

**atf**

**animal  
task  
force**

A European Public-Private Partnership



**EAAP**

European Federation of Animal Science



## LIVESTOCK ARE MORE THAN FOOD



## 4<sup>th</sup> one-day symposium of the Animal Task Force & the EAAP Commission on Livestock Farming Systems: *Livestock are more than food*

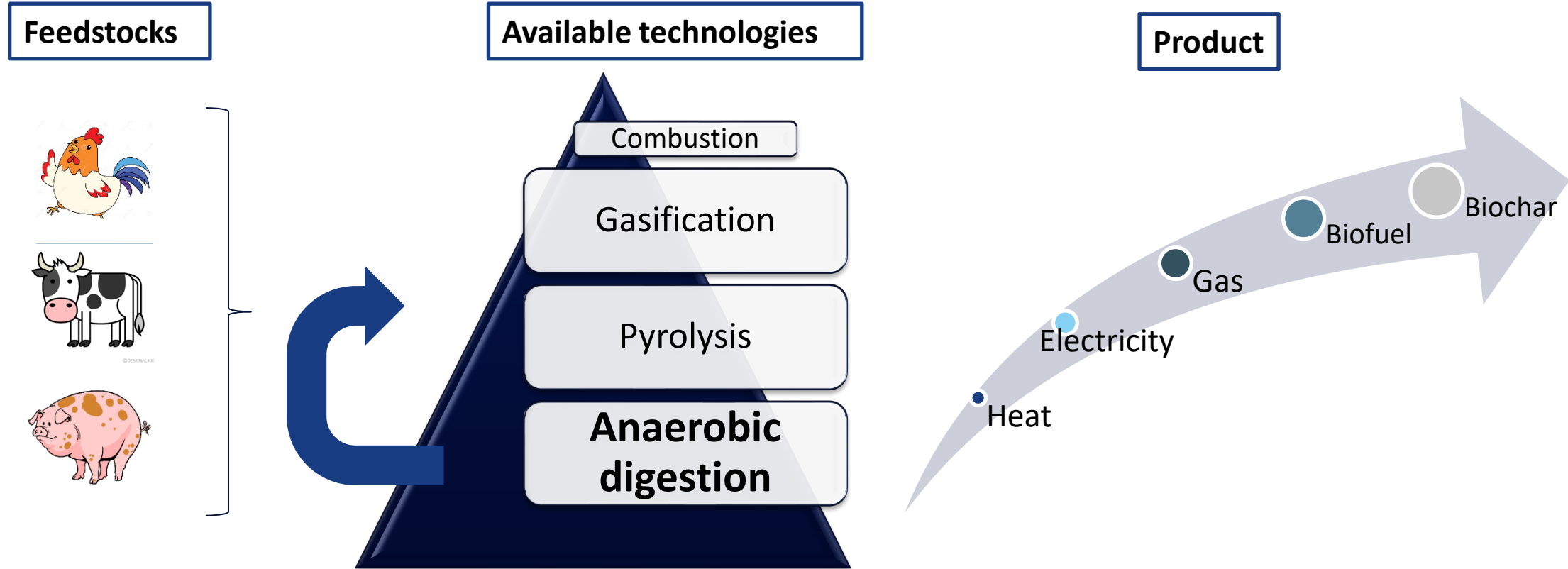
## Livestock manure for fertilizer and biofuels

Henrik B. Møller

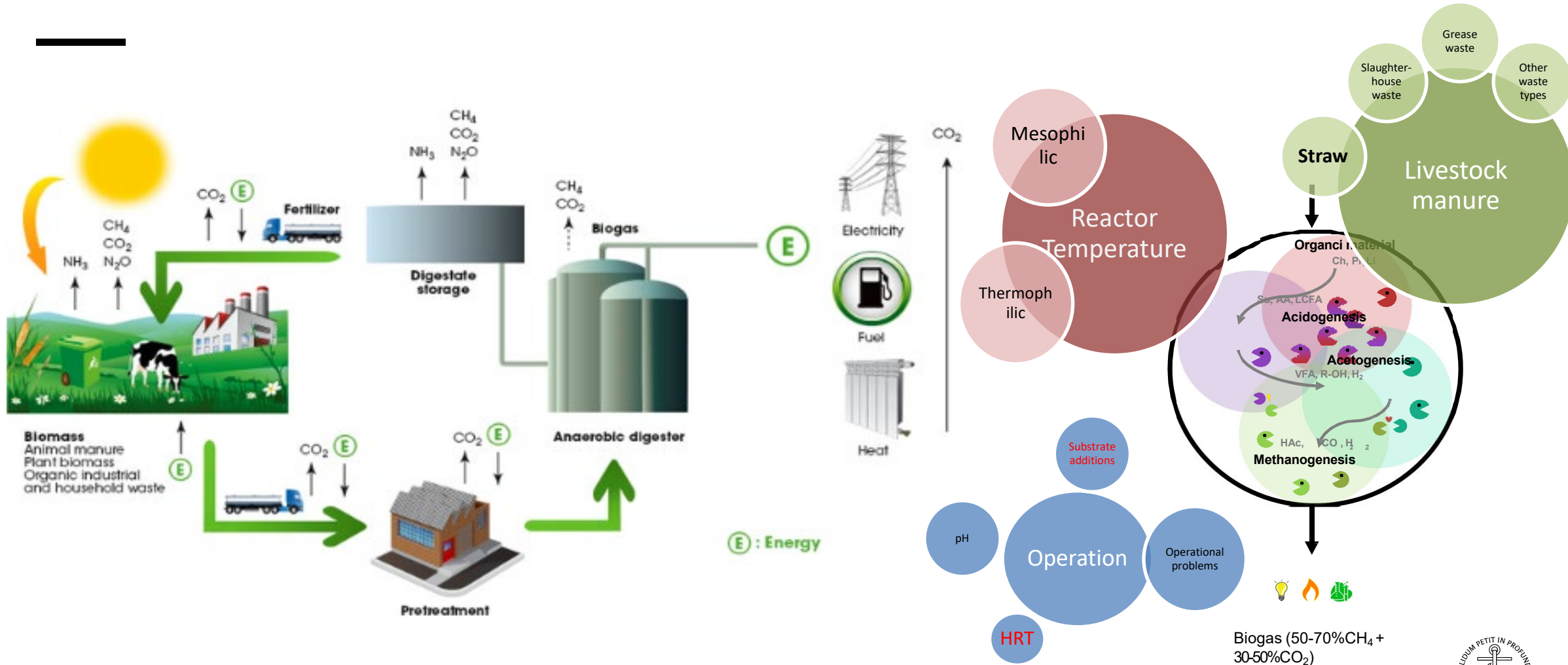
Aarhus University

Denmark

# LIVESTOCK MANURE FOR BIOFUEL



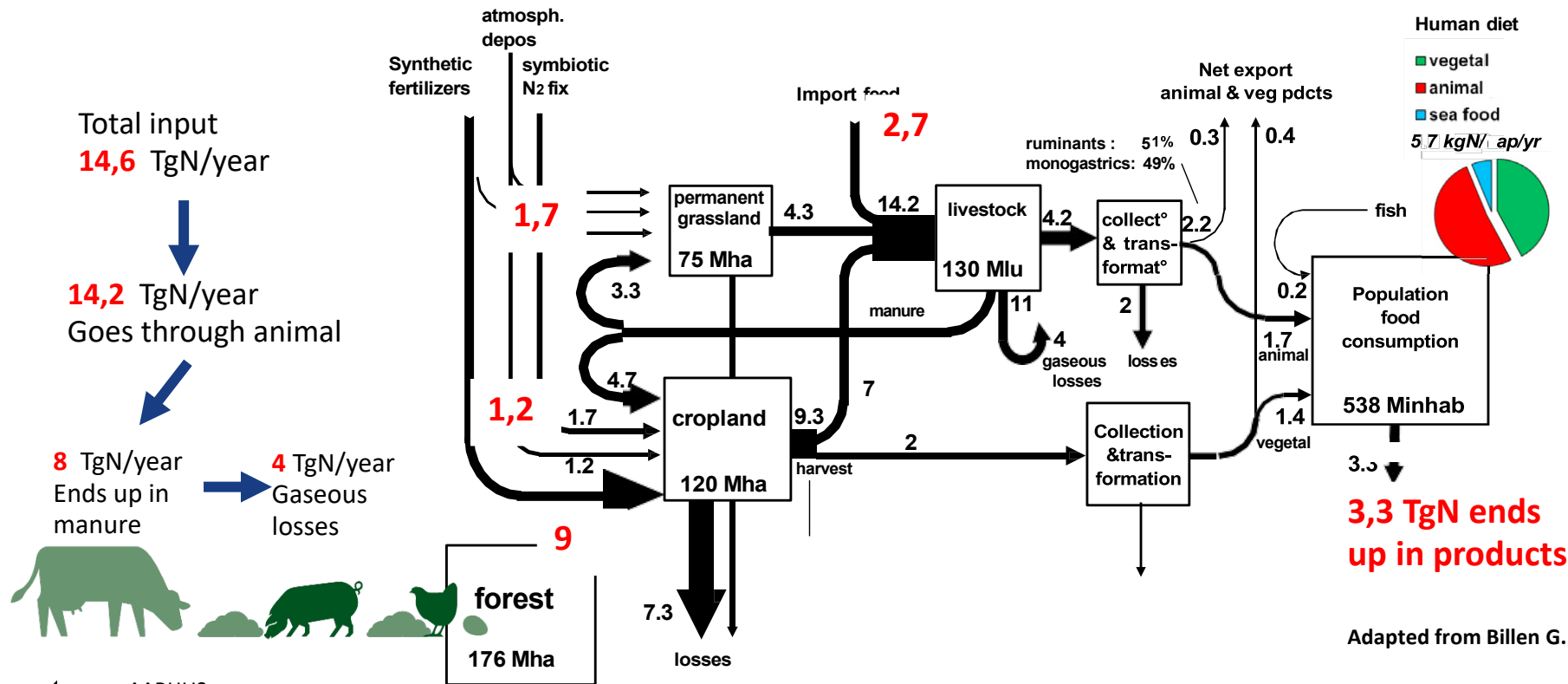
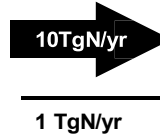
# AD – THE MOST DEVELOPED BIOFUEL



# NUTRIENTS IN LIVESTOCK MANURE

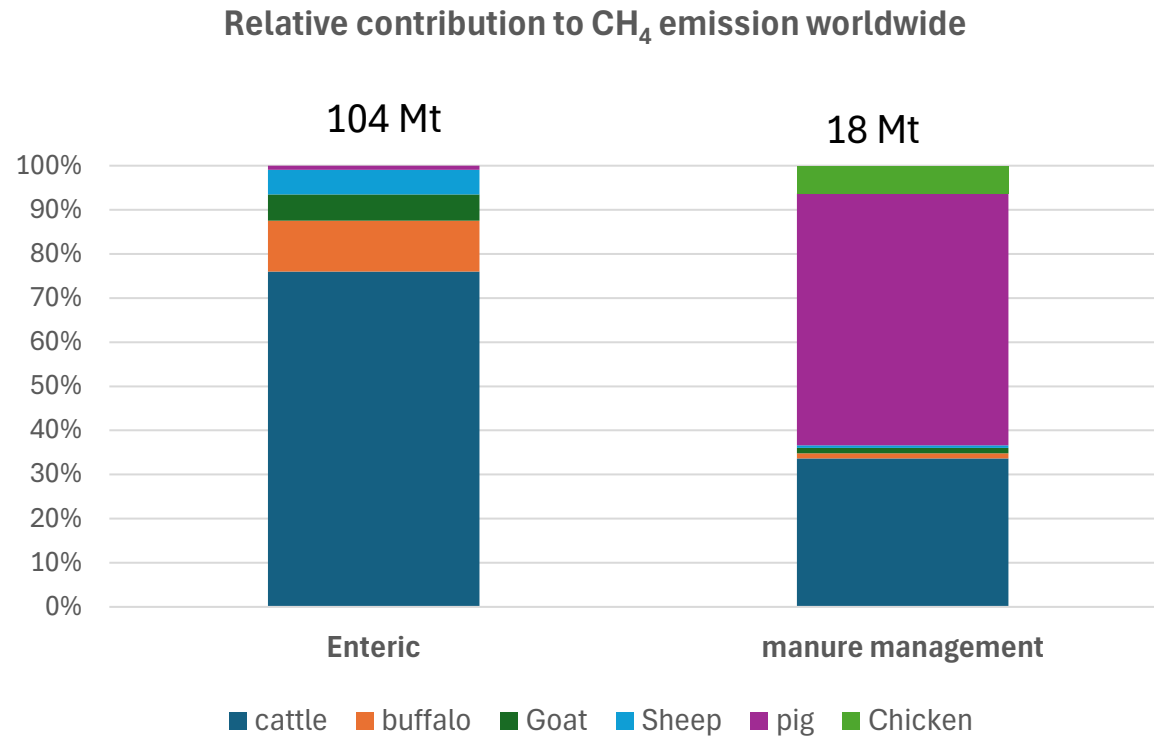
Europe (TgN/year)

1 Mt = 1 million tons =  $10^{12}$  g = 1 Tg)



Adapted from Billen G. et al 2021

# LIVESTOCK AS A SOURCE OF GHG



**CH<sub>4</sub>:** Hard to capture when it has been *let out of the bottle!*



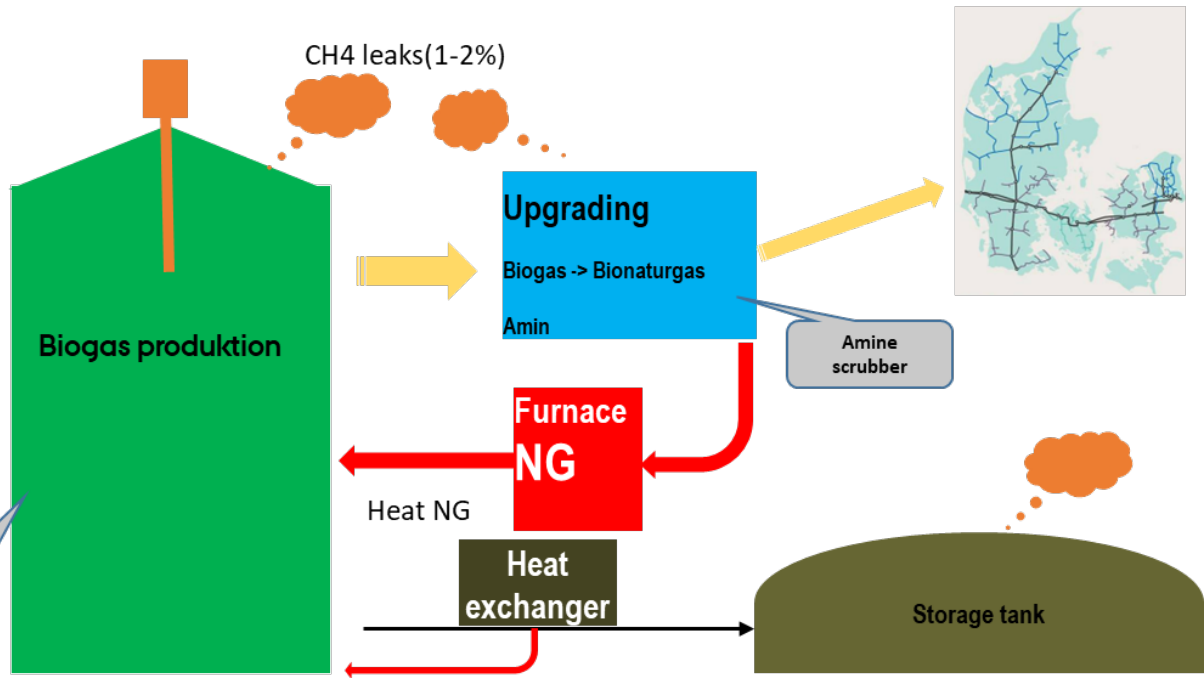
Global animal population and methane emitted by enteric fermentation and manure management. Data from FAO (2023)

# SUSTAINABILITY OF BIOGAS



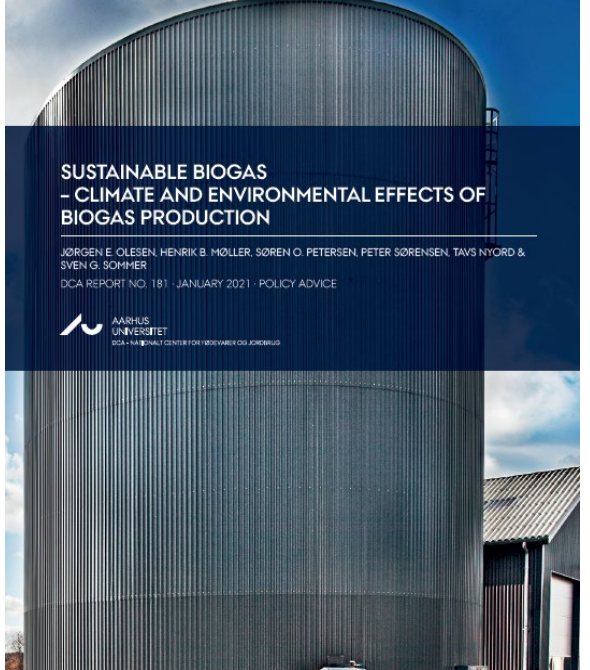
**Transport Diesel**  
(2,7 kg CO<sub>2</sub>/liter)

**Electricity Energimix**  
(0,150 g CO<sub>2</sub>/kwh)

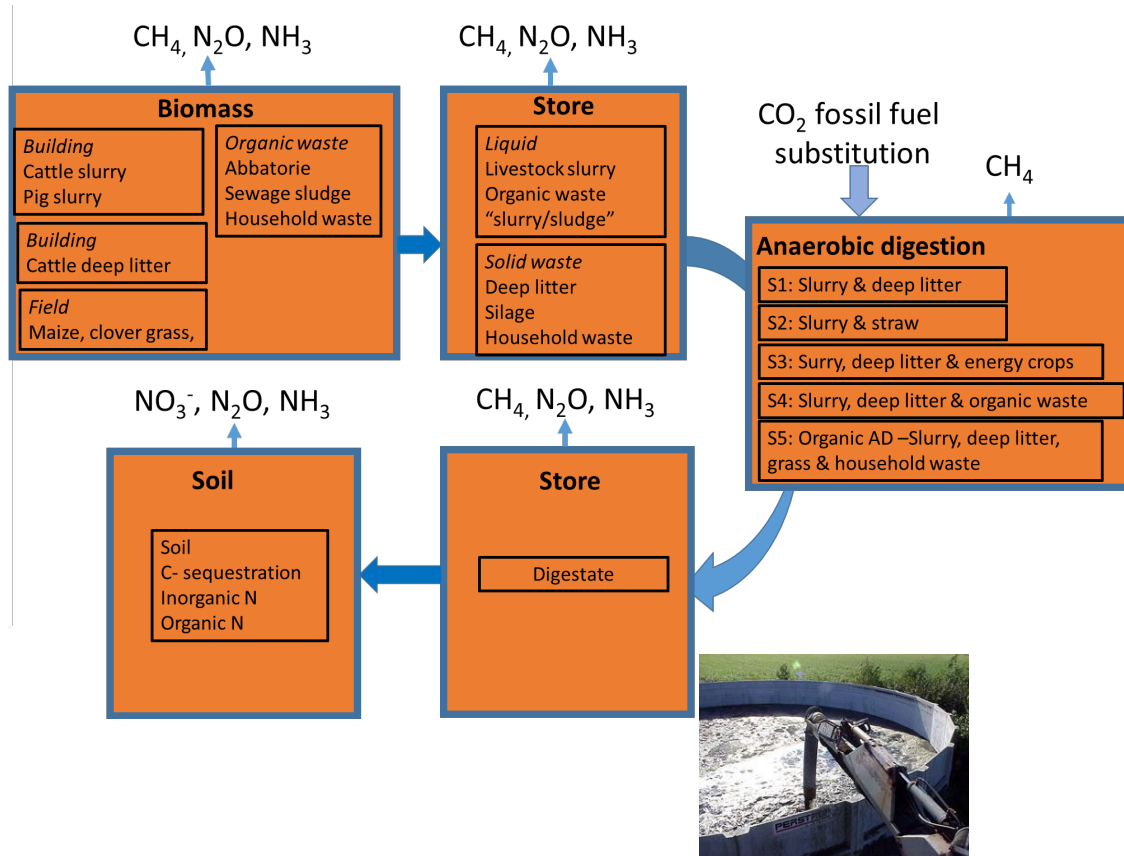


45 days with thermophilic operation (49-55C). + increased retention times of 60 and 90 days. Serial connections of 2 digesters

Digestate is 20° C when it leaves the biogas plant



# SUSTAINABILITY OF BIOGAS



$$F(t) = (VS_d + 0.01 \times VS_{nd}) \times \exp(\ln A - E_a/RT)$$

- Two VS pools of volatile solids (VS)
- degradable VS (VS<sub>d</sub>)
  - "non-degradable" VS (VS<sub>nd</sub>)

Temperature response of CH<sub>4</sub> production expressed *via* Arrhenius relationship



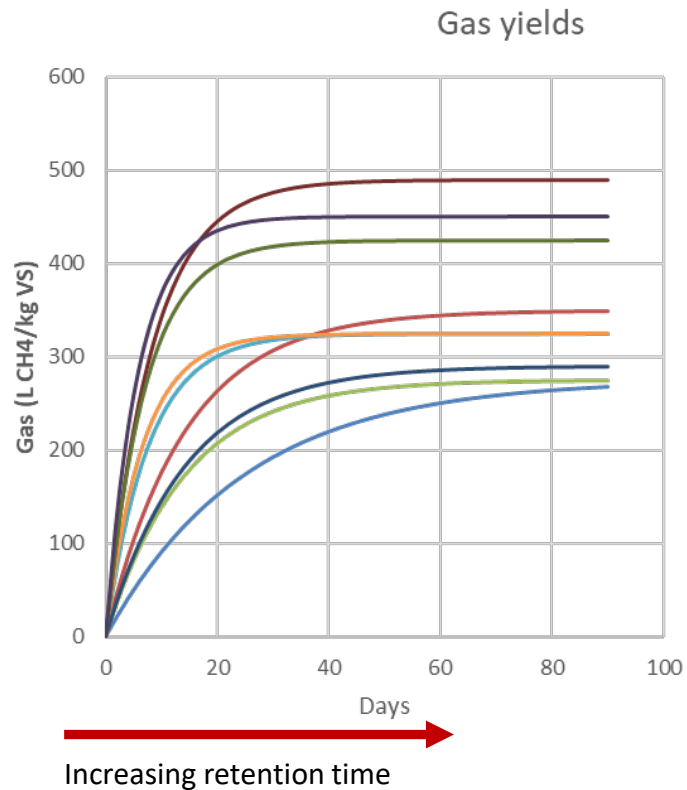
*Nutrient Cycling in Agroecosystems* 69: 143–154, 2004.  
© 2004 Kluwer Academic Publishers. Printed in the Netherlands.

Algorithms for calculating methane and nitrous oxide emissions from manure management

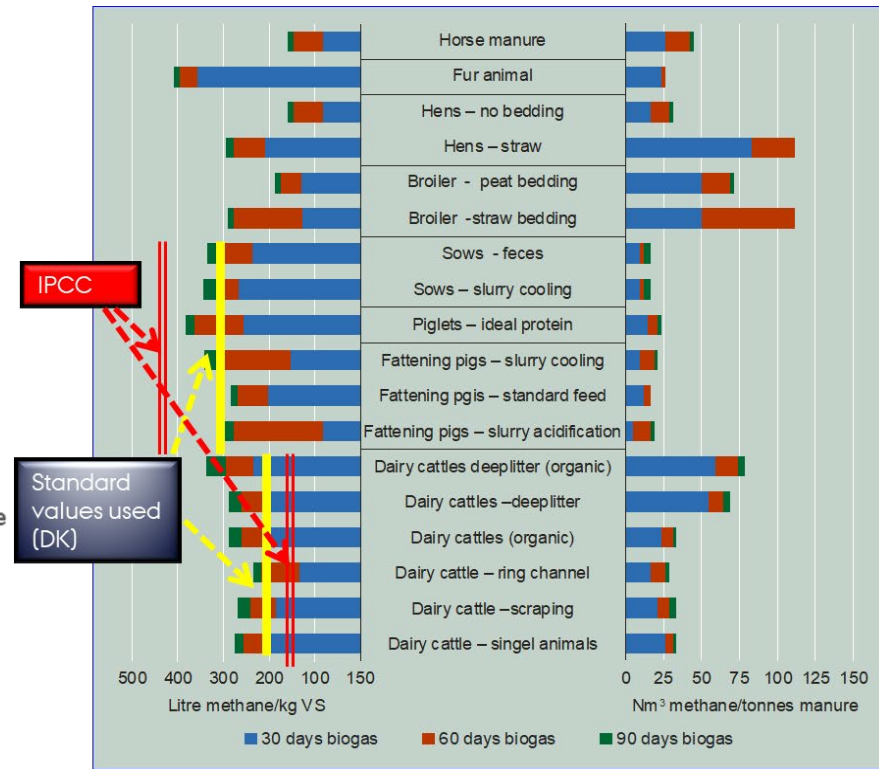
S.G. Sommer<sup>1,\*</sup>, S.O. Petersen<sup>2</sup> and H.B. Møller<sup>1</sup>



# BIOGAS POTENTIAL

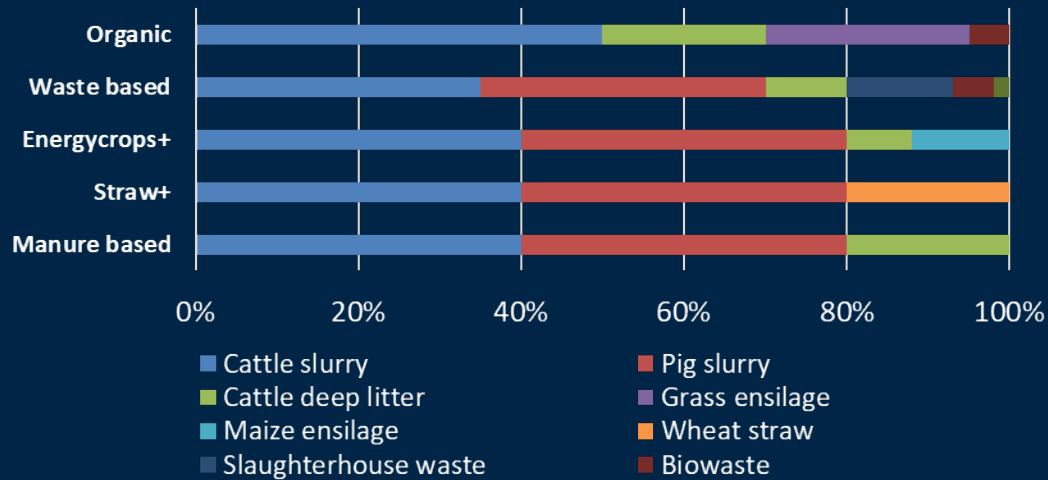


- Cattle slurry
- Pig slurry
- Cattle deep litter
- Grass ensilage
- Maize ensilage
- Wheat straw
- Slaughterhouse waste
- Biowaste
- Glycerol

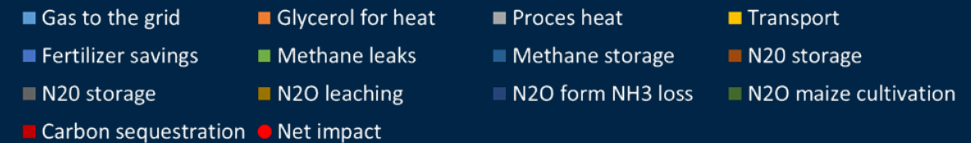
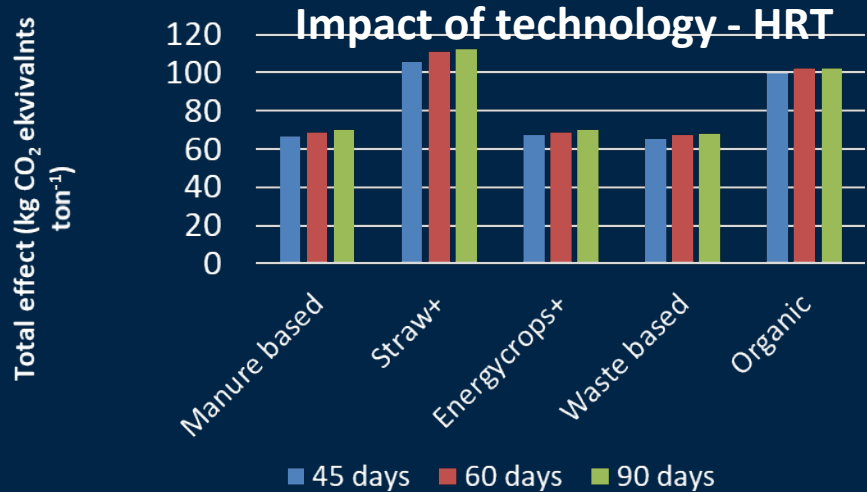
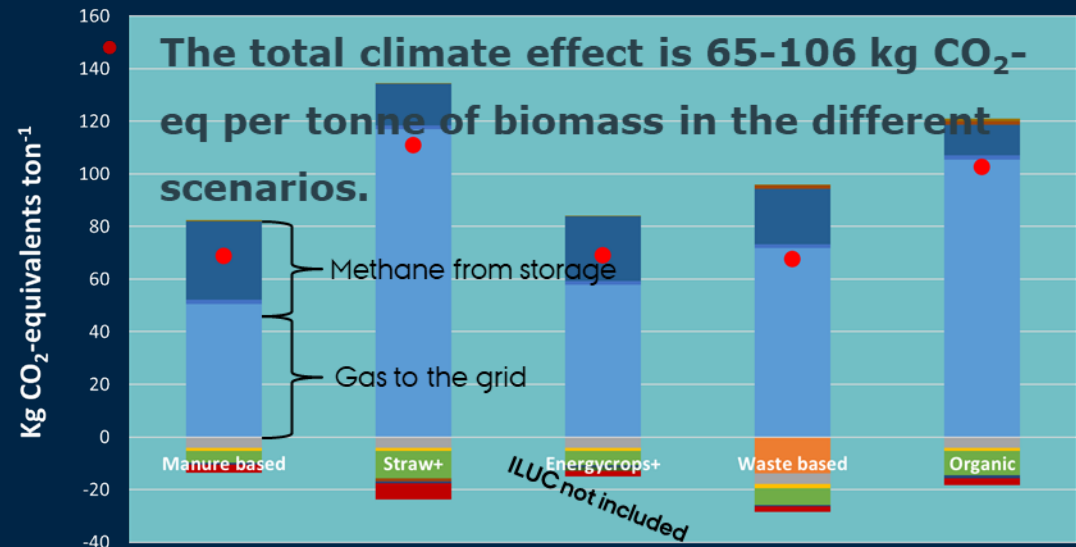




# Biomass



# GHG mitigation

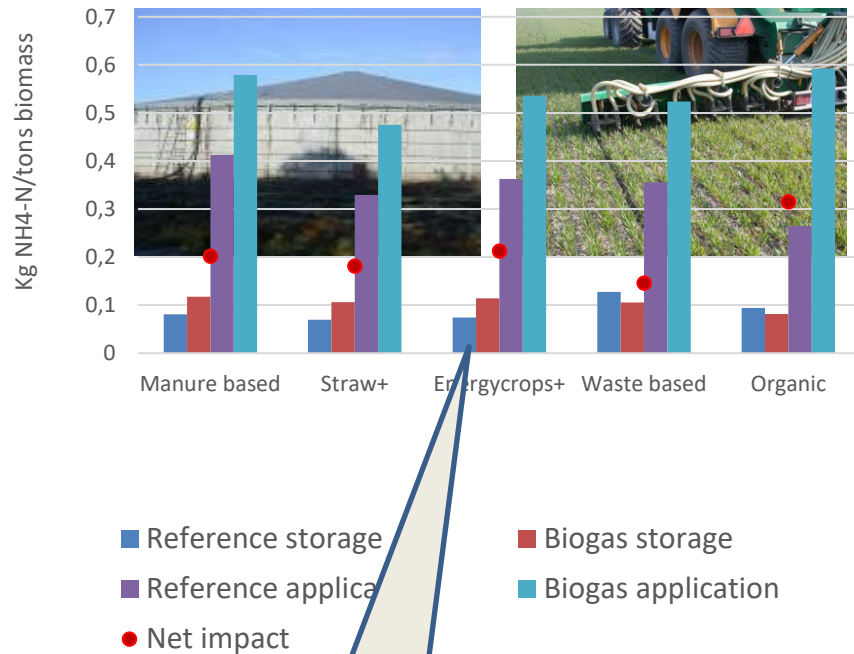


- High positive energy balance for all plants, heat exchangers improve the balance significantly and is needed to reduce storage CH<sub>4</sub> loss.
- Straw plant need technology development
- The nitrate leaching is reduced with 0,04-0,45 kg/tonnes. Energycrops limits the positive impact
- Emission of NH<sub>3</sub> is higher by AD if digestate is surface applied.



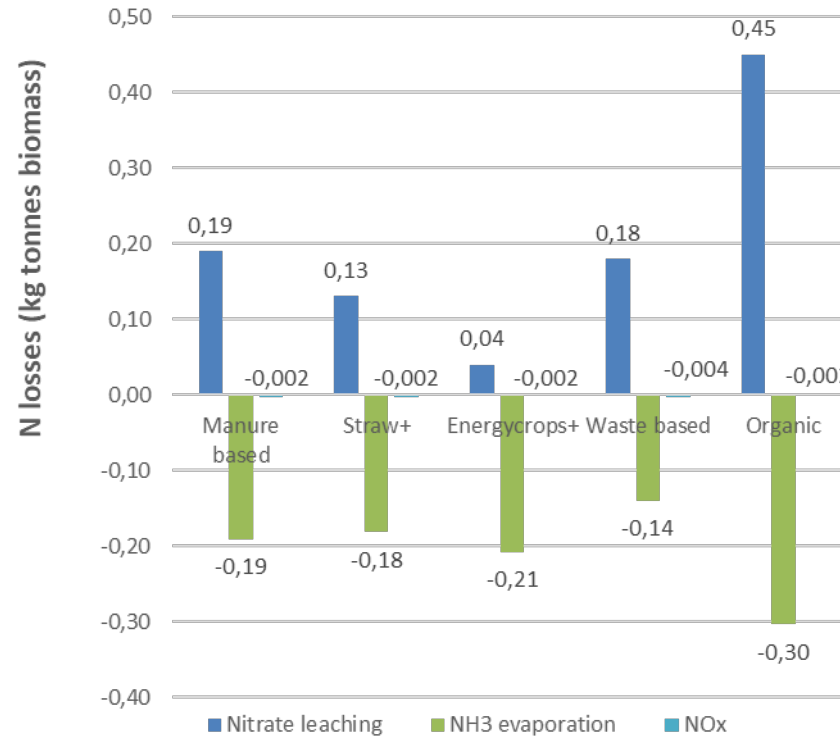
# NITROGEN

## NH3 emissions



High share is surface applied in Denmark

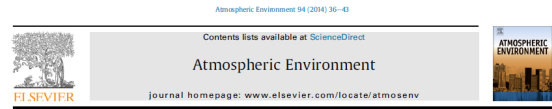
## Nitrogen losses



Nitrogen

- The models shows positive effect on NO3 but increased NH3 loss and increased NOx by extra transport

# INFLUENCE OF DIET WITH FOCUS ON FAT SUPPLEMENT AND ROUGHAGE TYPE



Feces composition and manure derived methane yield from dairy cows: Influence of diet with focus on fat supplement and roughage type

Henrik Bjarne Møller<sup>1,\*</sup>, Verónica Moset<sup>2</sup>, Maike Brask<sup>1</sup>, Martin Riis Weisbjerg<sup>2</sup>, Peter Lund<sup>1</sup>

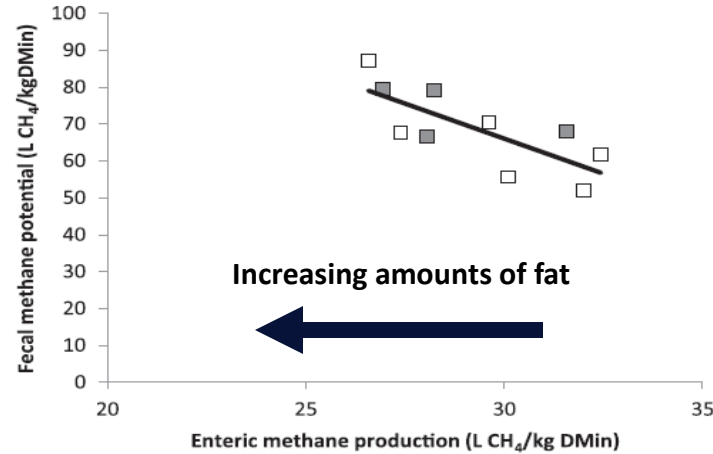
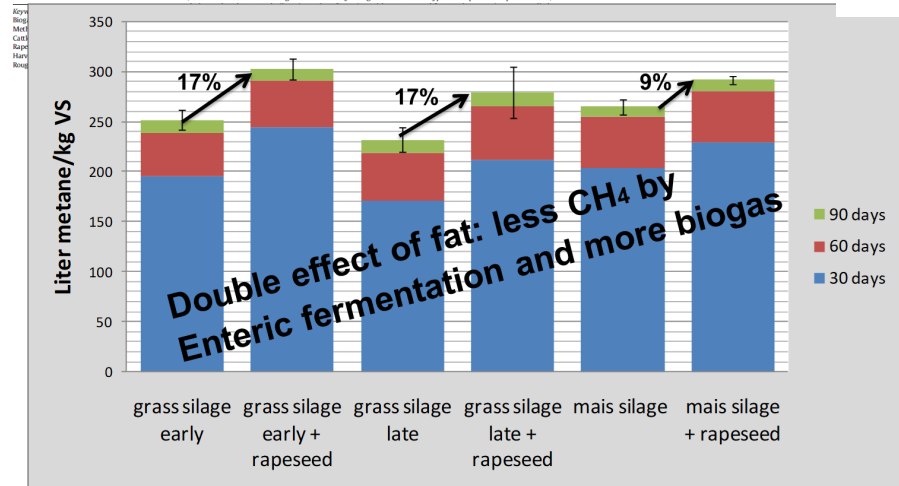
<sup>1</sup>Aarhus University, Department of Engineering, Blichers Allé 20, DK-8659 Silkeborg, Denmark  
<sup>2</sup>Aarhus University, Department of Animal Science, Blichers Allé 20, DK-8659 Silkeborg, Denmark

**HIGHLIGHTS**

- We model the methane potential from manure by diet and feces composition.
- We correlate crude fat in feces with the methane potential.
- Increasing fat in the diet increase the methane potential.

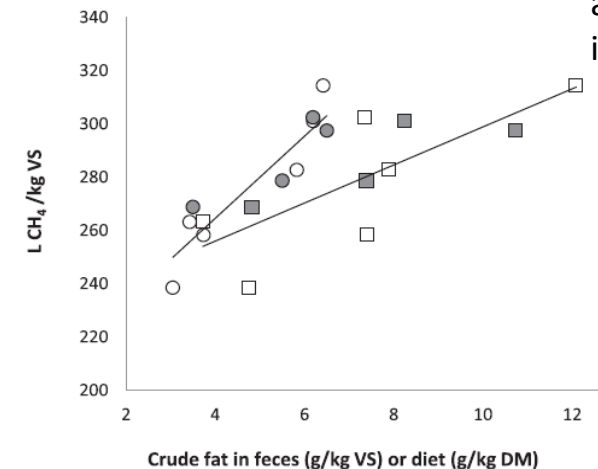
**ARTICLE INFO**      **ABSTRACT**

The objective of the present study was to evaluate the effect of dairy cow diets on feces composition and methane (CH<sub>4</sub>) potential from manure with emphasis on fat level and roughage type and compare these results with the corresponding enteric CH<sub>4</sub> emissions. In experiment 1 six different diets, divided into two fat levels (low and high) and three different roughage types (early cut grass silage, late cut grass silage and maize silage), were used. The high fat level was achieved by adding crushed rapeseed. In experiment 2, the influence of increasing the fat level by using three different types of rapeseed: rapeseed cake,



**Win-Win**

Increasing amount of fat reduce enteric methane production and at the same time increase methane potential



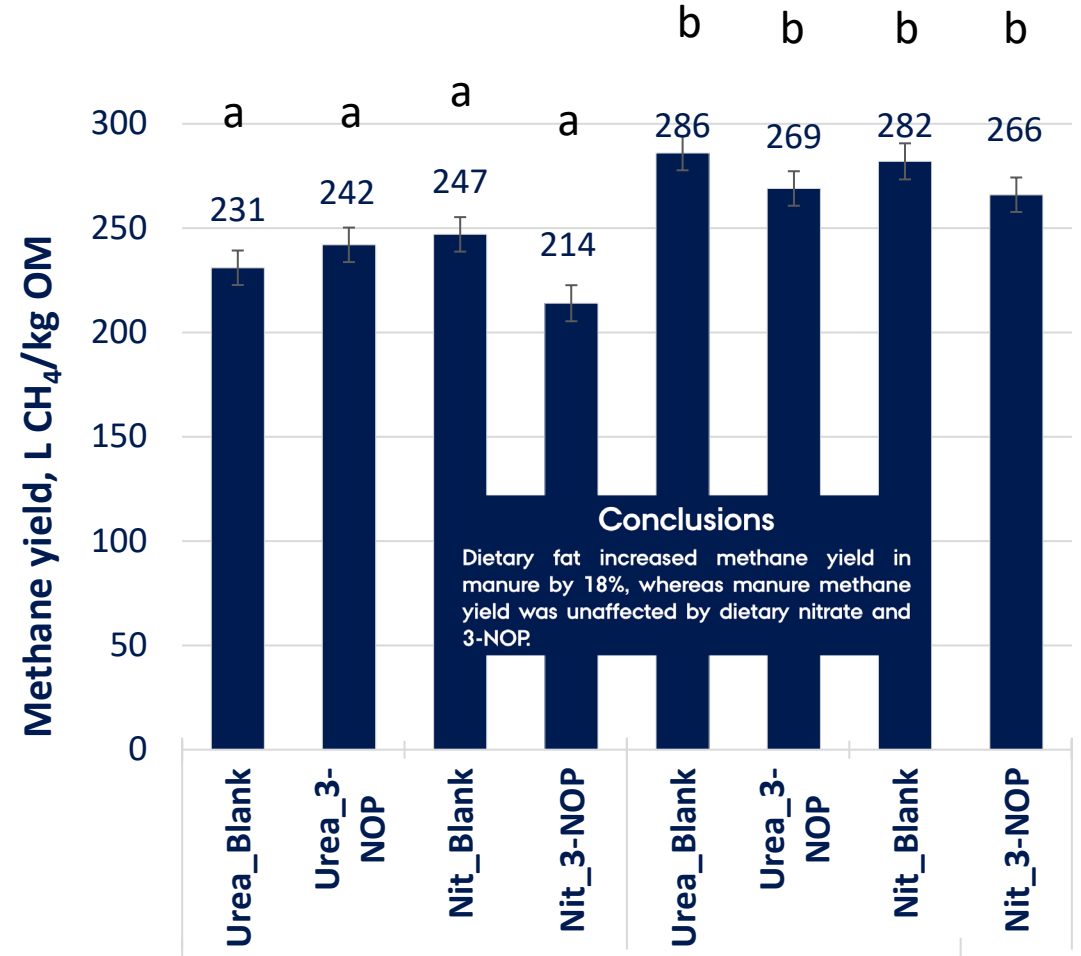
# IMPACT OF ADDITIVES

## Methane Potential of Manure from Dairy Cows Supplemented with Dietary Fat, Nitrate and 3-NOP

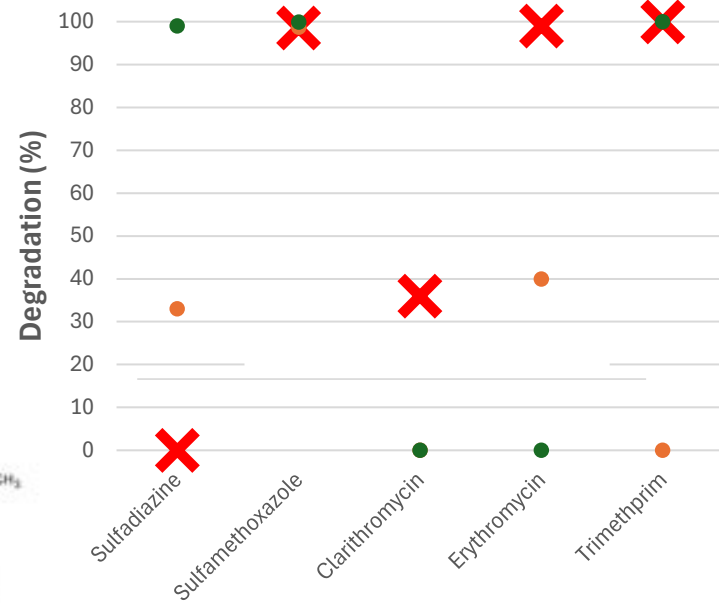
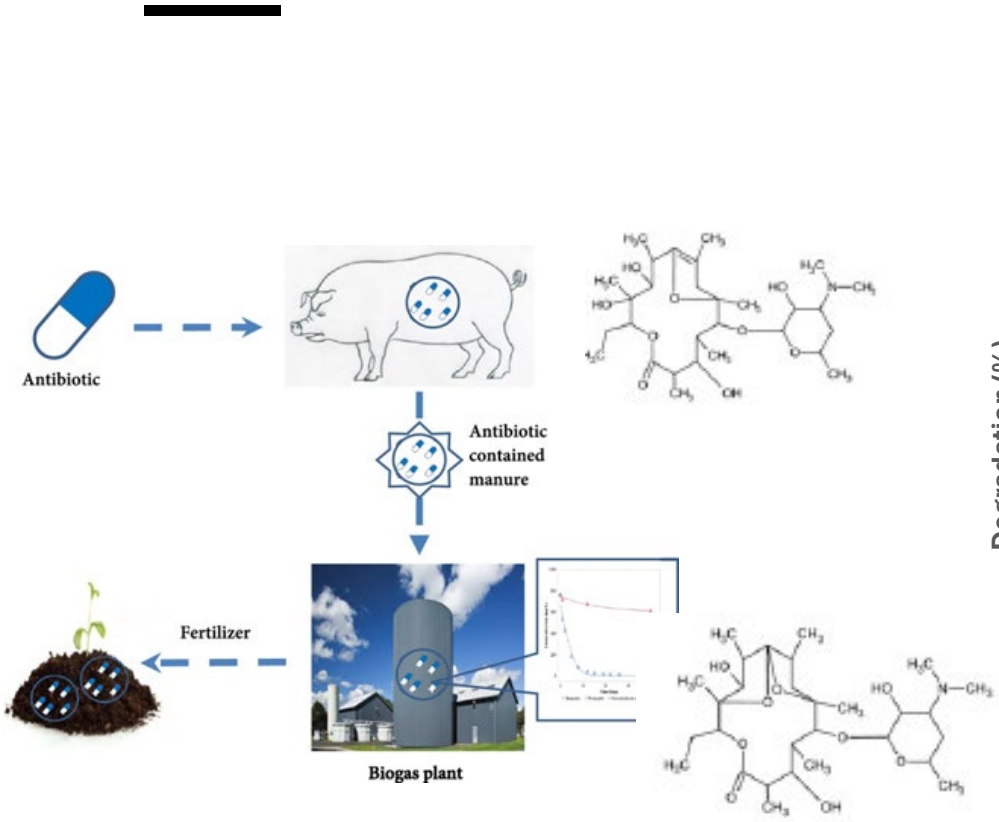
### Treatments

Cows were fed ad libitum. Diets were formulated with 50% forage inclusion of dry matter (DM). Forage DM constituted 48% grass-clover silage and 52% maize silage.

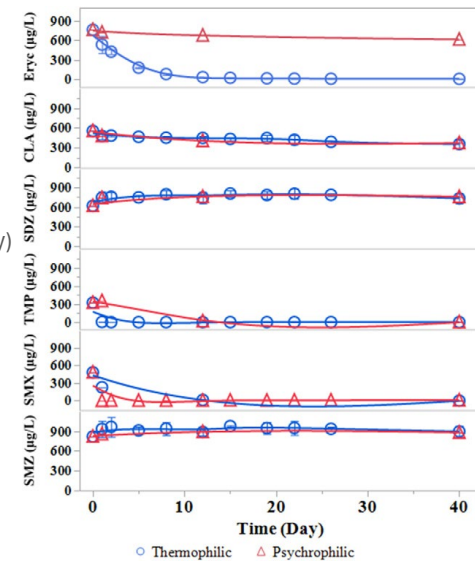
- 2 levels of fat (Low fat (**LF**); 30 g CF/kg DM or High Fat (**HF**); 63 g CF/kg DM)
- 2 levels of nitrate (source: SilvAir®) (0 g/kg DM; **Urea** or 10 g/kg DM; **NIT**)
- 2 levels of 3-NOP (0 mg/kg DM; **Blank** or 80 mg/kg DM; **3-NOP**)



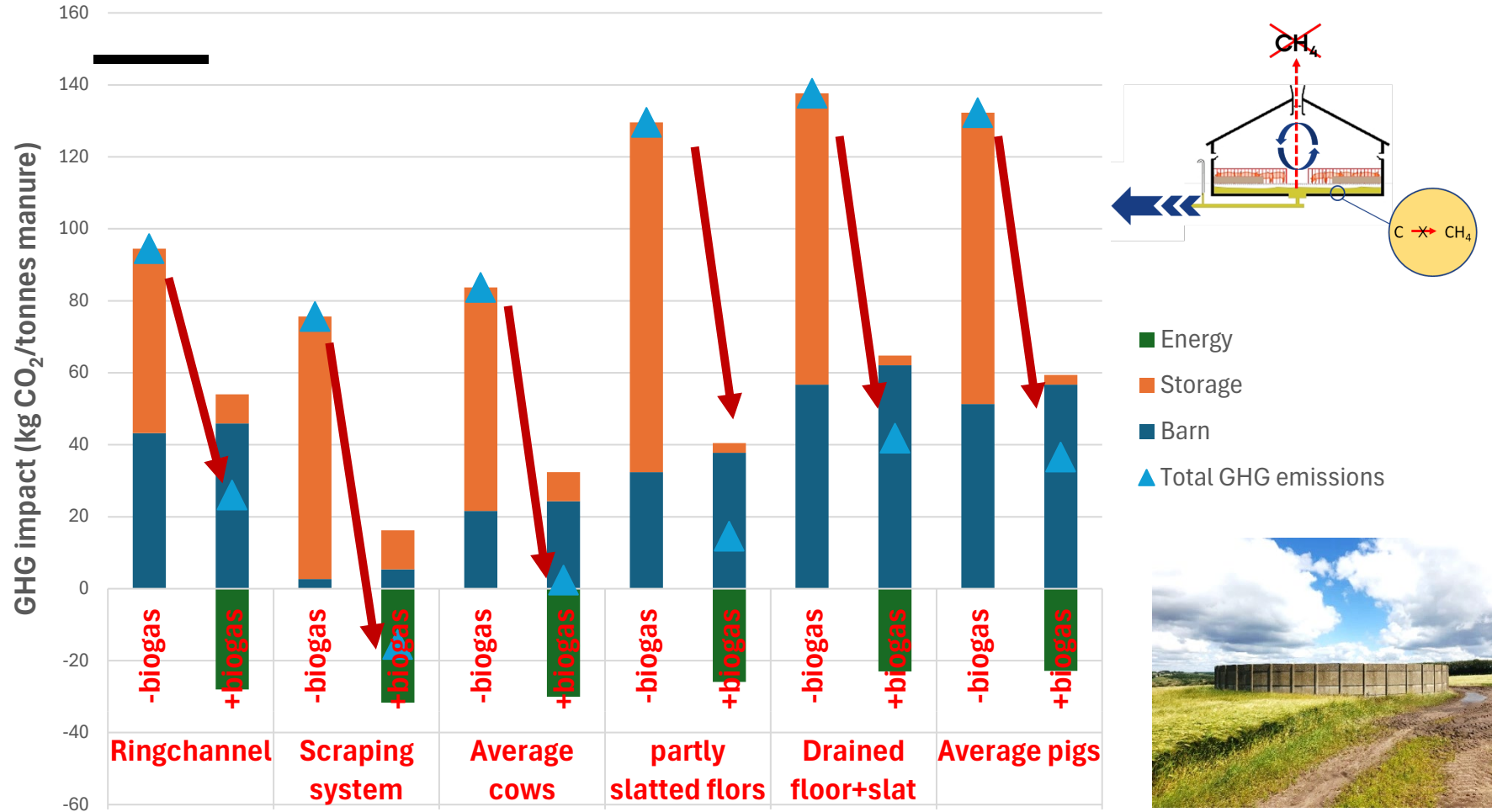
# AD AND ANTIBIOTICS!



✖ Thermophilic AD (our study)  
● Litterature (low)  
● Litterature (high)



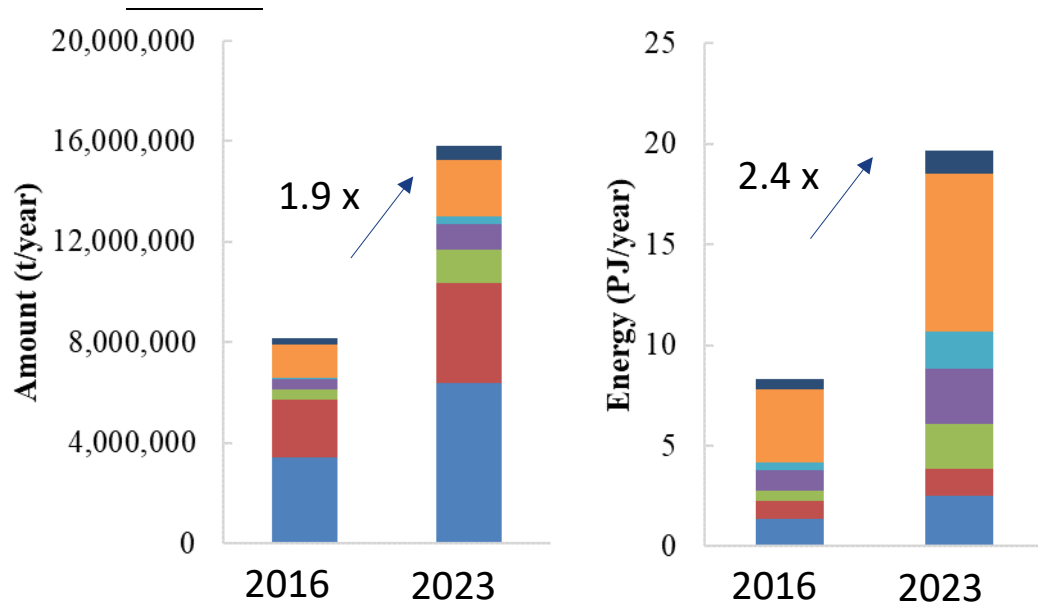
# IMPROVED CARBON MANAGEMENT!



- **Frequent discharge** of manure combined with treatment
  - + More degradable carbon for biogas



# THE DANISH BIOGAS SECTOR



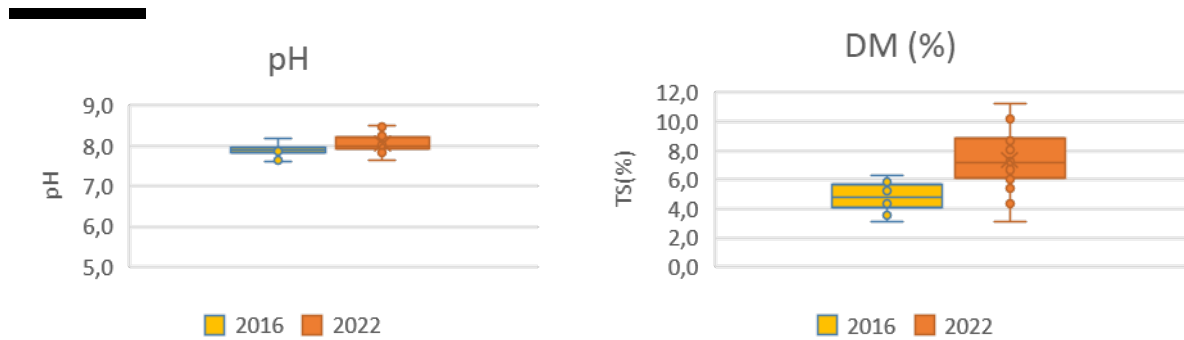
- Cattle manure
- Pig manure
- Deep litter
- Energy crops
- Straw products
- Industrial waste
- Municipal solid waste

## Intensification and changes of the biogas sector in Denmark in recent years

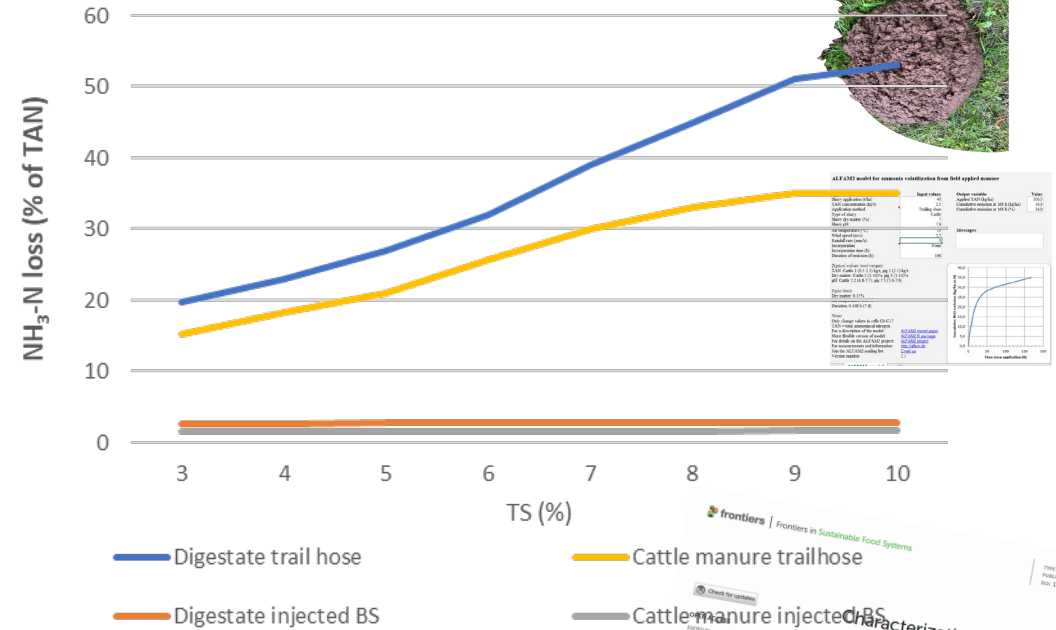
- More than doubling of amount of biomass utilized in anaerobic digestion and energy produced from 2016 to 2024;
- Change on feedstock composition driven by larger utilization of deep litter and straw:
  - Deep litter fraction: 9% of total mass in 2023 → increase of 70%;
  - Straw fraction: 2% of total mass in 2022 → increase of 125%;
  - Some biogas plants operate with up to 25% deep litter + straw!
  - There are new projects with 100% straw



# DIGESTATE



TS increase in by 52% from 2016 until today → slower soil infiltration rate → longer digestate exposition to atmosphere → increased risks for NH<sub>3</sub> emissions during field application.



ALFM2 model

## NH<sub>3</sub> emissions mitigation technologies:

- Acidification with H<sub>2</sub>SO<sub>4</sub> (expensive, over S fertilization)
- Soil injection (expensive, crops damage, not suitable for hard soils);
- Plasma treatment
- Solid-liquid separation.

**Characterization and valorization of biogas digestate and derived organic fertilizer products from separation processes**

**Henrik Bjarne Møller\***  
 \*Department of Biological and Chemical Engineering, Aarhus University, Aarhus, Denmark

**Cristiane Romão, Alastair James Ward\* and**  
 \*Department of Biological and Chemical Engineering, Aarhus University, Aarhus, Denmark

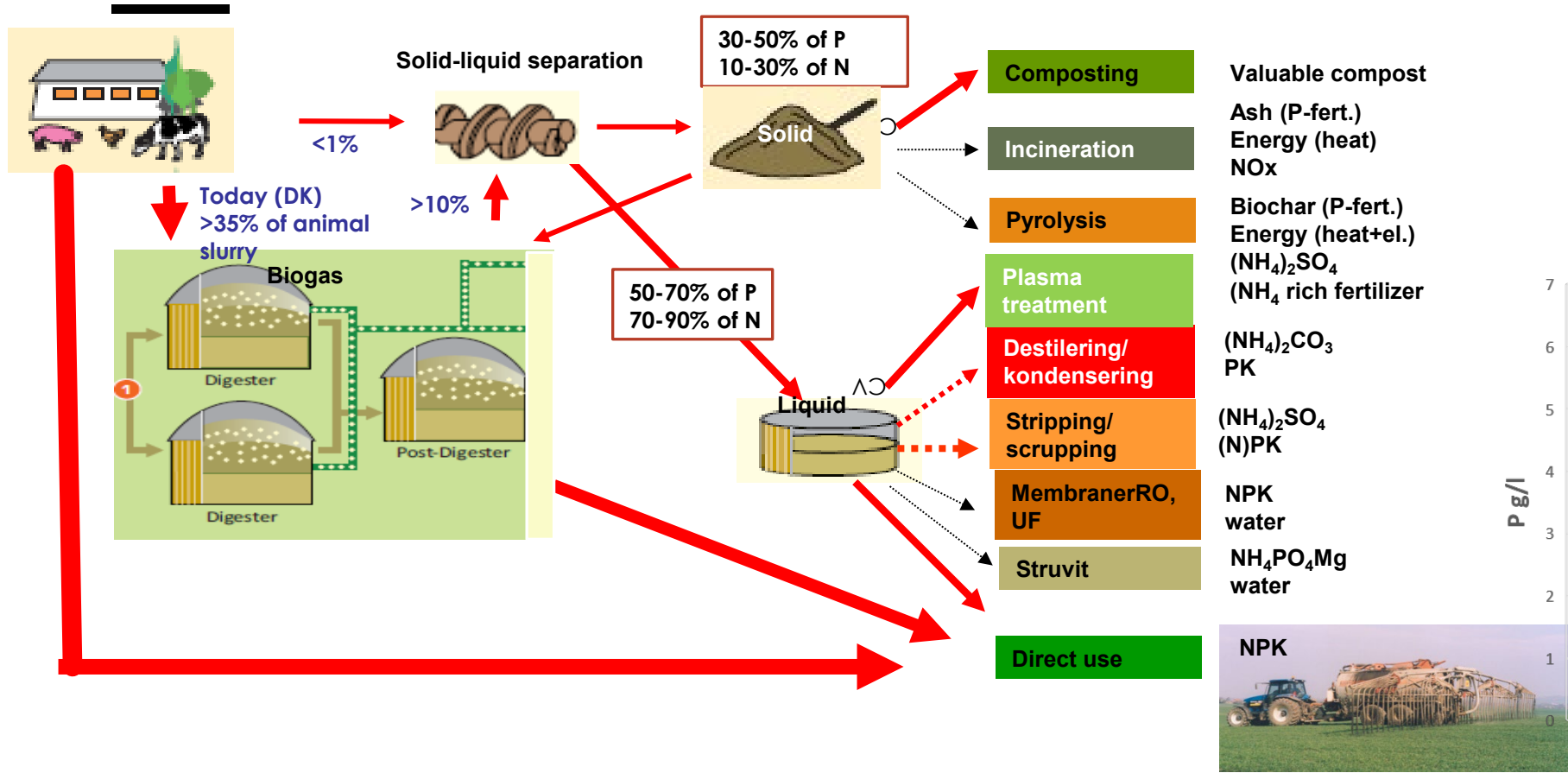
**Introduction:** Anaerobic digestion of manure, together with other biowastes, produces biogas that can substitute fossil energy and thereby reduce CO<sub>2</sub> emissions and post-digestion greenhouse gas emissions. The feed digestate of the process is an organic fertilizer rich in plant nutrients and recalcitrant organic constituents. The digestate characteristics and quality depend on several parameters, such as input feedstocks and operational conditions of the biogas plants. In Denmark, the rapid expansion of the biogas sector in recent years has resulted in a great variety of feedstocks used in the plants. The first generation of biogas plants mostly treated manure, industrial wastes, and energy crops with high attention to while the new generation of biogas plants are co-digesting with various cow manure, pig manure, and other organic waste streams. This study evaluated whether this shift in feedstock composition affects the fertilizer quality and the nutrient application of digestate.

**Methods:** Organic emissions, pH, and ammonia emissions were collected and analyzed from several digestate samples. The efficiencies of solid-liquid separations of digestate were investigated and the nutrient contents of the liquid and solid fractions of digestate were evaluated.

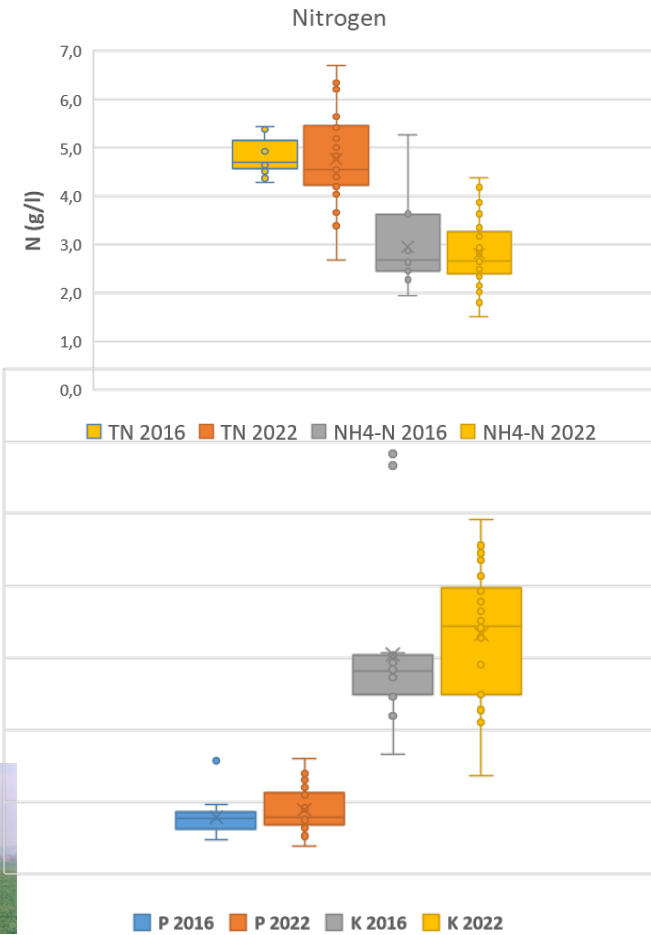
**Results and Discussion:** The most evident change caused by the feedstock transition was an average increase of 52% in the total solids content of digestate, which can negatively impact ammonia emissions during digestate application. It can also indicate considerable risks of methane emissions on a fresh matter basis of approximately 5 L/kg of industrially separated digestate during storage. The liquid fraction presented similar to those of unseparated digestate, while the solid fraction presented similar K, lower total ammoniacal nitrogen, and higher organic N and P concentrations of the industrially separated solid fraction. The average residual methane yield while the average calorific value was 21 MJ/kg volatile solids, indicating its potential for additional energy generation.



# DIGESTATE



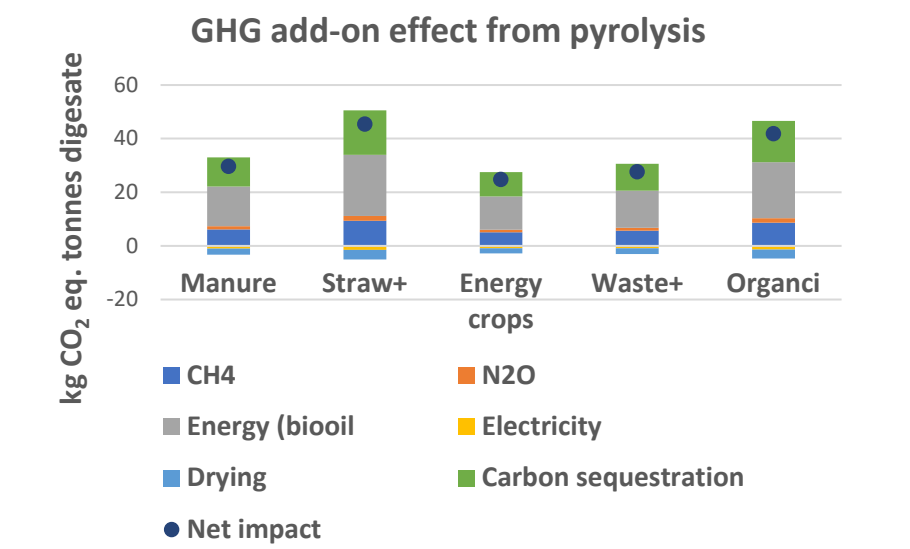
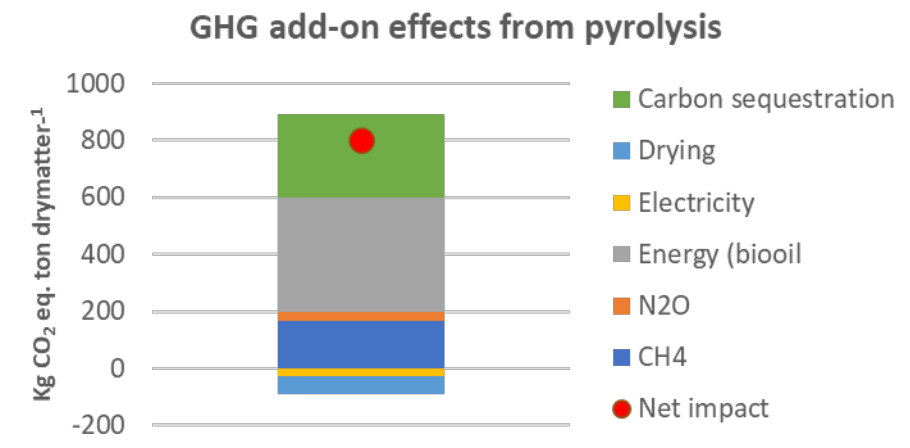
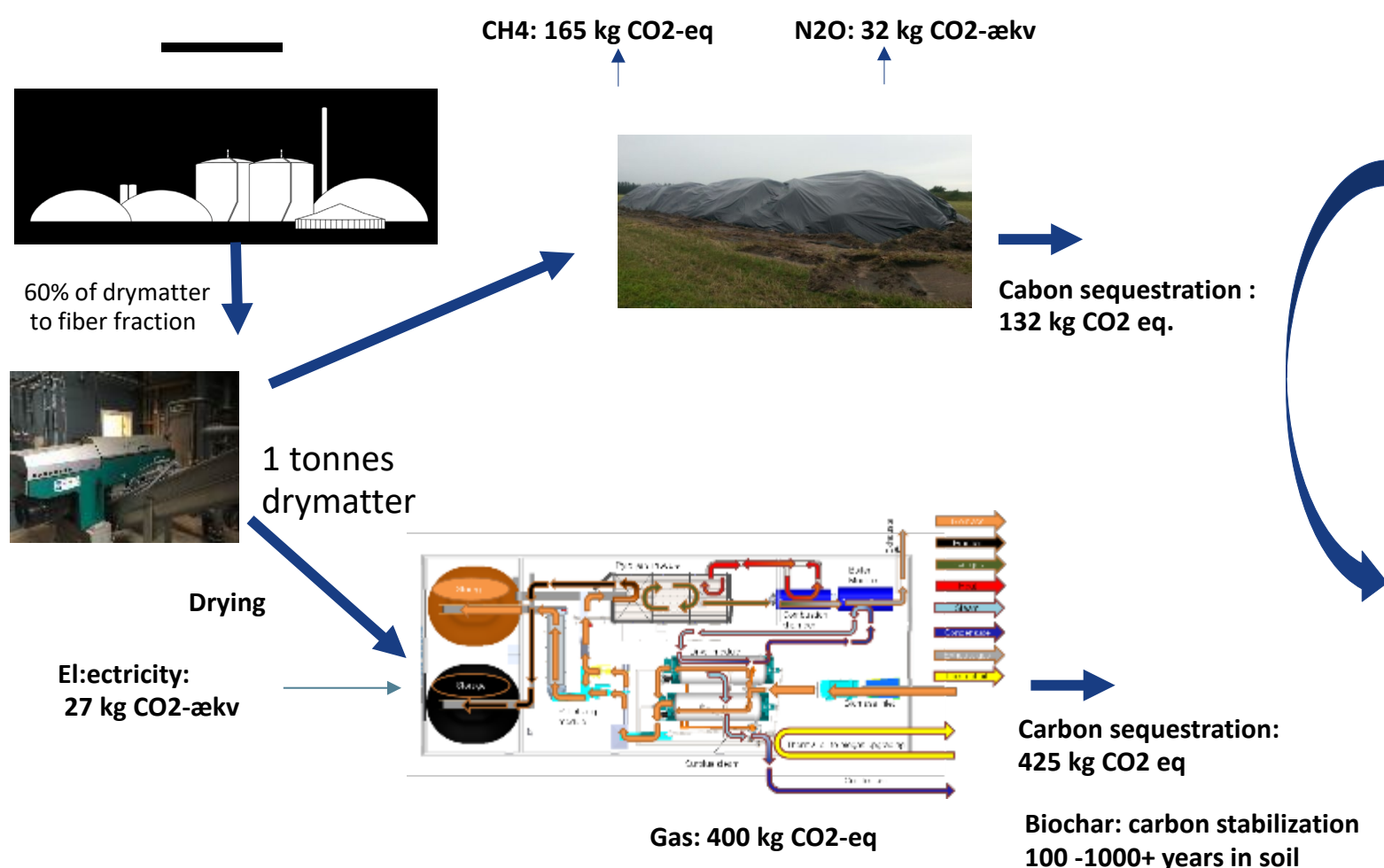
- Composting**: Valuable compost
- Incineration**: Ash (P-fert.), Energy (heat), NOx
- Pyrolysis**: Biochar (P-fert.), Energy (heat+el.),  $(\text{NH}_4)_2\text{SO}_4$ ,  $(\text{NH}_4)$  rich fertilizer
- Plasma treatment**:  $(\text{NH}_4)_2\text{CO}_3$ , PK
- Destilering/kondensering**:  $(\text{NH}_4)_2\text{SO}_4$ , (N)PK
- Stripping/scrupping**:  $(\text{NH}_4)_2\text{SO}_4$ , (N)PK
- MembranerRO, UF**: NPK water
- Struvit**:  $\text{NH}_4\text{PO}_4\text{Mg}$  water



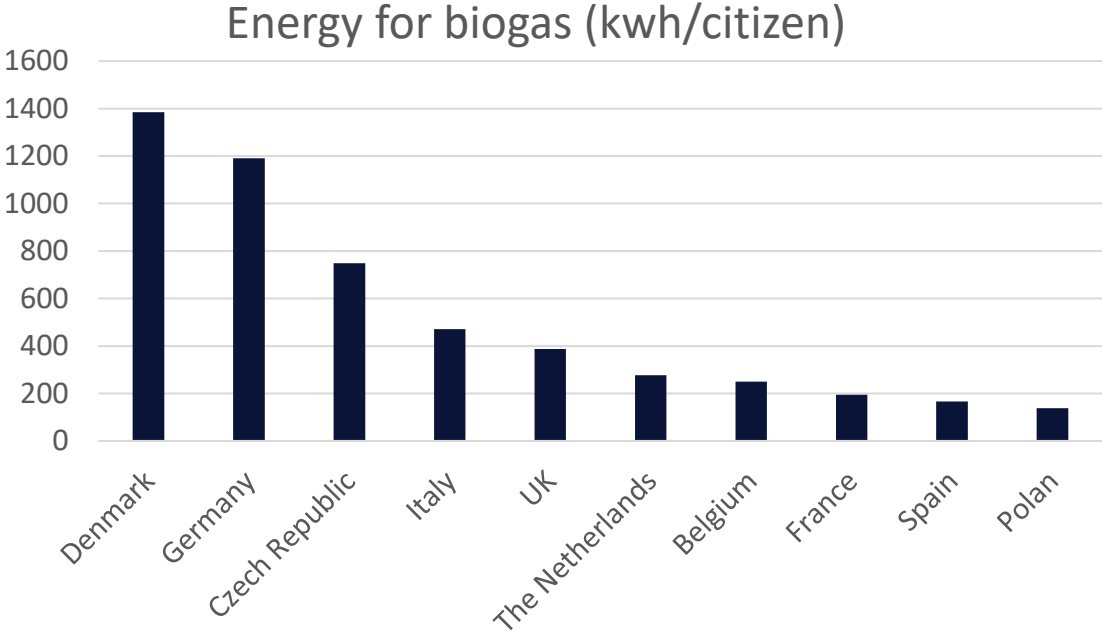
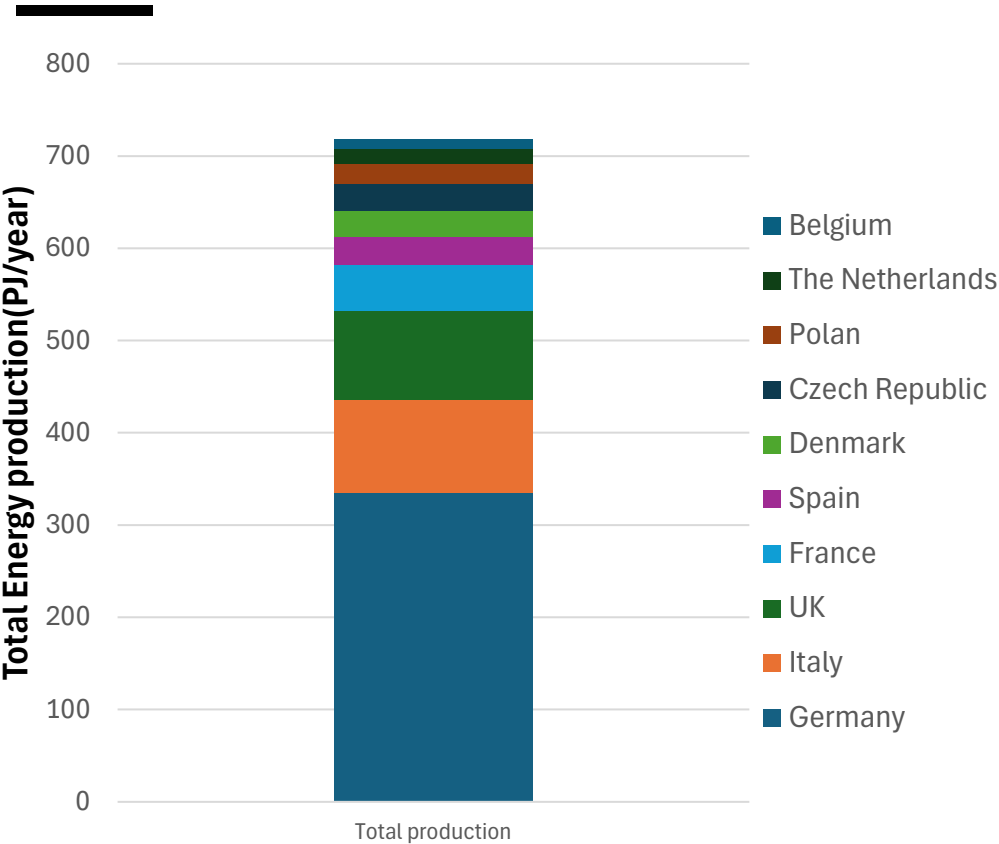
Digestate Rich in nutrients but highly variable



# PYROLYSIS OF FIBER FROM AD



# THE ROLE AND FUTURE OF BIOGAS IN EUROPE

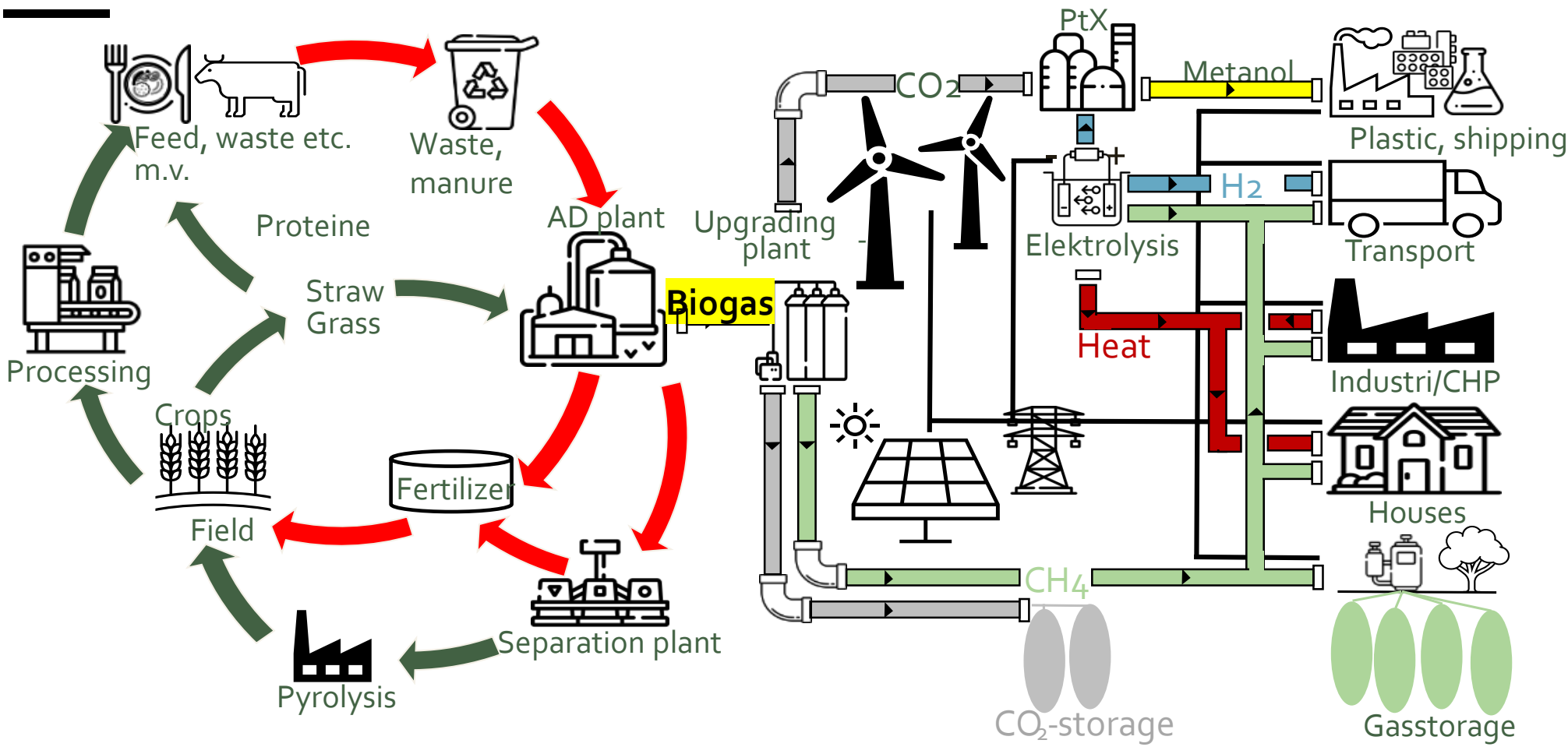


Data from: EBA Statistical Report 2023

EBA: Doubling before 2030



# THE ROLE AND FUTURE OF BIOGAS IN DENMARK



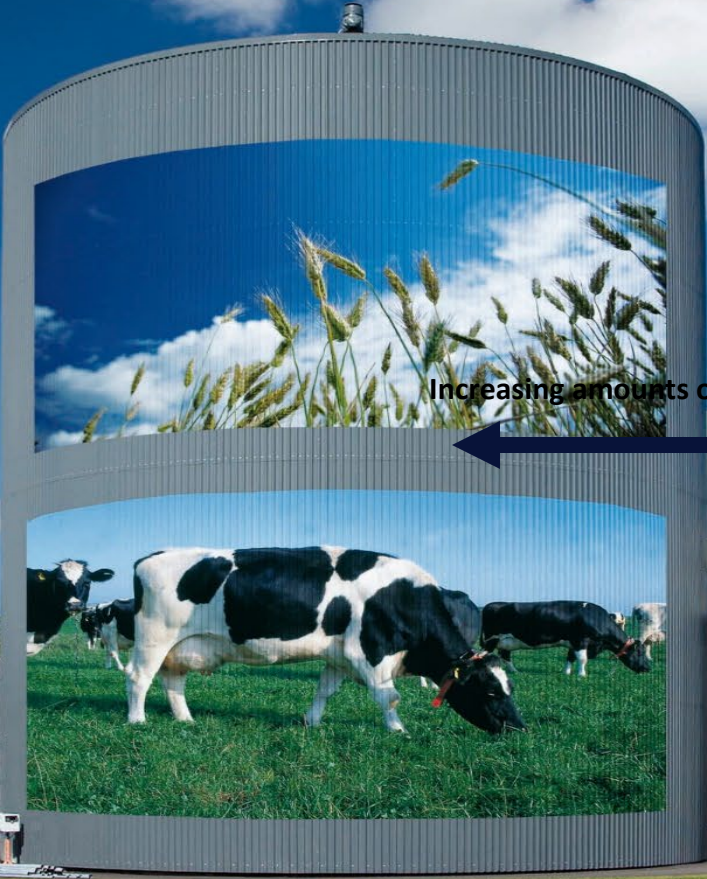
# CONCLUSIONS

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- Animal manure contains large amounts of carbon and nutrients that can be used and transformed into biofuel and fertilizers
- AD is the most developed route for utilization of carbon from animal manure to biofuel
- AD is an important tool to reduce the agricultures carbon foot-print and optimize gain of feed additives, feed and management changes.
- AD can degrade most antibiotics
- AD plays a major role in the transformation of the society to green energy



# THANKS FOR YOUR ATTENTION



Increasing amounts of fat