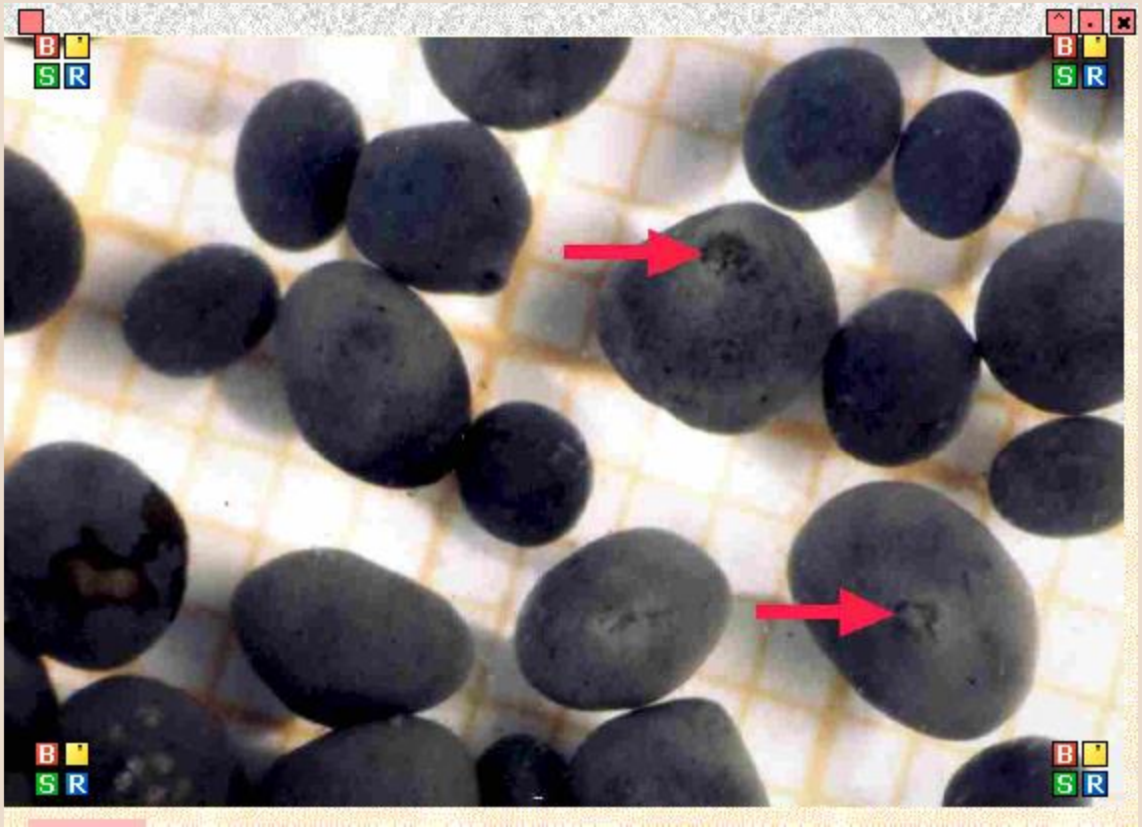

Farms far from biogas plant
Solid fraction from separation
Farms close to the biogas plant: raw slurry
Svin
Separation
Væske-
fraktion
Ammonium
gødning
Mark
Kvæg
Separation
Væske-
fraktion
Ammonium
gødning
Mark
Mink
Separation
Væske-
fraktion
Ammonium
gødning
Mark
Fjerkræ
Fiber-
fraktion
Svin
Kvæg
Mink
Rågylle
ManuPower®
med NiX® forbehandling
NiX®
Biogas-
anlæg
Separation
Fosfor-
gødning
Mark eller væk
fra området
Væske-
fraktion
Ammonium-
sulfat
(handelsgødning)
Ammonium
gødning
Mark eller væk
fra området
Mark
Example from Xergi

Foss 24.10.2014



Granules; Natural, self-generating biological catalysts

(0,1 – 7 mm diameter)

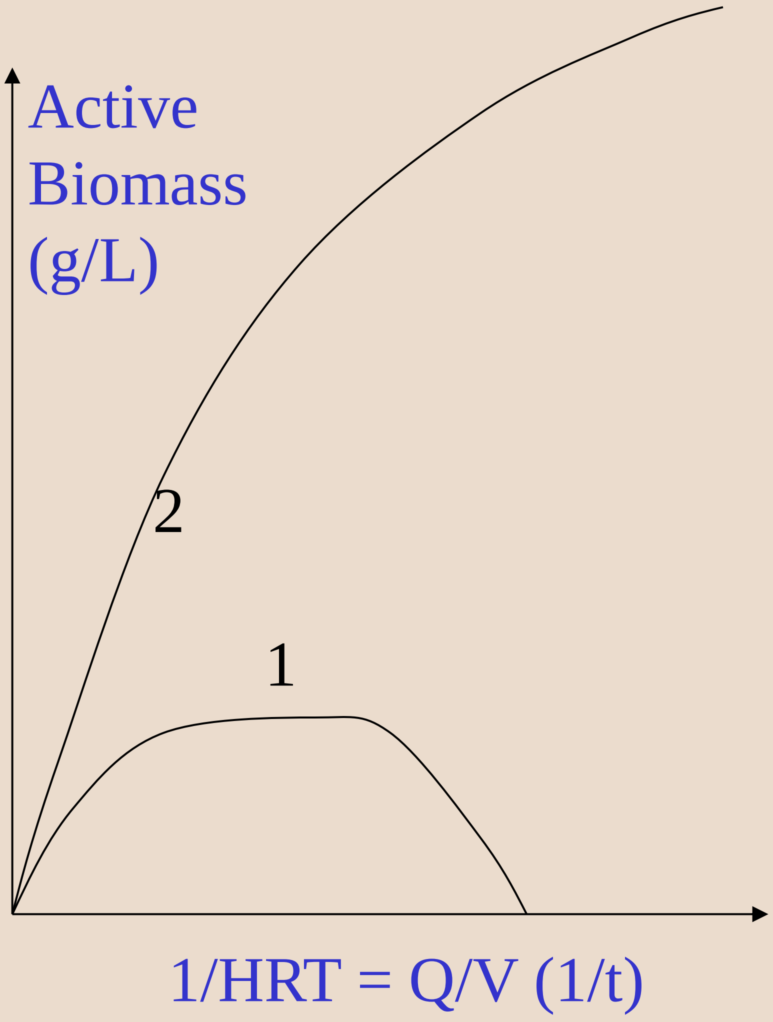


Retention time and growth rate

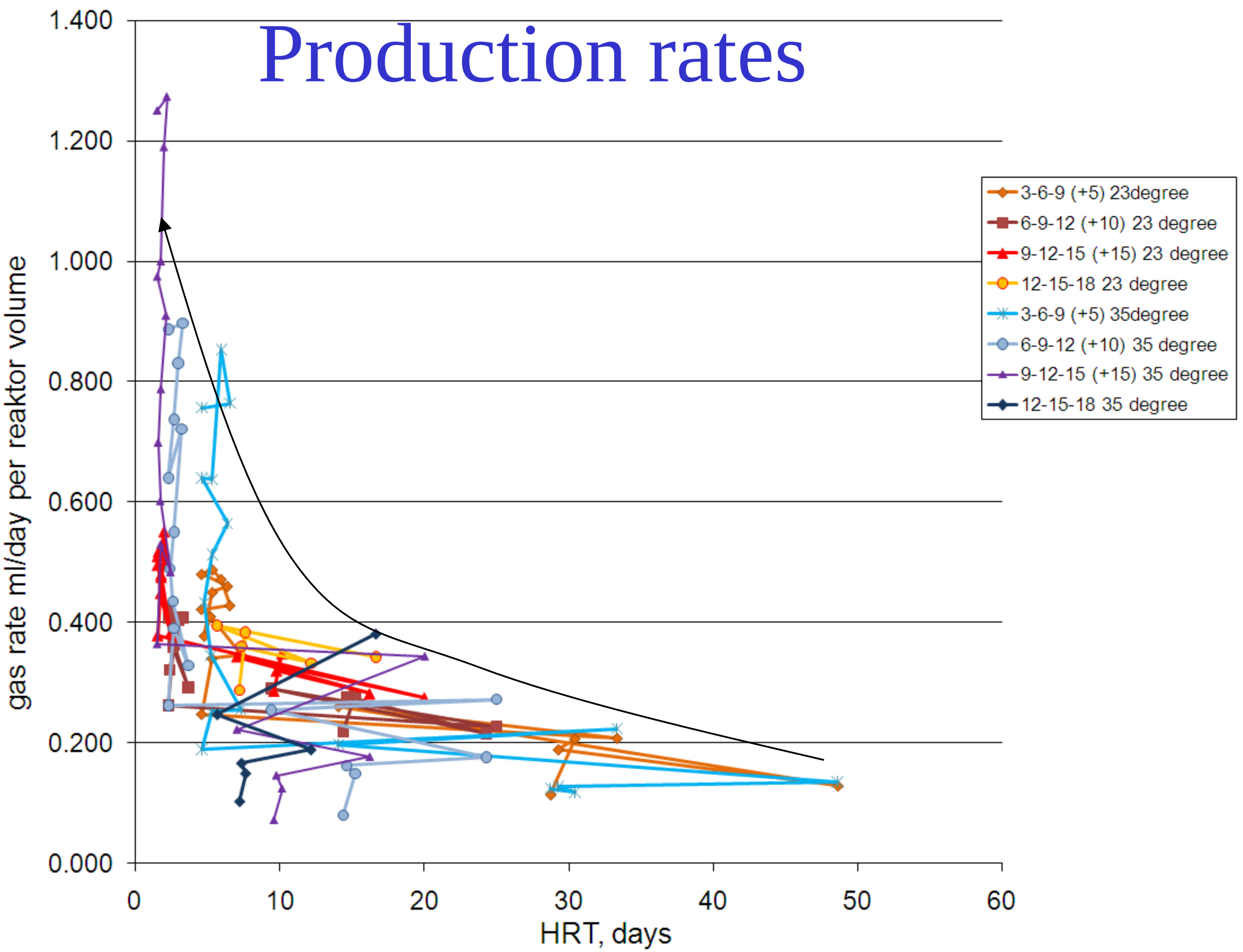
- Limiting factors: Low growth rates
  - Need Generation time of 10 – 50 d

    => “Sludge age” (SRT) > 50 d

1. when SRT = HRT => Large reactor V
2. when SRT >> HRT => Small reactor V
   - Our research focus



Production rates

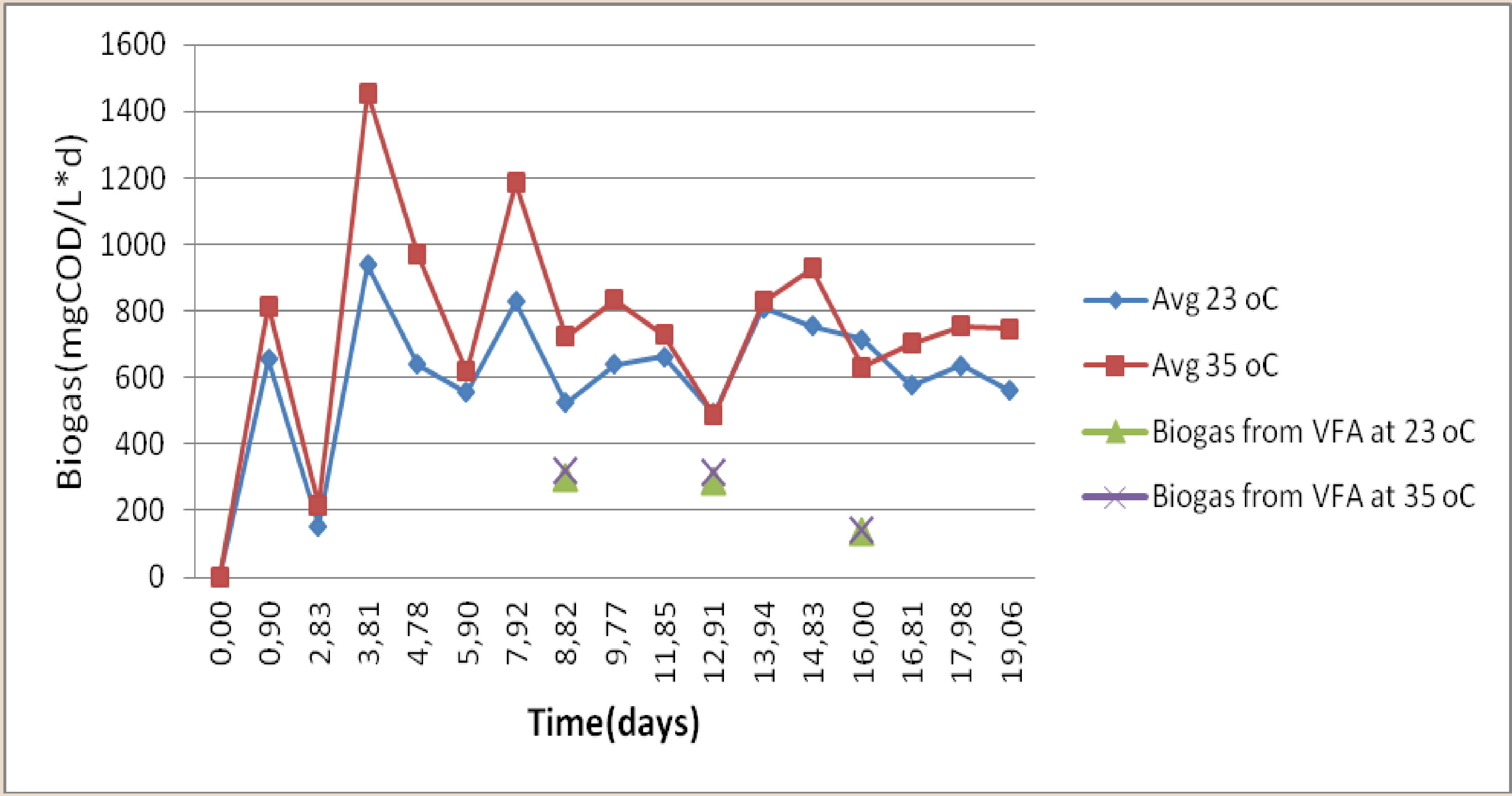


- Measured production in 8 reactors.
- Test increasing load; reduced HRT
- Feed – pig manure

=> SRT >> HRT and Adaptation to high ammonium

Pilotanlegg i Bjørkedalen

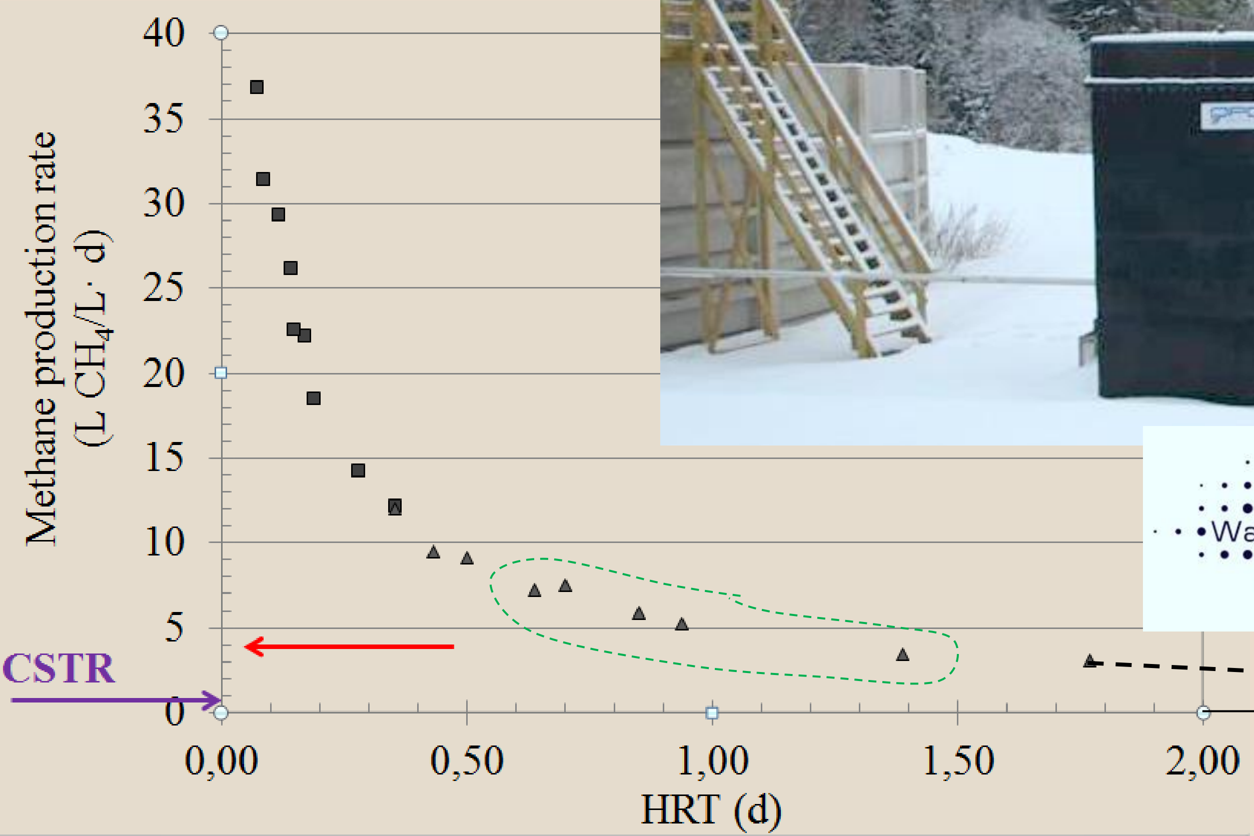
Temperature Effect on Production



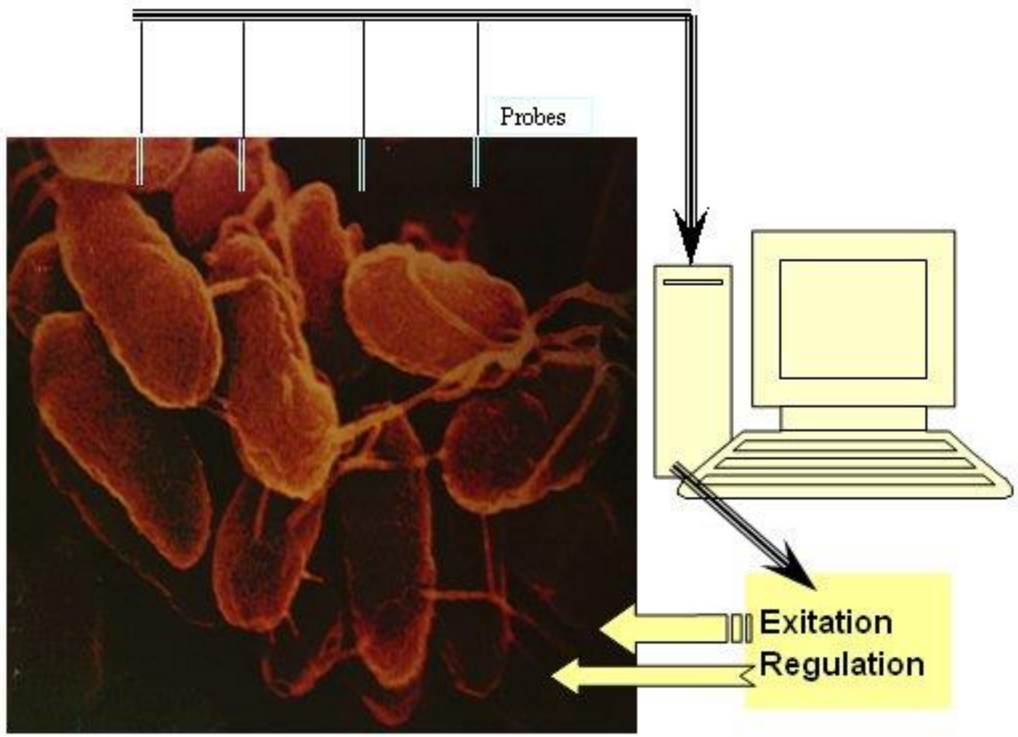
Feed: Gravitation separated pig manure

Kostnadseffektive små biogassanlegg for VA slam

- ABR: SRT >> HRT



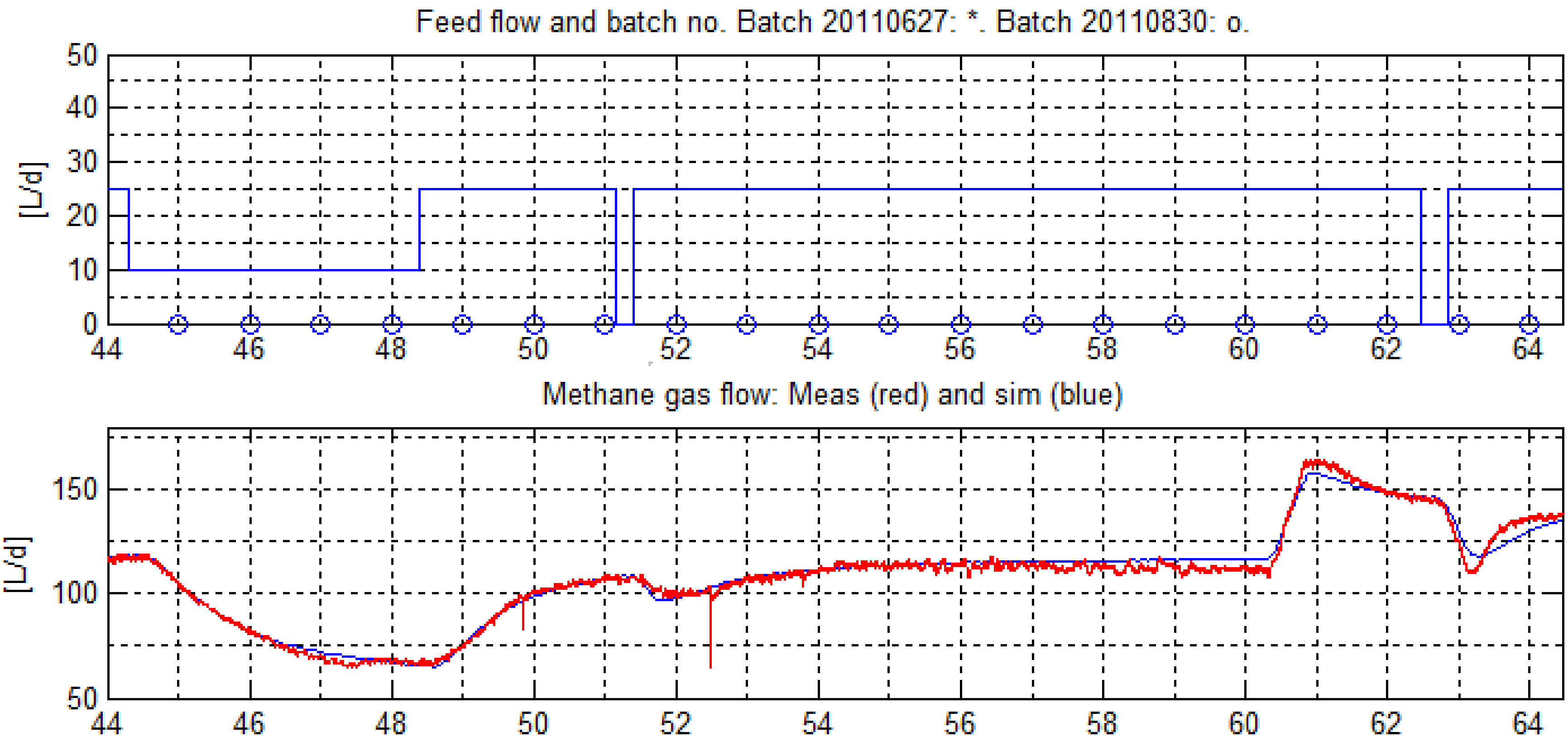
"CYBUG"

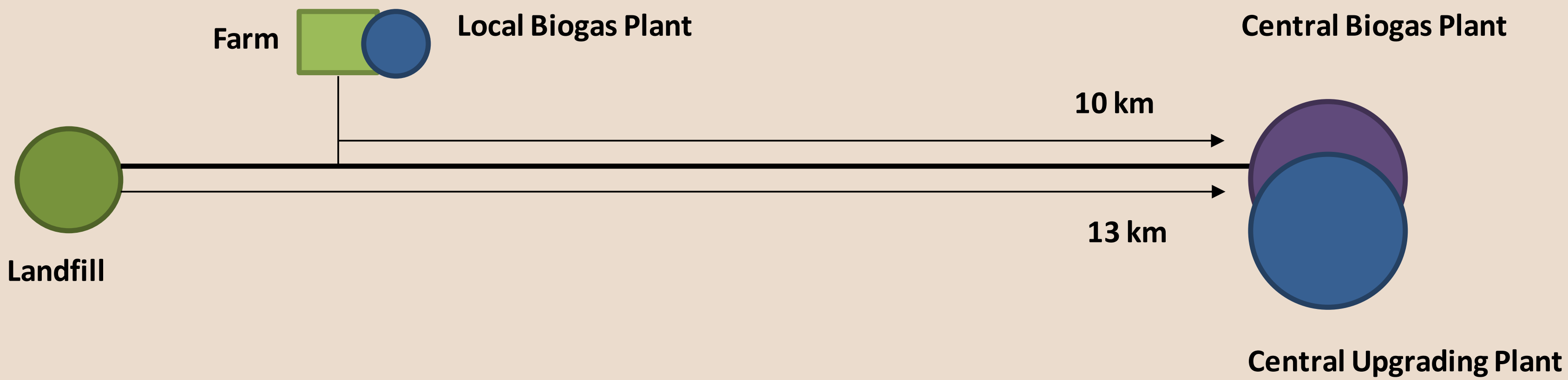


Foss141011

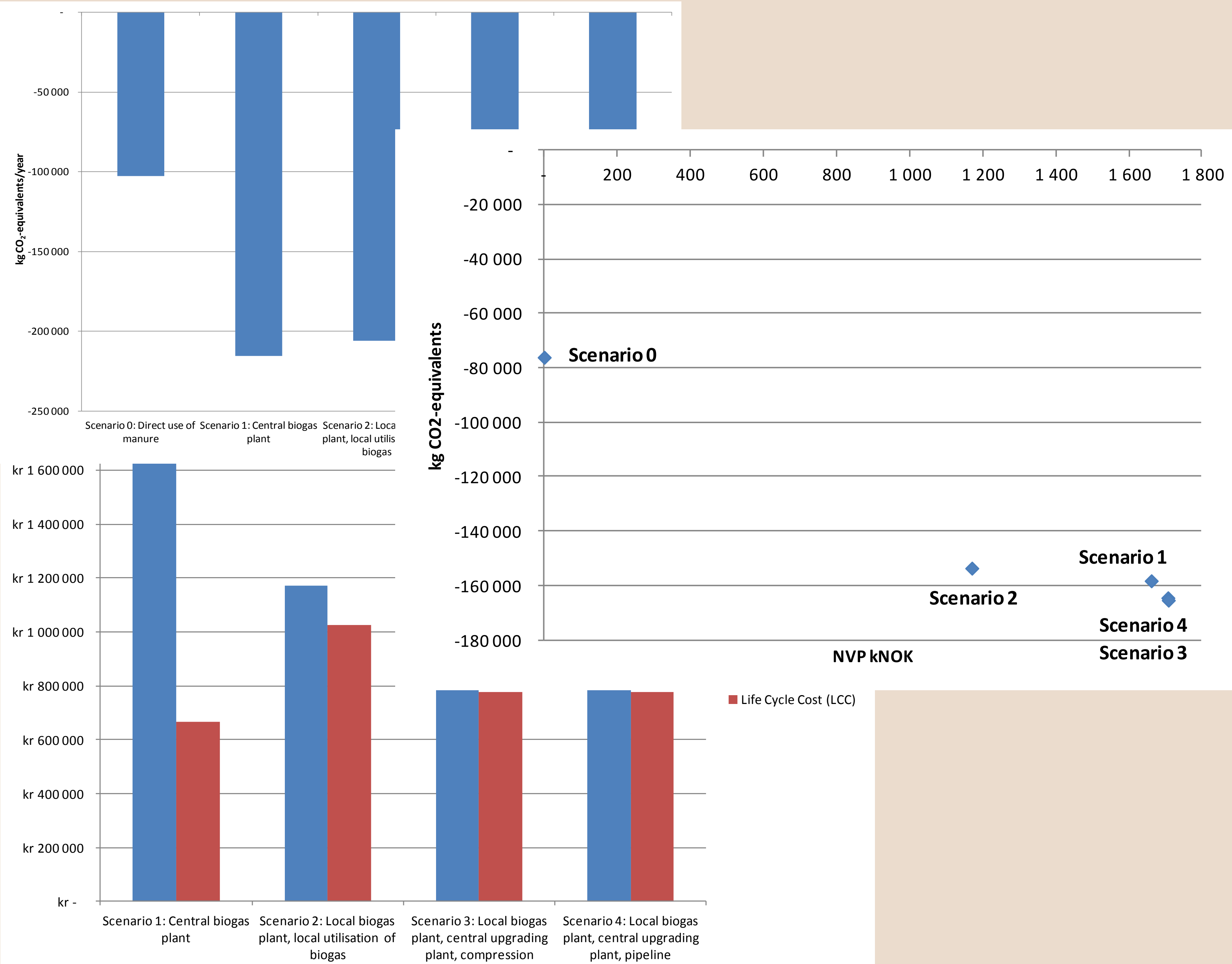

https://fossfarm-nitklfesde.app03-12.logmein.com/main.html
Show Compact View
Dashboard
Remote Control
File Manager
File Sharing
Desktop Sharing
Chat
Computer Management
Computer Settings
Scheduling & Alerts
Performance Info
Preferences
Help
Disconnect
LogMeIn Pro
FOSSFARM
QuickLinks
Options
LogMeIn - Remote Session
biogasreactor_foss_22_sept_2011.vi
File Edit View Project Operate Tools Window Help
Biogas reactor (Foss farm)
Finn Haugen (finn.haugen@hit.no)
22. September 2011
Stop program
Batch code (yyyymmdd)
20110830
Present time
14.10.2011 09:56:54
Elapsed time from start
22 00:39:56
Temp reactor [deg C]
29.92
Temp reservoir [C]
3.22
Temp room [C]
10.94
Reactor temp setpoint is set on West controller in cabinet.
Writing data to file to LVM and TDMS files:
Folder must exist, but file name(s) may be new.
File of same name will be overwritten!
Writing data to file:
File Name (logfile_started_yyyy_mm_dd):
Start writing
Stop writing
C:\biogas\logfiles\logfile_started_2011_09_22.lvm
TDMS file Name (type your file name here):
C:\biogas\logfiles\logfile_started_2011_09_22.tdms
Gas clock flow [L/d]
227.40
Gas flow (Bronkhorst) raw [L/d]
190.54
Gas flow (Bronkhorst) filt [L/d]
198.79
Gas volume [L]
3569.700
Momentary gas clock flow [L/d]
229.4
Feed flow setpoint [L/d]
25.00
CH4 concentration [%]
73.5
CO2 concentration [%]
26.5
Feed flow setpoint [L/d]
Feed pump control [V]
1.47238
Effluent volume [L]
487.1
Momentary effl. flow [L/d]
23.2
Daily effluent flow [L/d]
22.5
CH4 flow=Gas flow filt*CH4 conc [L/d]
146.05
Time [d]

Measured and simulated CH4 production; Load and temperature transitions





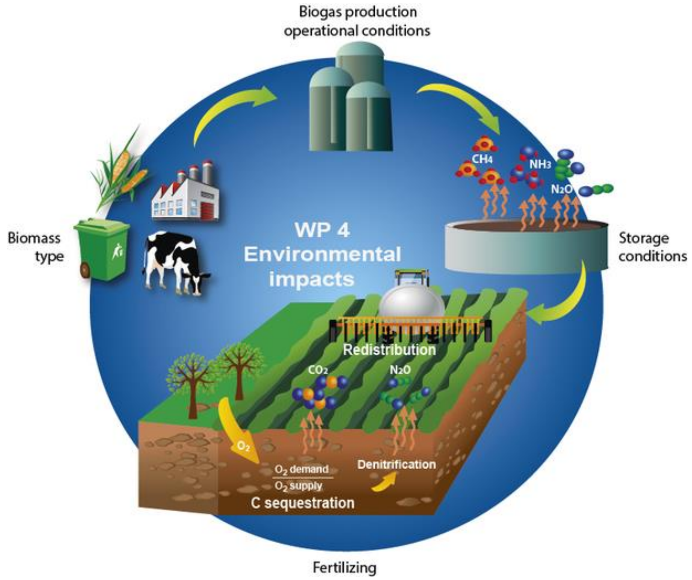
Scenario 0: Direct use of manure (replaces mineral fertilizers).
Scenario 1: Central biogas plant with central upgrading of the biogas to fuel quality (the farmers deliver manure and get back digestate).
Scenario 2: Local biogas plant, local utilization of biogas (replaces heat).
Scenario 3: Local biogas plant, central upgrade plant. Compression and transportation of biogas to upgrading plant.
Scenario 4: Local biogas plant, central upgrade plant. Transportation of produced biogas through pipeline network to upgrading plant.



kg CO2-equivalents/year
-
-50 000
-100 000
-150 000
-200 000
-250 000
Scenario 0: Direct use of manure
Scenario 1: Central biogas plant
Scenario 2: Loca plant, local utilis biogas
kr 1 600 000
kr 1 400 000
kr 1 200 000
kr 1 000 000
kr 800 000
kr 600 000
kr 400 000
kr 200 000
kr -
Scenario 1: Central biogas plant
Scenario 2: Local biogas plant, local utilisation of biogas
Scenario 3: Local biogas plant, central upgrading plant, compression
Scenario 4: Local biogas plant, central upgrading plant, pipeline
Life Cycle Cost (LCC)
kg CO2-equivalents
NVP kNOK
200
400
600
800
1 000
1 200
1 400
1 600
1 800
-20 000
-40 000
-60 000
-80 000
-100 000
-120 000
-140 000
-160 000
-180 000
Scenario 0
Scenario 1
Scenario 2
Scenario 4
Scenario 3

CO_2 and N_2O emission from digestates of co-digestion pig slurry and sugar beet pulp silage after land application

Quan Van Nguyen, Khagendra Jaj Baral , Sander Bruun,
Søren O. Petersen



Contents

- Short-term incubation experiment
- Estimation of N_2O emission using a model in Sommer et al. (2004)

Sommer, S.G., Petersen, S.O., Møller, H.B., 2004. Algorithms for calculating methane and nitrous oxide emissions from manure management. Nutrient Cycling in Agroecosystems 69, 143-154.

Objectives

- To determine degradable volatide solid (VS_d), and none-degradable volatide solid (VS_{nd}) in digestates
- To quantify the dynamic of CO_2 evolution after digestates applied to agricultural soil
- To estimate N_2O emission based on VS_d and VS_{nd}

Hypotheses

- Higher degradable VS in digestates resulted from higher proportion of sugar beet pulp silage lead to larger CO_2 and N_2O emission after land application.

Materials

Table 1. Undigested materials and digestates for the incubation

	Treatments	Sugarbeet root pulp silage (%)	Pig slurry (%)
Co-digestated	PgSb0	0	100
	PgSb12.5	12.5	85.5
	PgSb25	25	75
	PgSb90	90	10
Undigestated	BrS	100	0
	PgS	0	100
	Ctrl	0	0

The digestates were produced in the Biomass Laboratory, Southern Denmark University, with a hydraulic retention time (HRT) of 20 d at 37°C

Soil

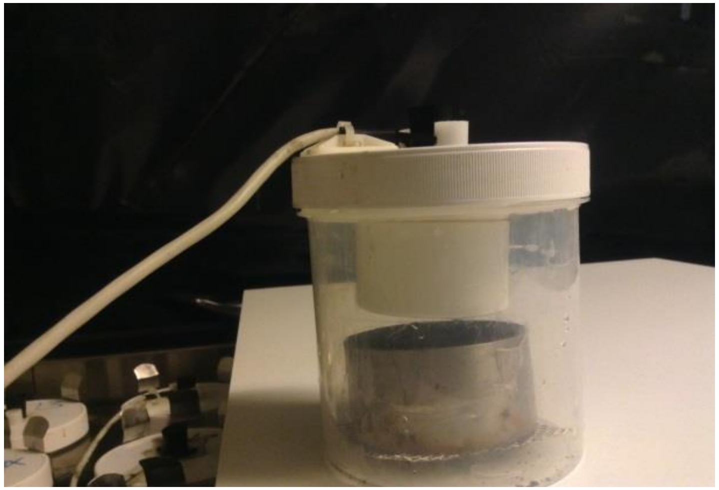
Top soil layer 0-25 cm, at Foulum gården Denmark , 10% clay content, sieved at 4mm.

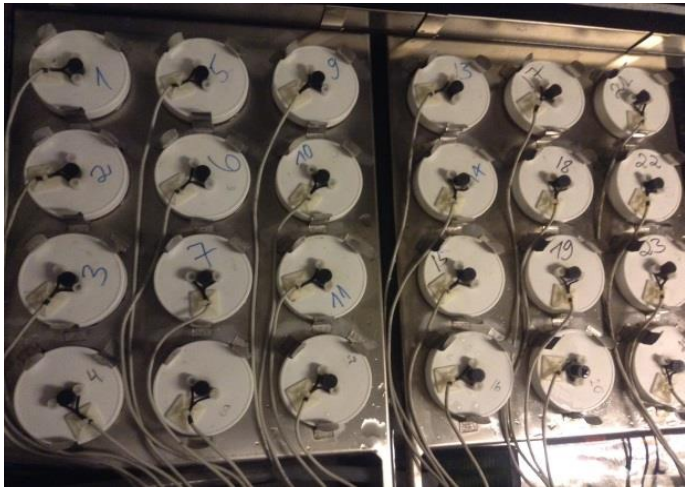
Table 1. Materials properties

Material	DM	Total VS		Total C		Total N		C:N
	%	g kg-1 DM	SE	% DM	SE	% DM	SE	
PgSb0	2.47	593.10	20.6	33.30	0.10	9.17	0.17	4
PgSb12.5	2.94	583.51	63.2	35.37	0.38	7.34	0.11	5
PgSb25	3.67	640.12	12.9	36.00	0.05	5.37	0.12	7
PgSb90	6.13	593.97	6.9	35.09	0.03	2.64	0.04	13
BrS	15.38	668.42	8.6	30.96	0.66	2.29	0.10	14
PgM	2.81	642.55	64.6	37.42	0.55	7.55	0.15	5
Soil	86.77			2.03	0.03	0.27	0.01	8

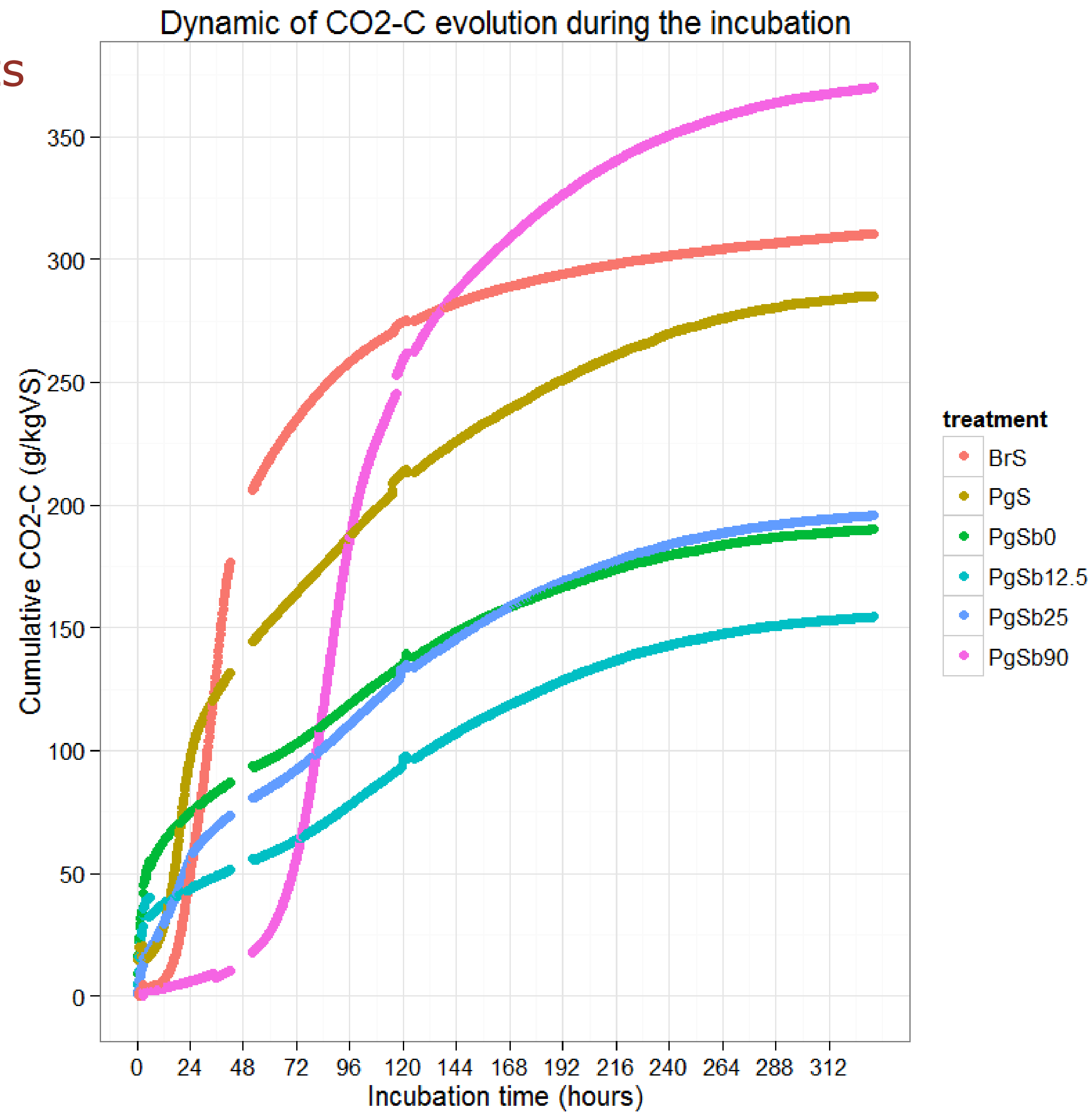
Incubation and CO2 measurement

- A bulk density of 1.2 g cm^{-3}, and final water-filled pore space (WFPS) of 40%,
- In the RESPICOND VI respirometer (A. Nordgren Innovation AB, Bygdeå, Sweden) at 20°C until CO_2 evolution rates were constant
- Alkaline (0.6 M) traps were replaced before 80% of the absorption capacity
- The concentration of CO_2, and cumulative CO_2 (mg) were measured in 15 minutes interval





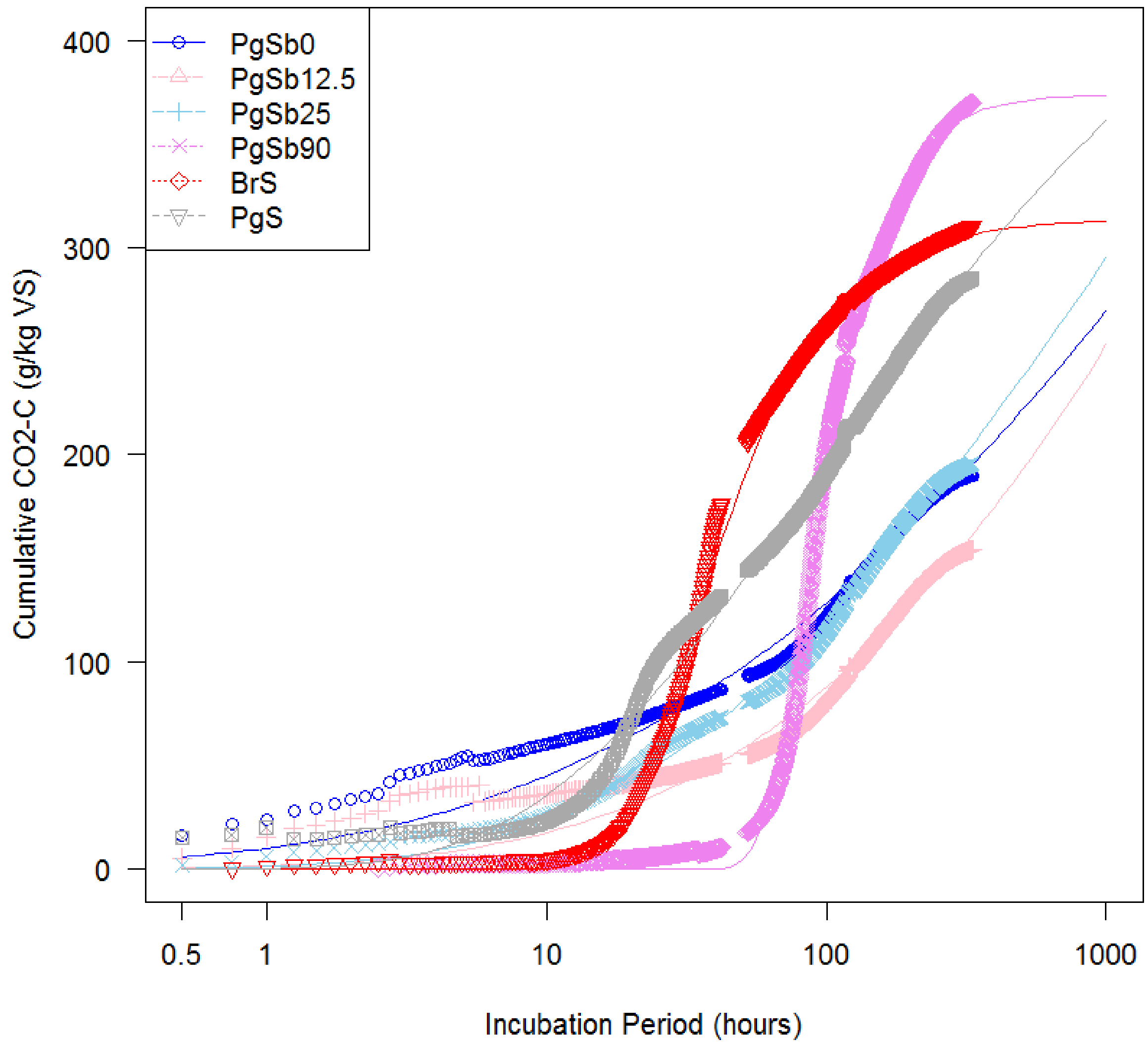
Results


Dynamic of CO2-C evolution during the incubation
Cumulative CO2-C (g/kgVS)
350
300
250
200
150
100
50
0
0
24
48
72
96
120
144
168
192
216
240
264
288
312
Incubation time (hours)
treatment
BrS
PgS
PgSb0
PgSb12.5
PgSb25
PgSb90

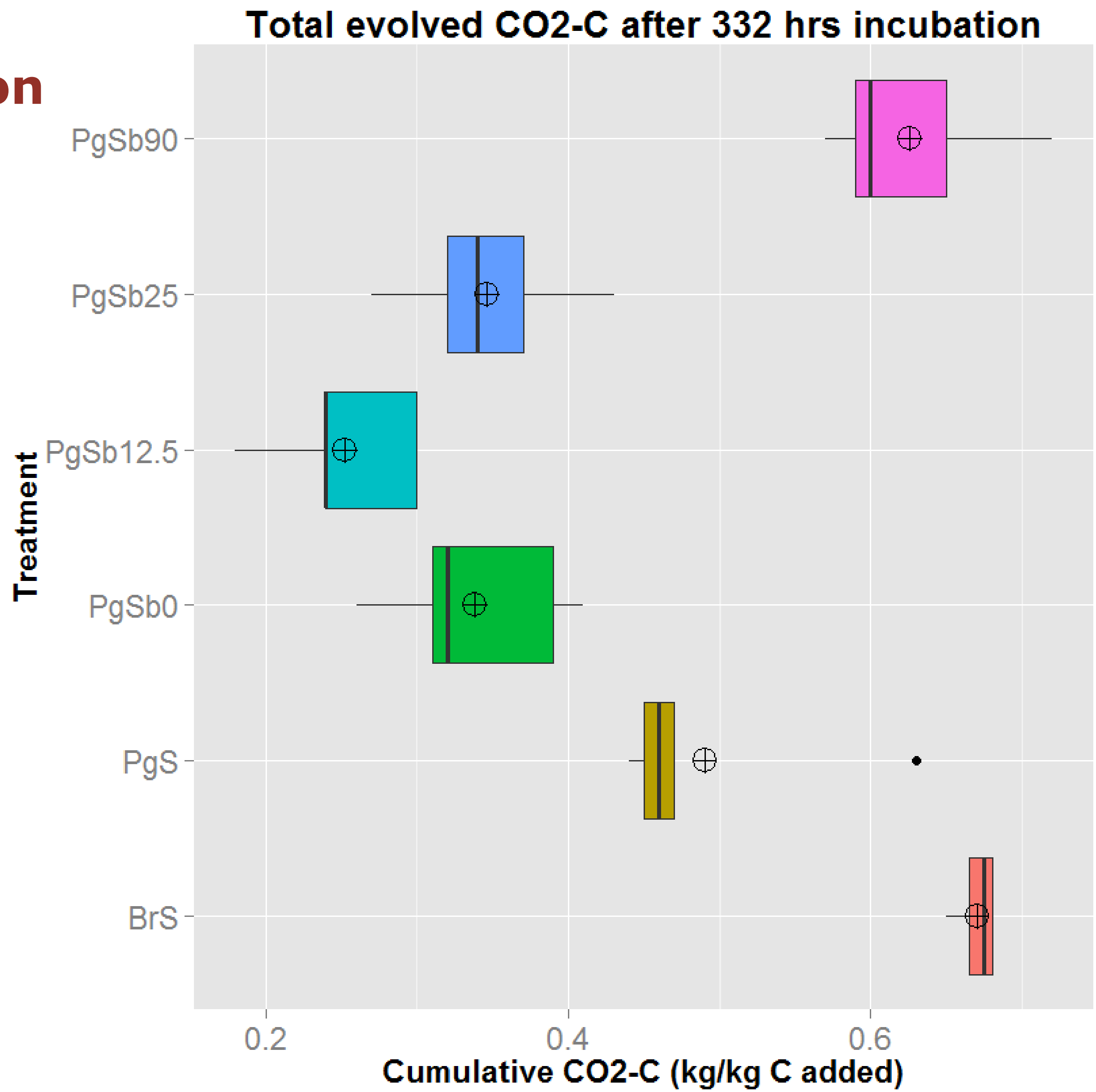
Dynamic of CO2 evolution

$$f(x) = 0 + (d - 0)/exp\left(-/\,exp\left(b(\frac{1}{log(x)} - e)\right)\right)$$

Fitted regression curves of cumulative CO2-C and incubation time



VS*d* fraction



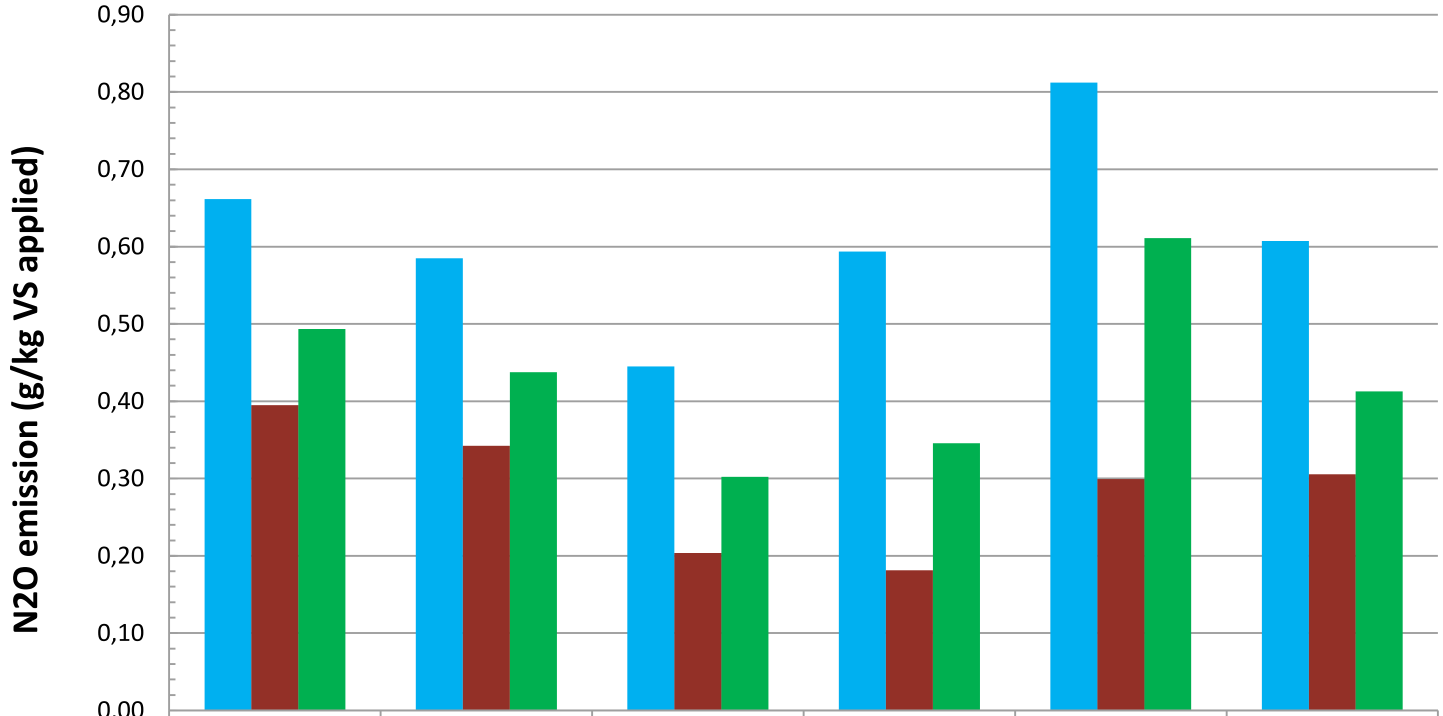
$$VS_d = (CO_2\text{-}C_{sample} - CO_2\text{-}C_{control}) / C_{applied}$$

Assumptions for N2O esmission Estimation

- VS_d in applied materials would be fully degraded when CO_2 evolution rates became constant
- The pools VS_d and VS_{nd} are assumed to have similar N concentrations, and VS_d to represent a pool of reactive N

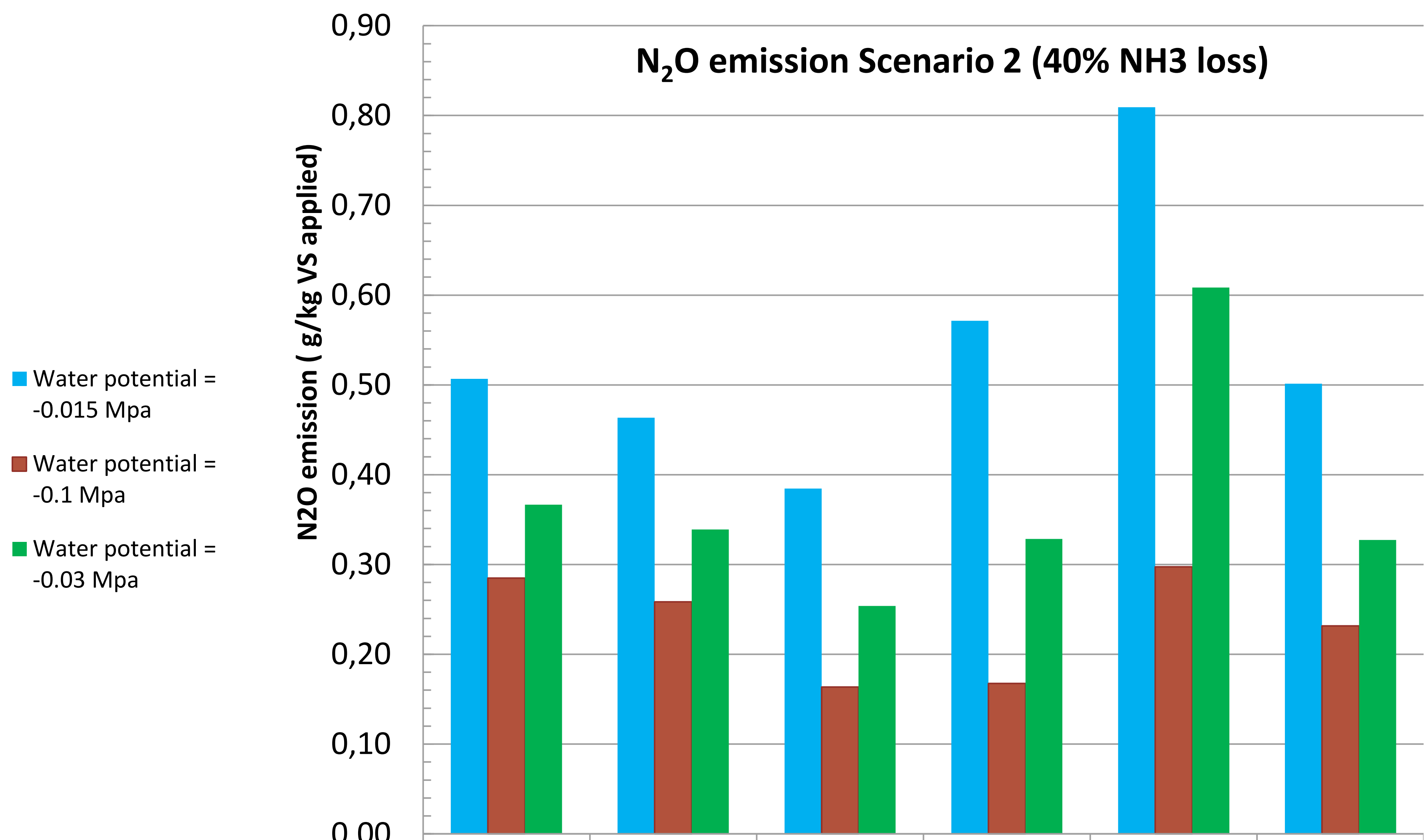
Estimation of N2O emission

N_2O emission Senario 1 (10% NH3 loss)



	PgSb0	PgSb12.5	PgSb25	PgSb90	BrS	PgS
Water potential = -0.015 Mpa	0,66	0,58	0,45	0,59	0,81	0,61
Water potential = -0.1 Mpa	0,39	0,34	0,20	0,18	0,30	0,31
Water potential = -0.03 Mpa	0,49	0,44	0,30	0,35	0,61	0,41

Water potential = -0.015 Mpa   Water potential = -0.1 Mpa   Water potential = -0.03 Mpa



	PgSb0	PgSb12.5	PgSb25	PgSb90	BrS	PgS
Water potential = -0.015 Mpa	0,51	0,46	0,38	0,57	0,81	0,50
Water potential = -0.1 Mpa	0,28	0,26	0,16	0,17	0,30	0,23
Water potential = -0.03 Mpa	0,37	0,34	0,25	0,33	0,61	0,33

References

Sommer, S.G., Petersen, S.O., Møller, H.B., 2004. Algorithms for calculating methane and nitrous oxide emissions from manure management. Nutrient Cycling in Agroecosystems 69, 143-154.

Thank you

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WP4

Greenhouse gas emissions during storage of slurry and digestates

(- and after field application)

Khagendra R. Baral & Søren O. Petersen

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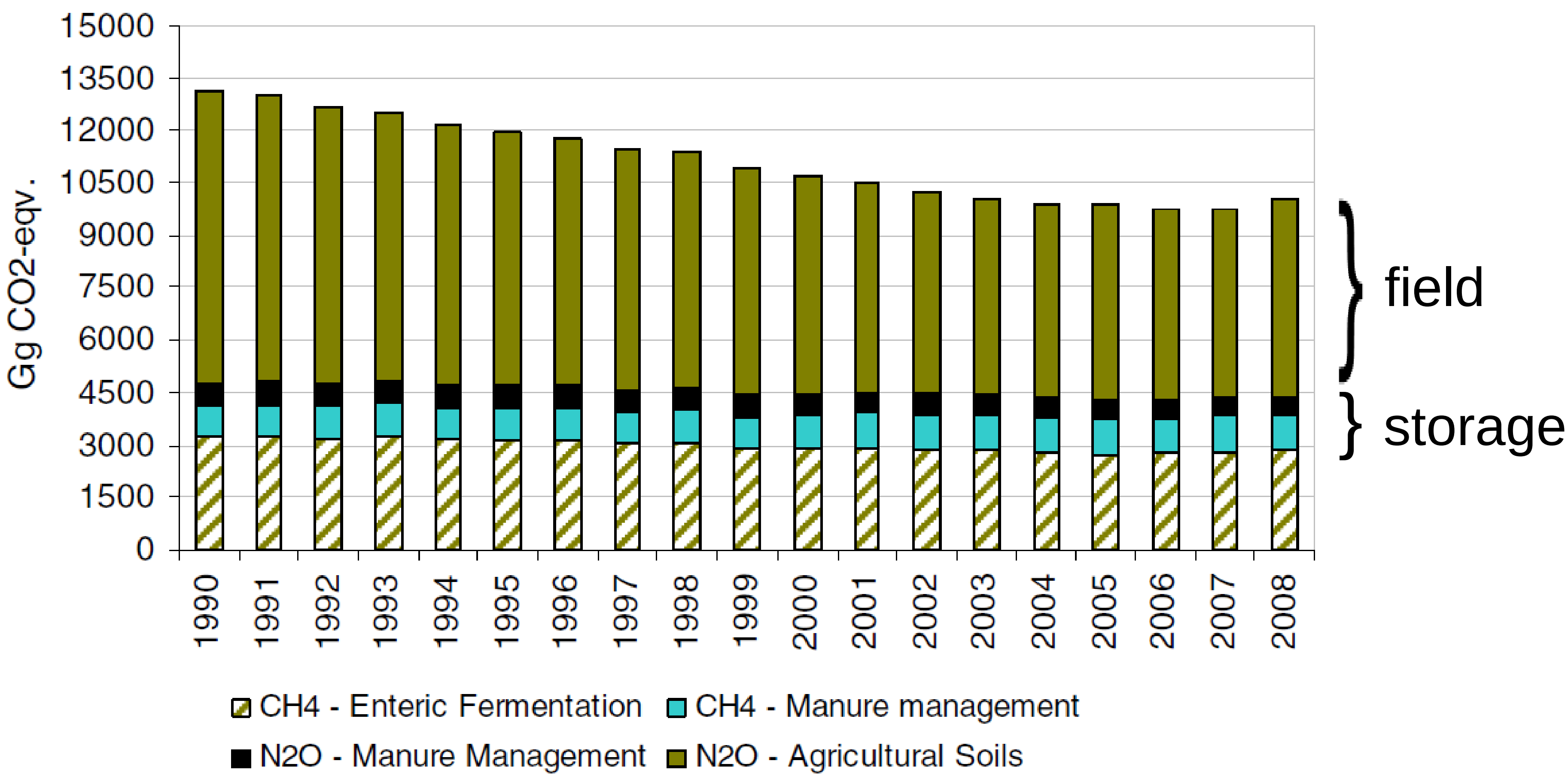
GHG emissions, DK agriculture
1990-2008



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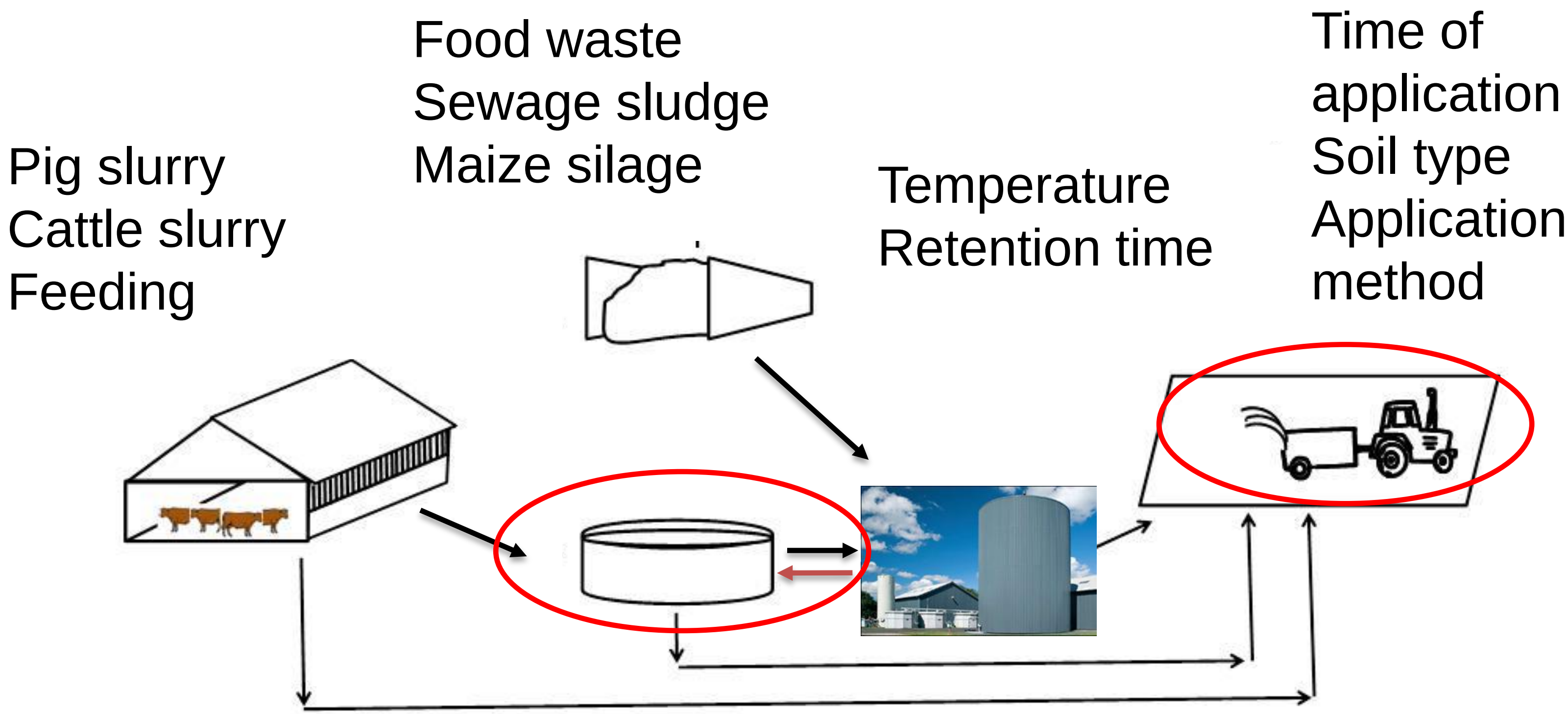
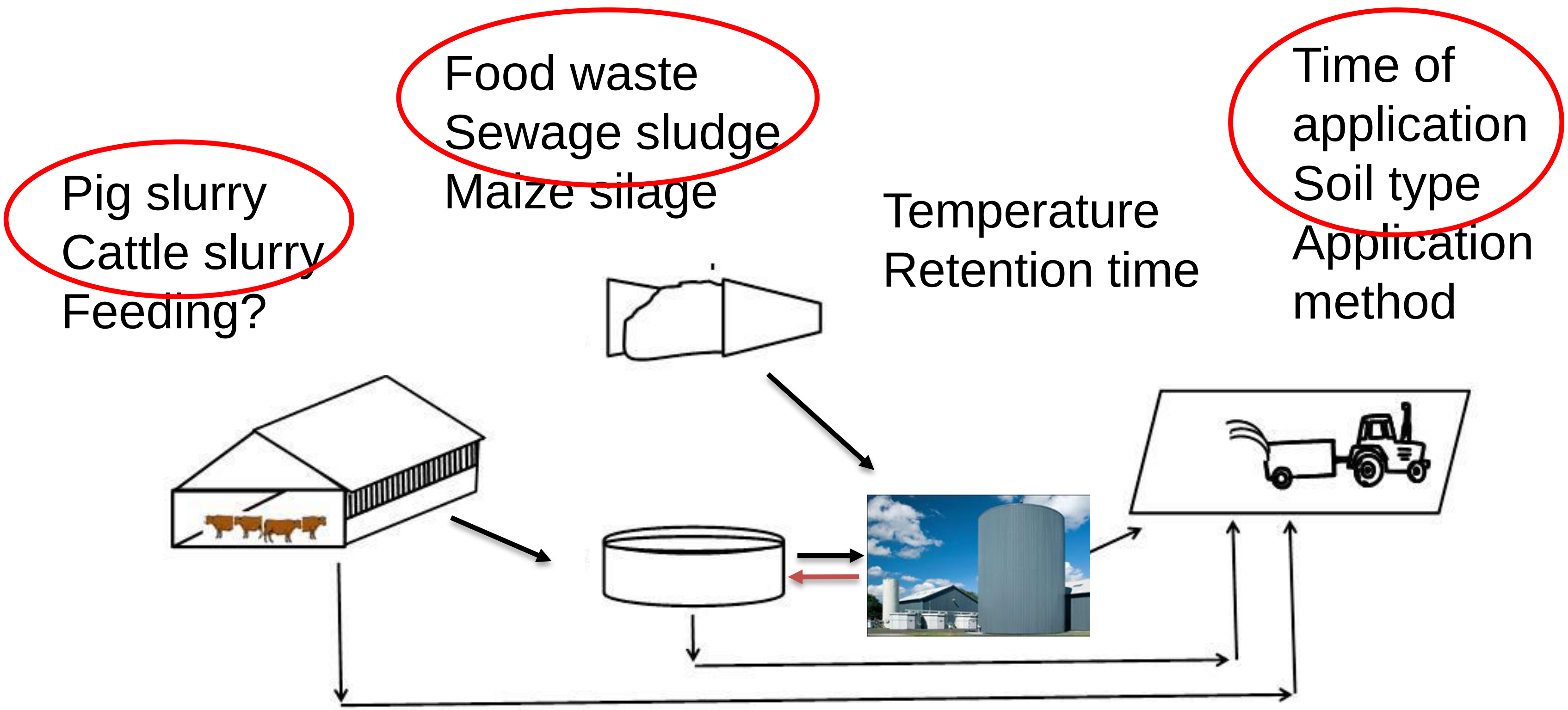
Biogas treatment in the whole-farm context



Biogas treatment in the whole-farm context

Experimental variables



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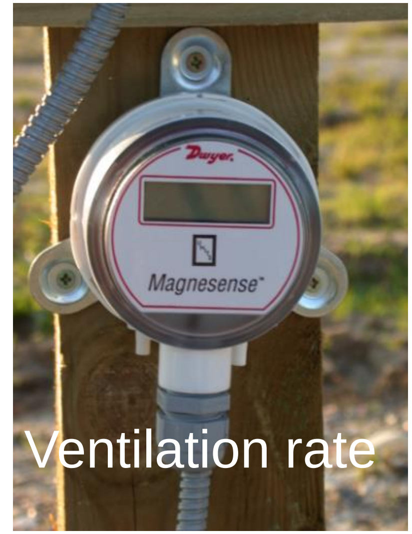
Storage of digestates, pig and cattle slurry

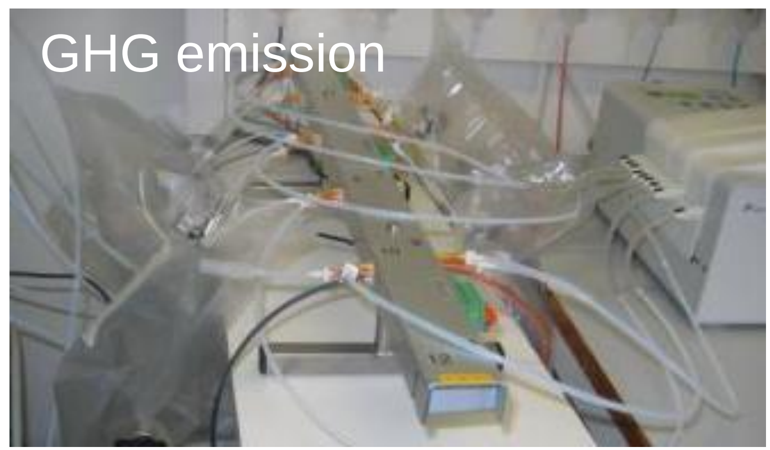
June 2014 – April 2015

Store	8	7	6	5	4	3	2	1
Treatment	Maabj.	SS Fred.	CS	PS	SS Fred.	CS	Maabj.	PS
Target volumes	4 m^3	1.3 m^3 CS 2.7 m^3	4 m^3	4 m^3	1.3 m^3 CS 2.7 m^3	4 m^3	4 m^3	4 m^3

Maabj., Maabjerg Bioenergy; SS Fred., sewage sludge, Fredericia Wastewater; CS, cattle slurry; PS, pig slurry

Pilot-scale storage facility





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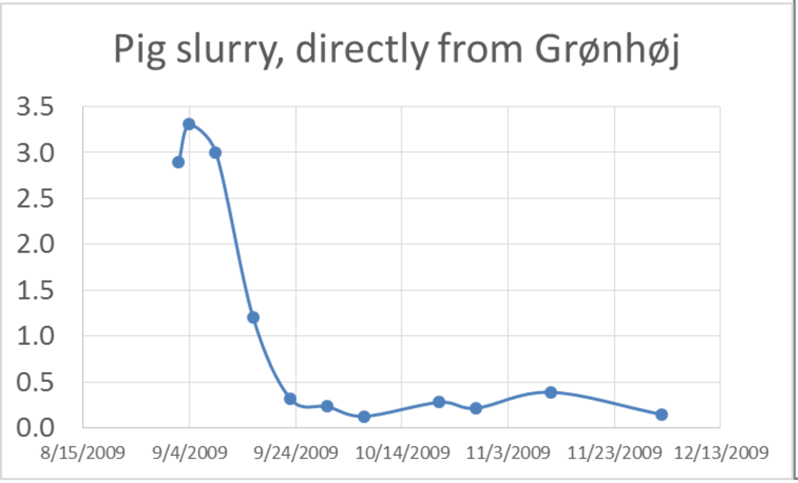
Sewage sludge, Fredericia (digested, dewatered)

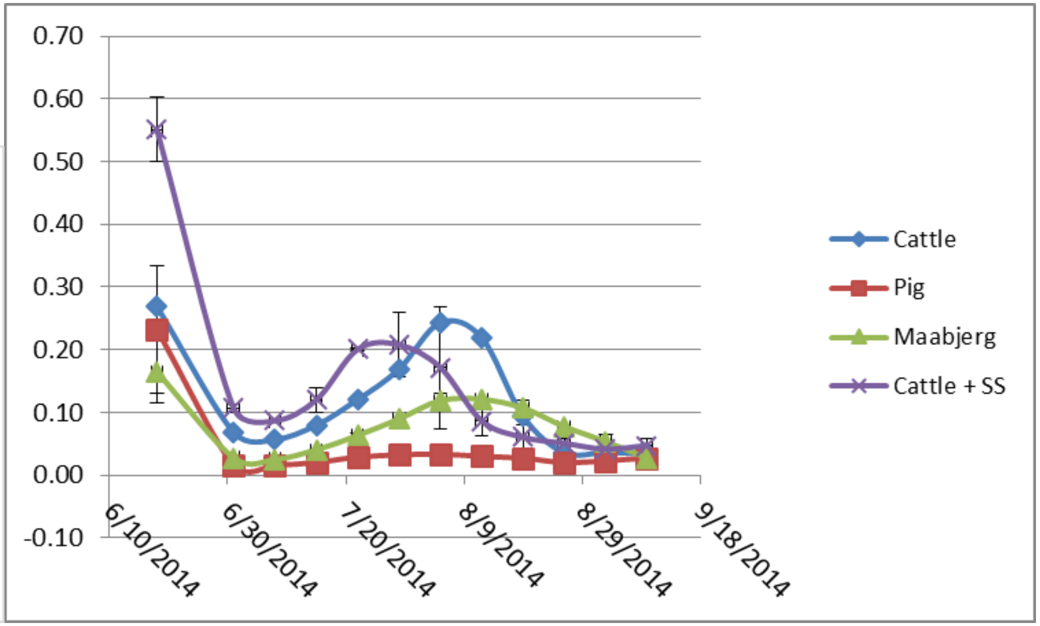
Digestate, Maabjerg Bioenergy (co-digested)

Storage of digestates, pig and cattle slurry

First 12 weeks



Methane (g CH_4 kg^{-1} VS d^{-1})

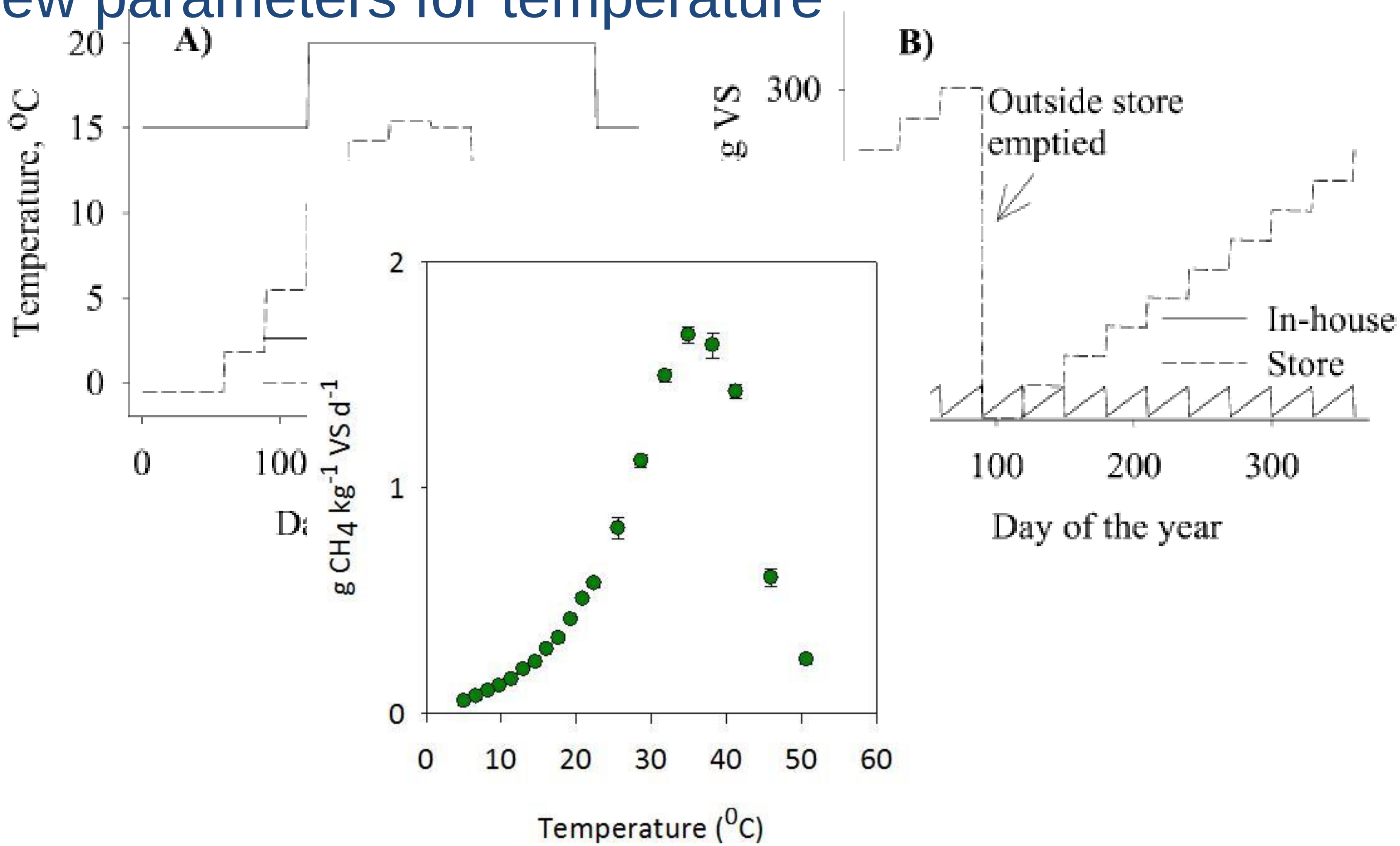


Campaign: CH_4 oxidation in crust?

Campaign: Source of N_2O?

Modelling emissions of CH_4 during storage

New parameters for temperature



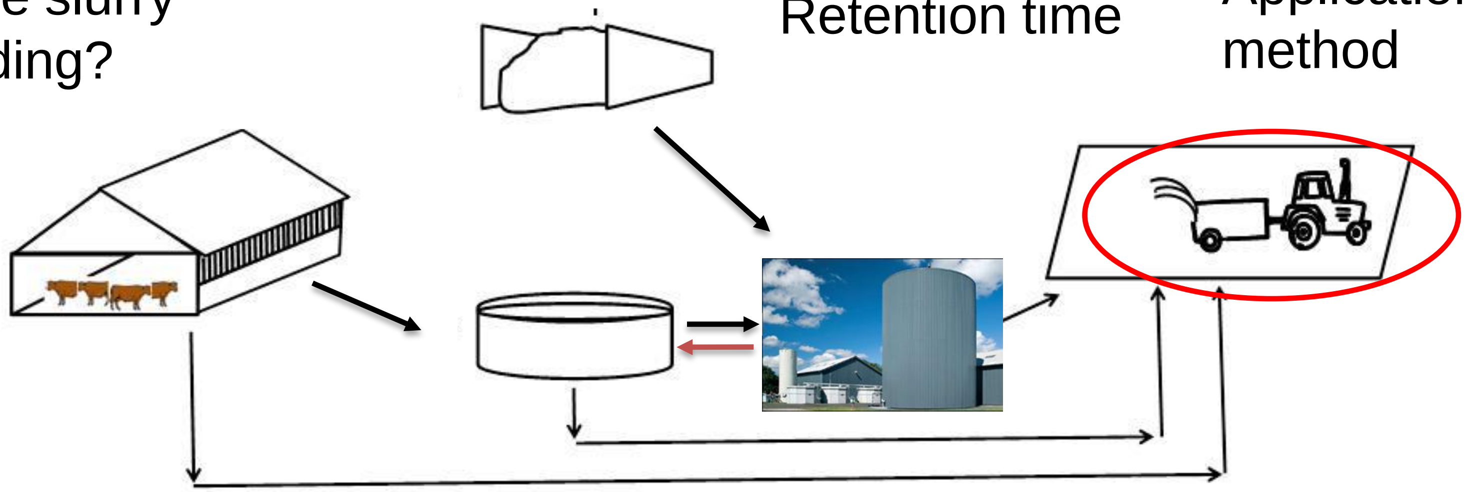
Biogas treatment in the whole-farm context
Experimental variables

Pig slurry
Cattle slurry
Feeding?

Food waste
Sewage sludge
Maize silage

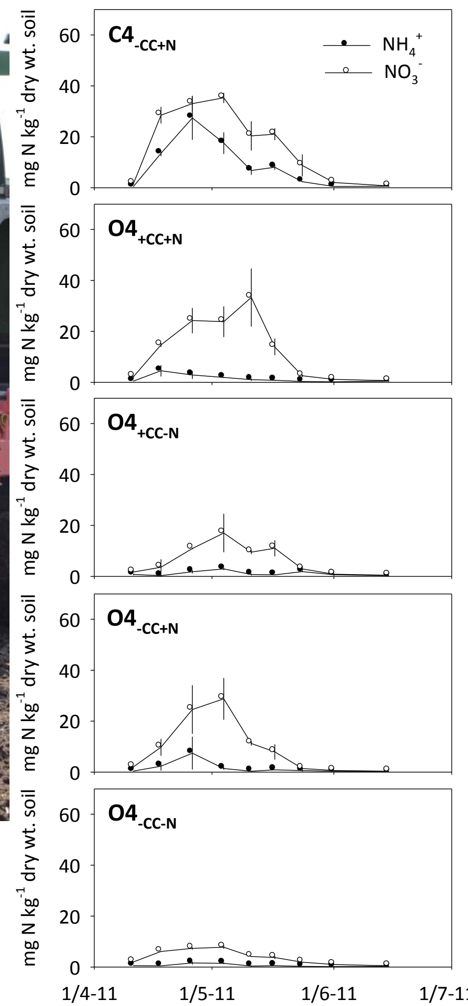
Temperature
Retention time

Time of application
Soil type
Application method

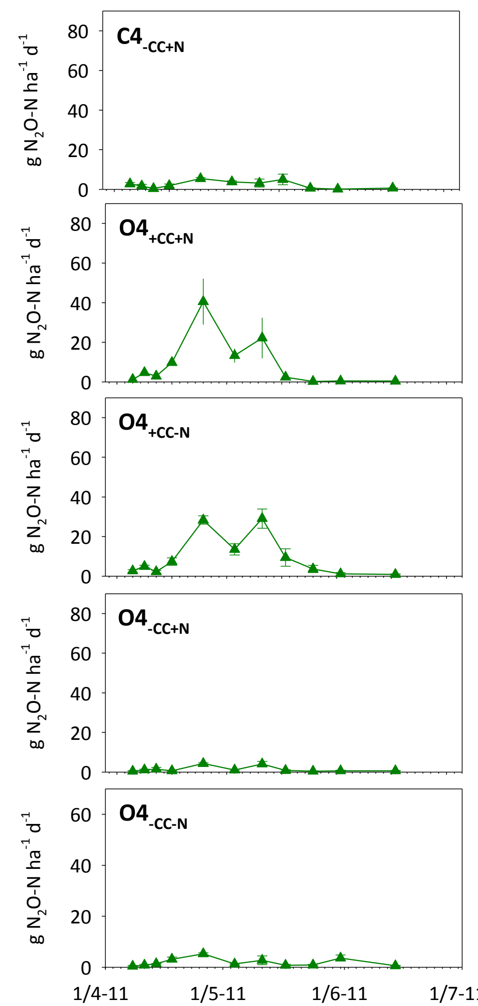


Example data:

Mineral N



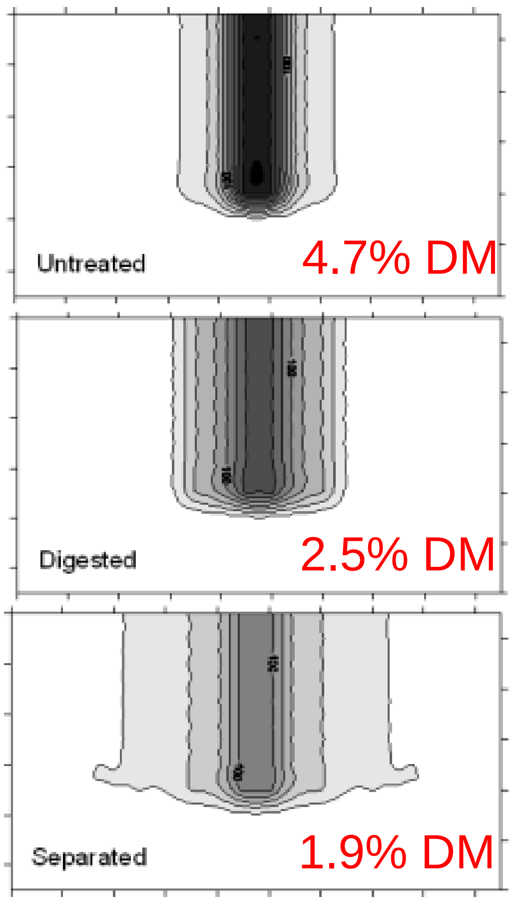
N_2O

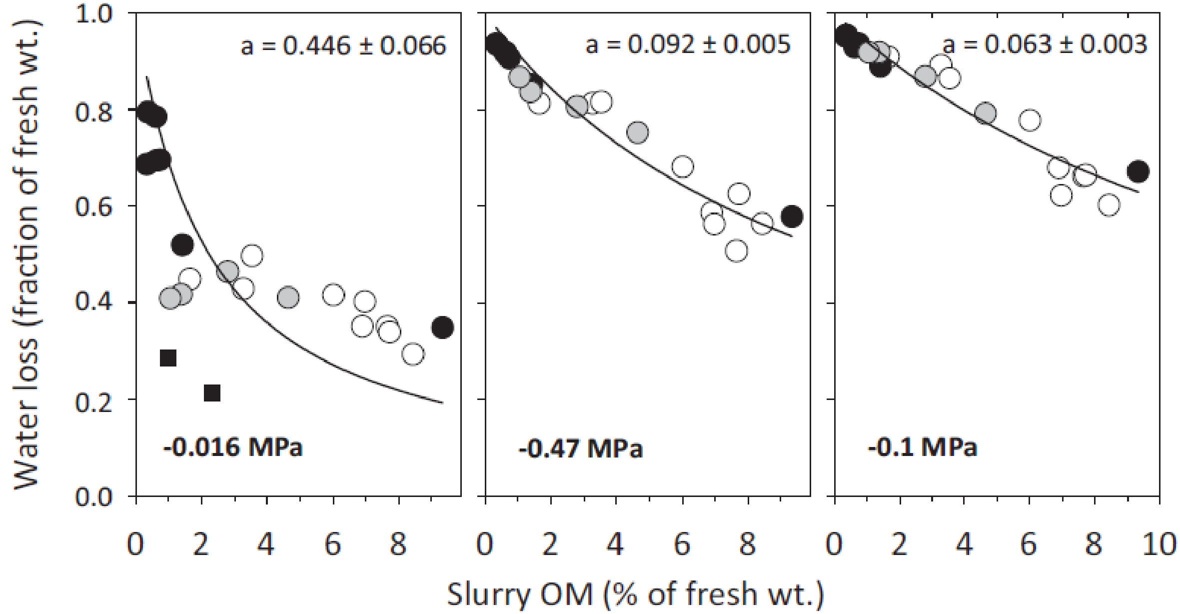


Fate of slurry/digestate in soil

Redistribution depends on slurry DM and soil moisture

NH_4^+





$$\text{relative water loss} = 1/(1 + a\text{VS})$$

(Thomsen et al., 2010)

(Petersen et al., 2003)

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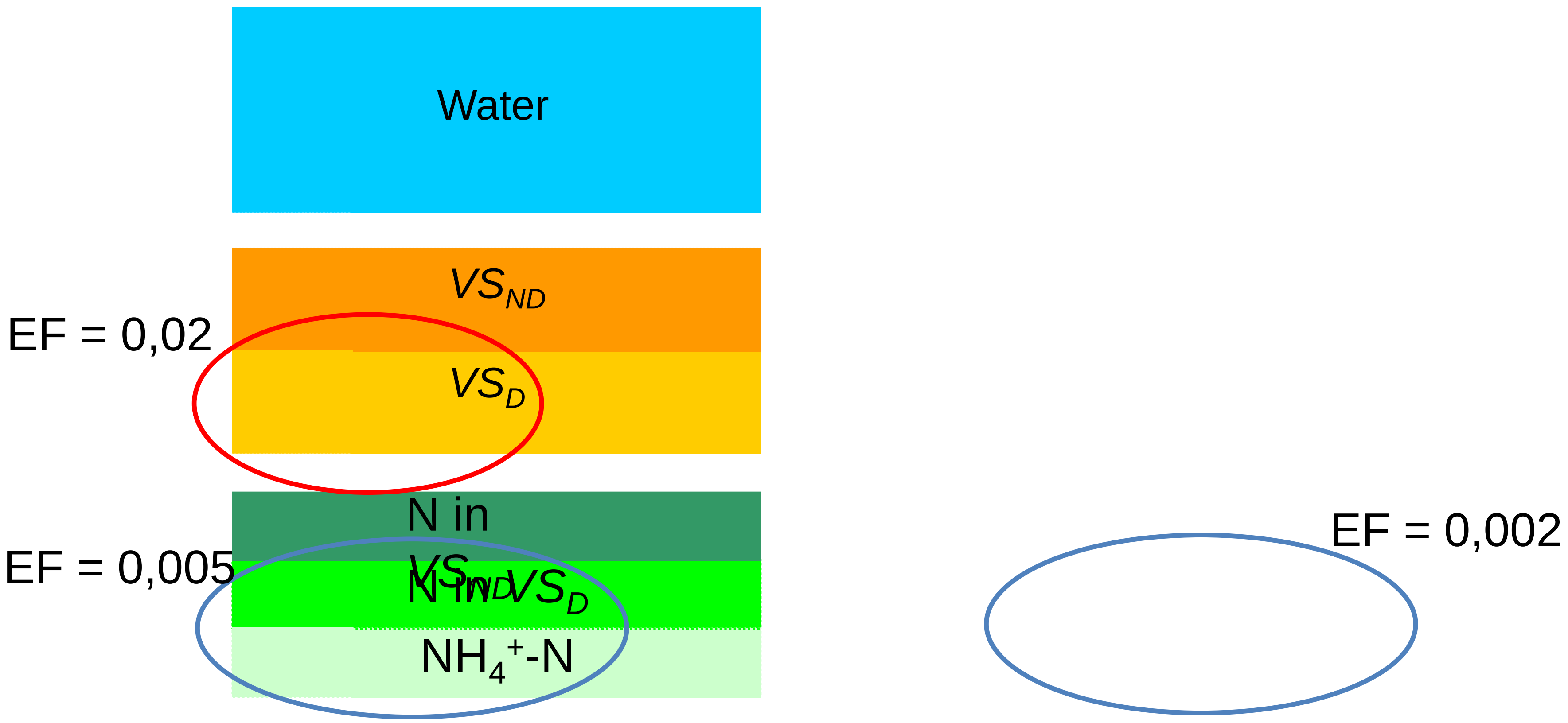
Degradable VS and reactive N drivers for N_2O emission

Manure ”clumps” | Bulk soil



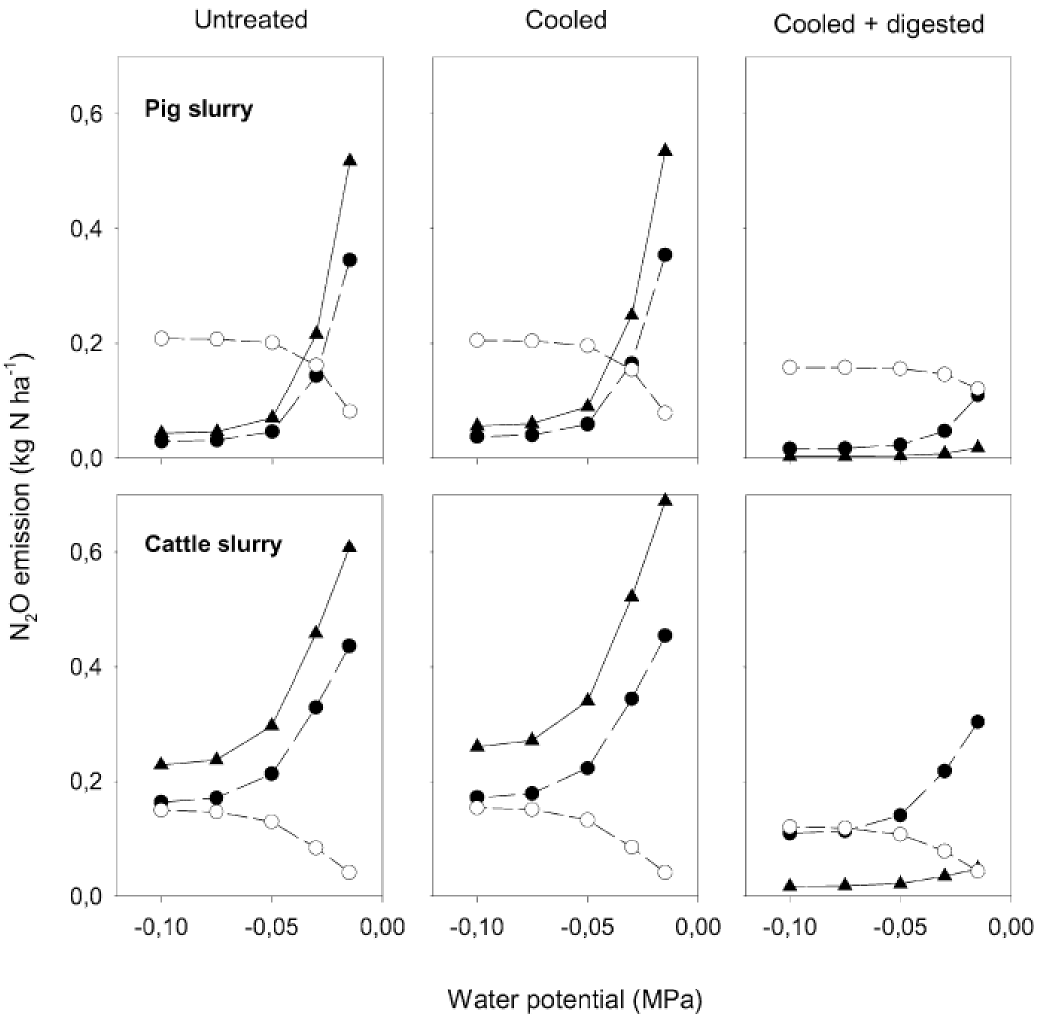
(Sommer et al., 2004)

Modelling N_2O emissions from slurry

▲ Denitrification, clumps

● Nitrification, clumps

○ Nitrification, soil



(Sommer et al., 2004)

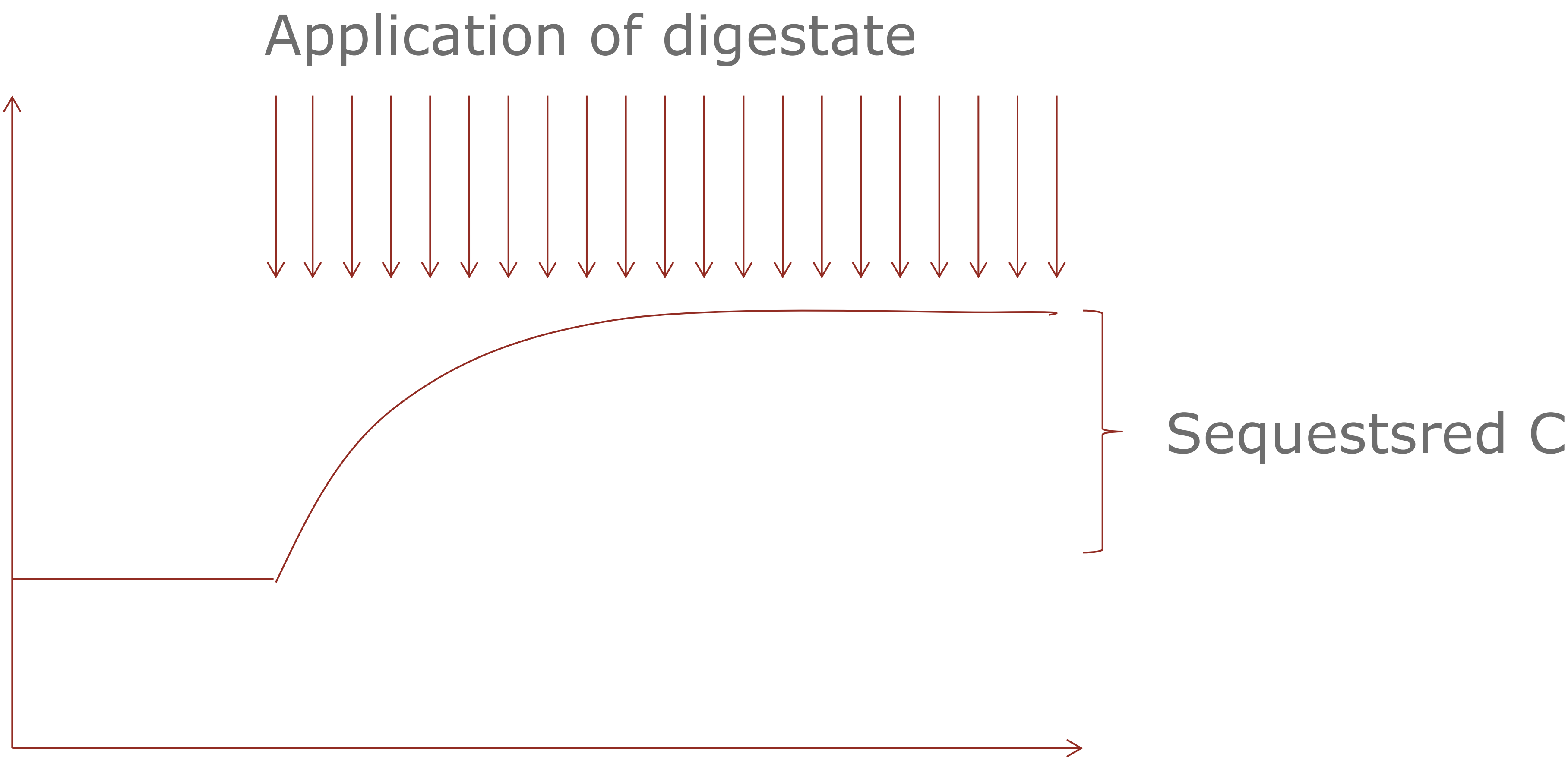
Carbon sequestration measured using isotope technology

Sander Bruun and Quan Van Nguyen

biochain

WORKSHOP 2014
27-29 OCTOBER
JOINT WORKSHOP WITH NORWEGIAN PARTNERS
WWW.BIOCHAIN.DK

What is carbon sequestration in soil?



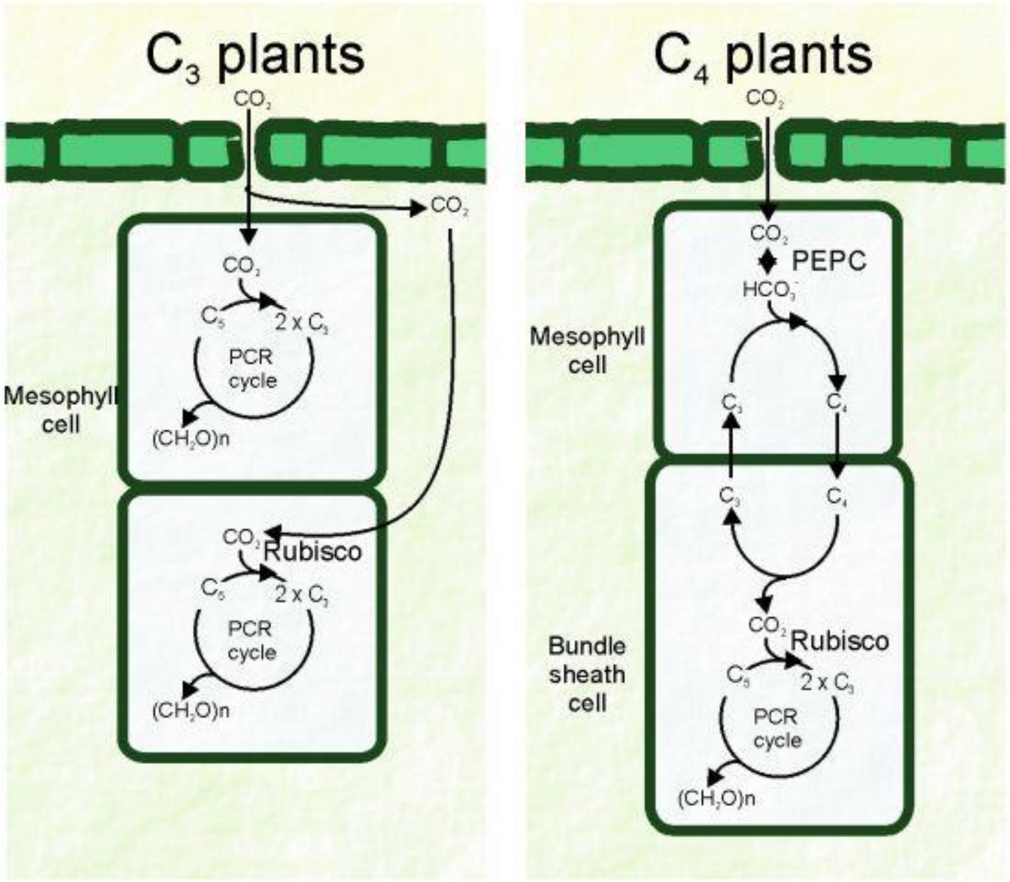
How is C sequestration affected by process conditions

Questions:

Manure (SDU):
How is sequestration affected by co-substrate
How is sequestration affected by mixing ratio
How is sequestration affected by mean residence time

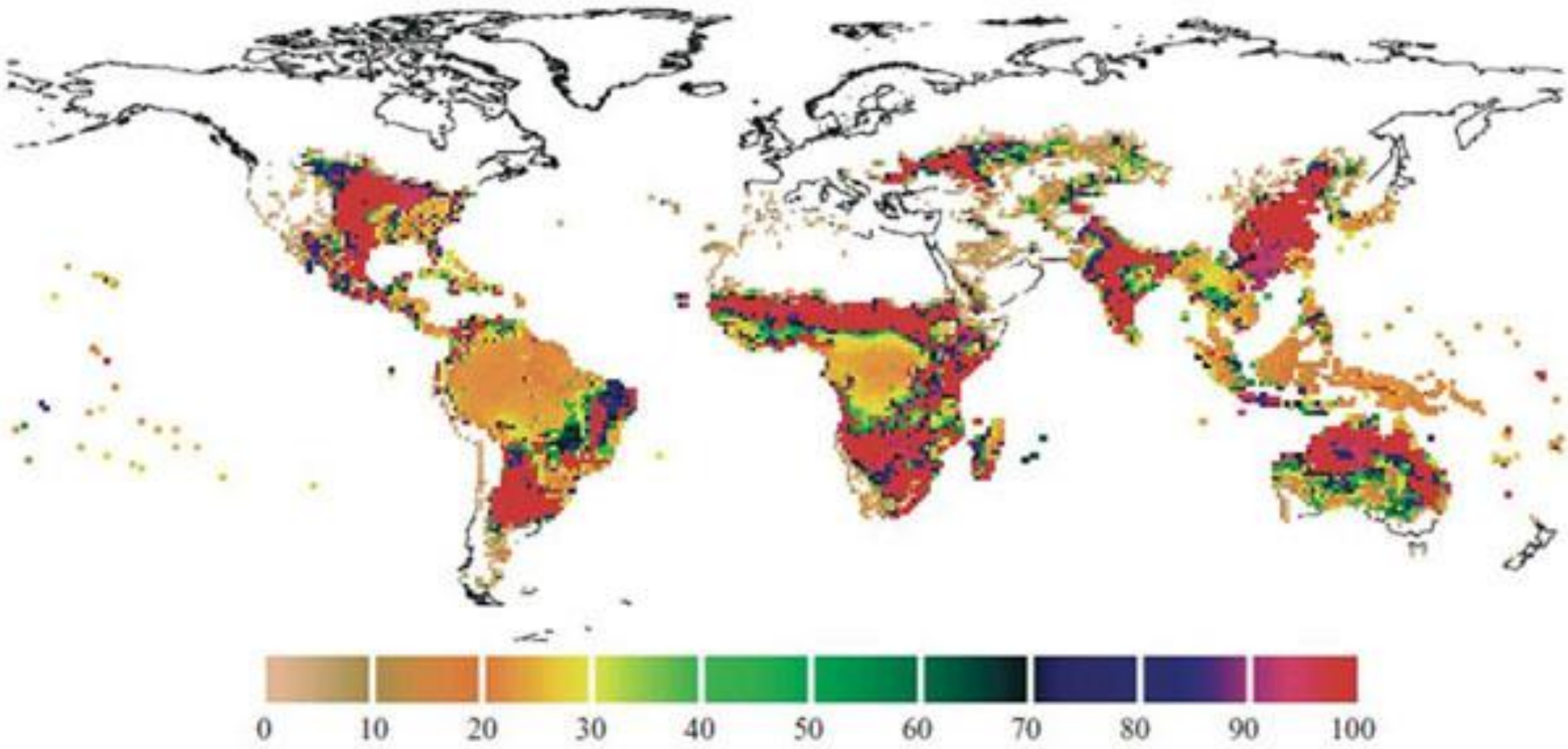
Sludge (DTU)
How is sequestration affected by co-substrate

Two different photosynthetic pahhways



$\delta_{13}C$ -27 -15

Distribution of C4 grasses in the world



Soil in South Africa: $\delta_{13}C = -13$
Soil in Denmark: $\delta_{13}C = -25$

Calculation of fraction of C from added material in South African soil

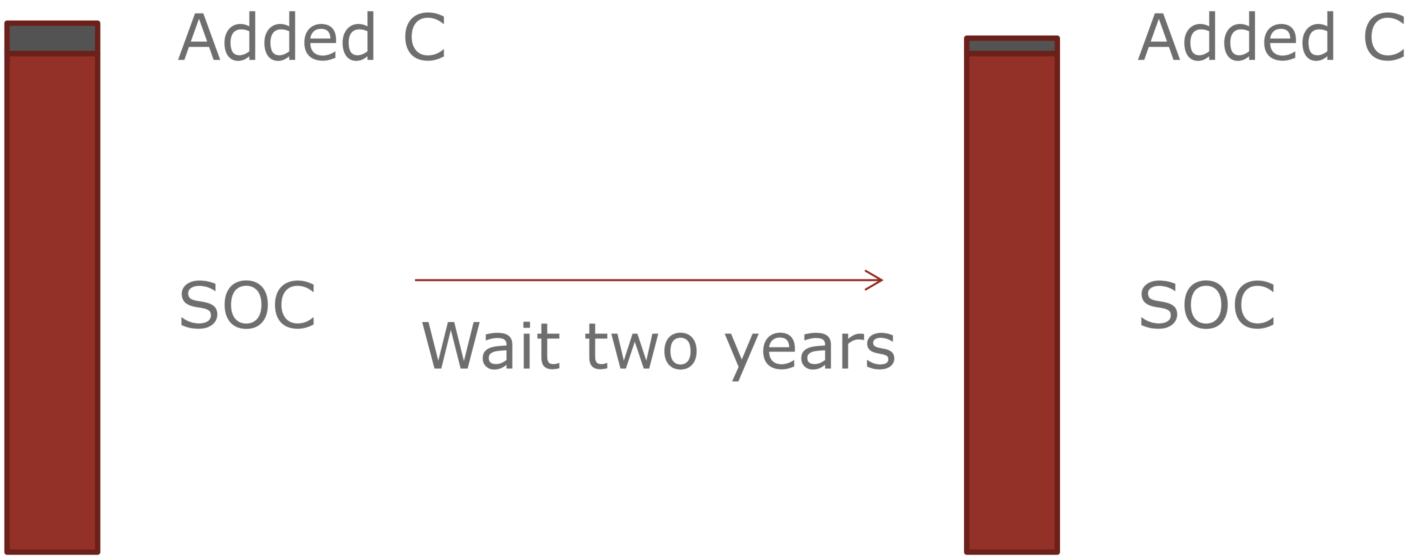
$\delta_{13}C$ = -13, South African soil

← $\delta_{13}C$ (Soil)

$\delta_{13}C$ = -27, Added material

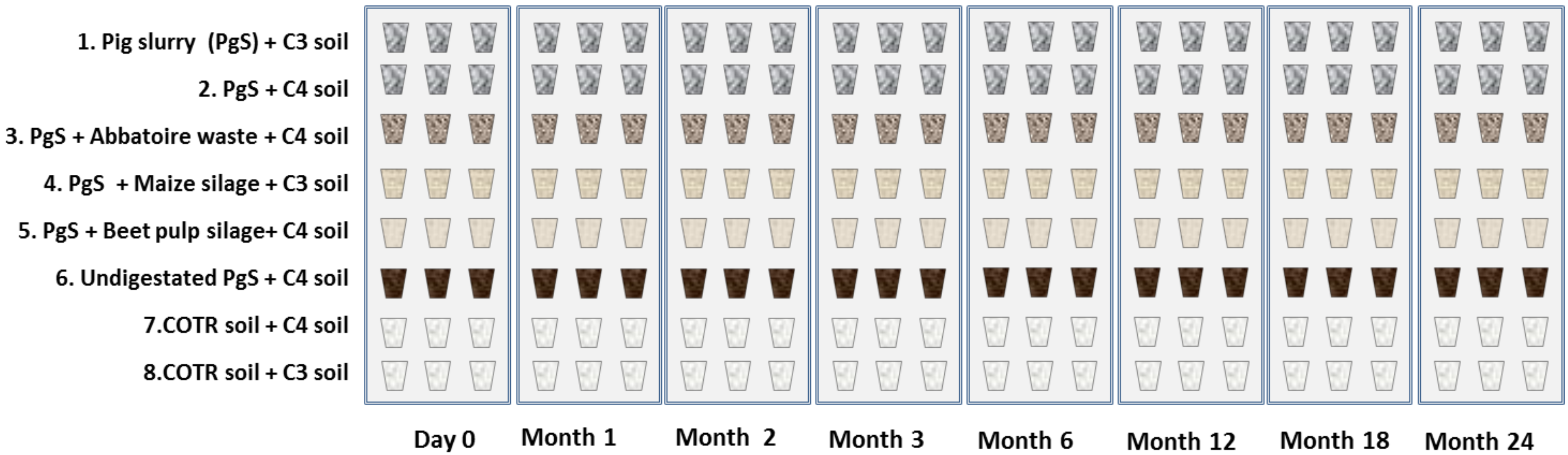
$$f = \frac{\delta_{13}C\,(\text{Soil}) - \delta_{13}C\,(\text{SA})}{\delta_{13}C\,(\text{SA}) - \delta_{13}C\,(\text{Added material})}$$

Why isotopes



Isotope measurements increases sensitivity

First plan


1. Pig slurry (PgS) + C3 soil
2. PgS + C4 soil
3. PgS + Abbatoire waste + C4 soil
4. PgS + Maize silage + C3 soil
5. PgS + Beet pulp silage+ C4 soil
6. Undigestated PgS + C4 soil
7.COTR soil + C4 soil
8.COTR soil + C3 soil
Day 0
Month 1
Month 2
Month 3
Month 6
Month 12
Month 18
Month 24