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GHG reduction with solid separation in POME ponds

Introducing new emission factors for alternative CH_4 reduction techniques

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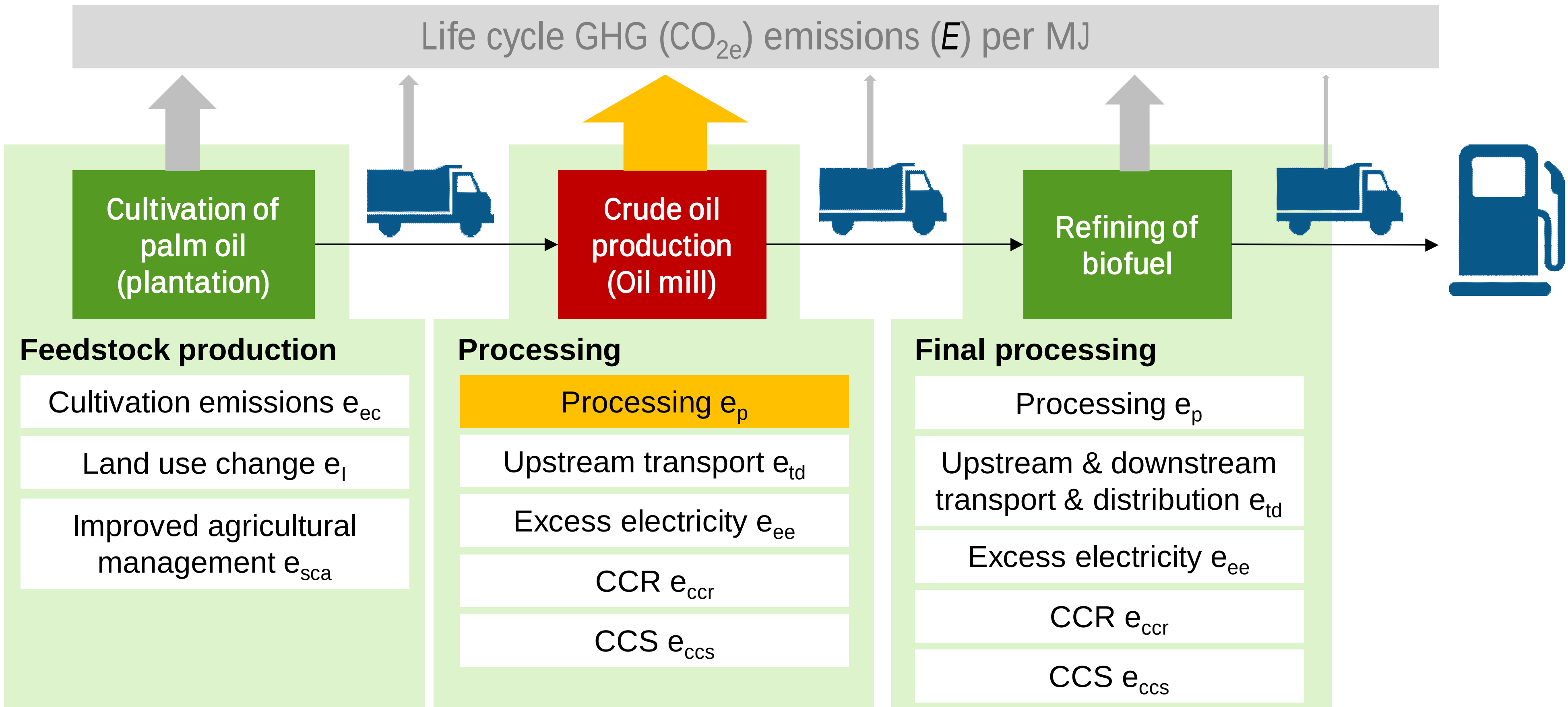
Content

A significant share of palm oil based biofuel's life cycle GHG emissions are caused by palm oil mill wastewater treatment



$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{CCS} - e_{CCR} - e_{ee}$$

e_p GHG emissions from processing

e_{td} GHG emissions from transport and distribution

e_{ccs} GHG emissions savings from carbon capture and geological storage

e_{ccr} GHG emissions savings from carbon capture and replacement

e_{ee} GHG emissions savings from excess electricity from cogeneration

Source: ISCC 2017, EU Renewable energy directive

Palm oil mill effluent (POME) is a waste stream of the Palm Oil Mill, which is collected and processed in anaerobic and aerobic ponds so that it can be safely discharged into the environment

Measures to reduce the wastewater treatment plant methane emissions have been developed

- Palm oil GHG emissions*
  - In 2015 Malaysian production of POME was 63.4 million m^3
  - This equals to approx. GHG emissions of 18.15 million t CO_{2e}
  - This equals to 6.5% of Malaysia's total GHG emissions in 2005

From open ponds to capture and prevention

- Co-composting
- Methane capture
  - Flaring
  - Biogas utilization
- Methane formation reduction

  à Solid separation

Source: Loh et. al 2017

Developing a calculation model for determining the impact of methane reduction measures on GHG emissions

GHG calculation of a biofuel is the sum of many parts of the supply chain.

Emissions from WWTP is part of the processing segment

Emission of input	Amount of input	Emission factor
$EM_{electricity}$	$= electricity\ consumption \left[\frac{kWh}{yr}\right]$	$* EF_{regional\ electricity\ mix} \left[\frac{kg\ CO_2eq}{kWh}\right]$
+		
EM_{inputs}	$= inputs\ consumption \left[\frac{kg\ or\ l}{yr}\right]$	$* EF_{inputs} \left[\frac{kg\ CO_2eq}{kg\ or\ l}\right]$
+		
$EM_{wastewater}$	$= wastewater \left[\frac{cbm}{yr}\right]$	$* EF_{wastewater} \left[\frac{kg\ CO_2eq}{cbm}\right]$
+		
EM_{heat}	$= fuel\ consumption \left[\frac{kg\ or\ l}{yr}\right]$	$* EF_{fuel} \left[\frac{kg\ CO_2eq}{kg\ or\ l}\right]$ or
	$= heat\ produced\ from\ fuel \left[\frac{MJ}{yr}\right]$	$* EF_{fuel/heat\ system} \left[\frac{kg\ CO_2eq}{MJ}\right]$

Especially of relevance for palm oil mills

EM = Emission; EF = Emission factor

- The EU RED calculation methodology that is implemented by the voluntary schemes does not provide any framework for the **GHG calculation** of alternative methane avoidance measures at **palm oil mills** aside from installations with methane capture or co-composting of POME and EFB
- However, promising **methane avoidance measures** are currently being developed and implemented by companies

Content

Solid separation: need for a study

- Previous POME research* has generally been concentrating on biogas formation potential and applicability of anaerobic bioreactors
- EU RED calculation methodology: current requirements and criteria for palm oil GHG
- Based on carbon balance and literature review it became evident that solid separation reduces CH_4 emissions
- Actual methane measurements had been done only in few studies, but none with solid separation

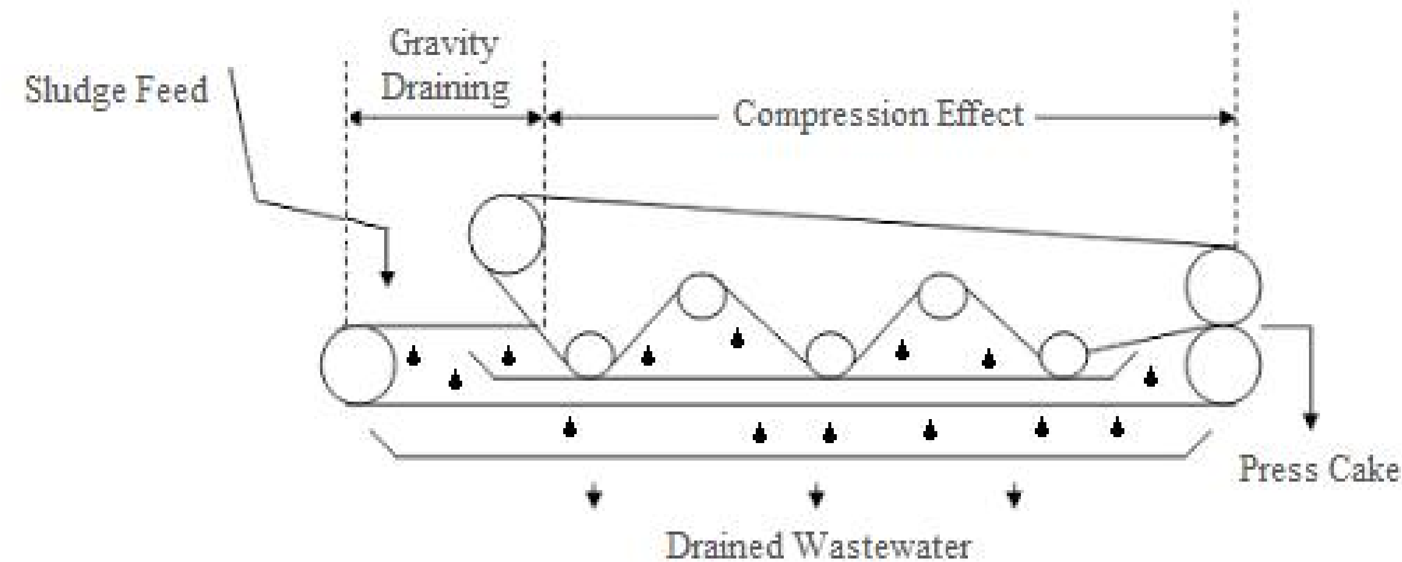
Need for a study: General CH_4 emission factor applicable for organizations in palm oil industry, utilizing solid separation, without extensive, complicated and expensive actual gas measurements

- in co-operation with ISCC, IDH, KLK and Neste
- Project started 2013, IDH in 2016
- Solid separation in operation, in comparison with open pond emissions

** e.g. Yacob et al 2005, Poh et al 2010, Taylor et al 2017, Loh et al 2017*

Belt filter press system

- Solid-liquid separation
- Obtained by passing a pair of filtering cloths, belts through a system of rollers
- The system takes sludge, effluent or slurry as a feed, often pretreated with flocculant, and separates them into a filtrate and a solid press cake.
- The separated solid, “filter cake” can be used for fertilizer in the plantation which reduces the need for other GHG-intensive fertilizers.



Belt filter press system

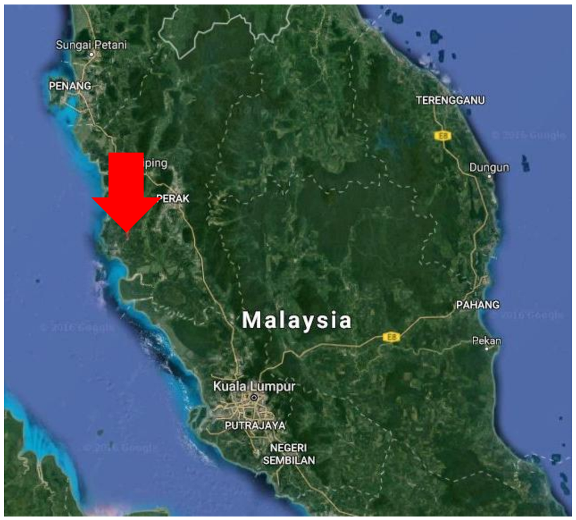
Content

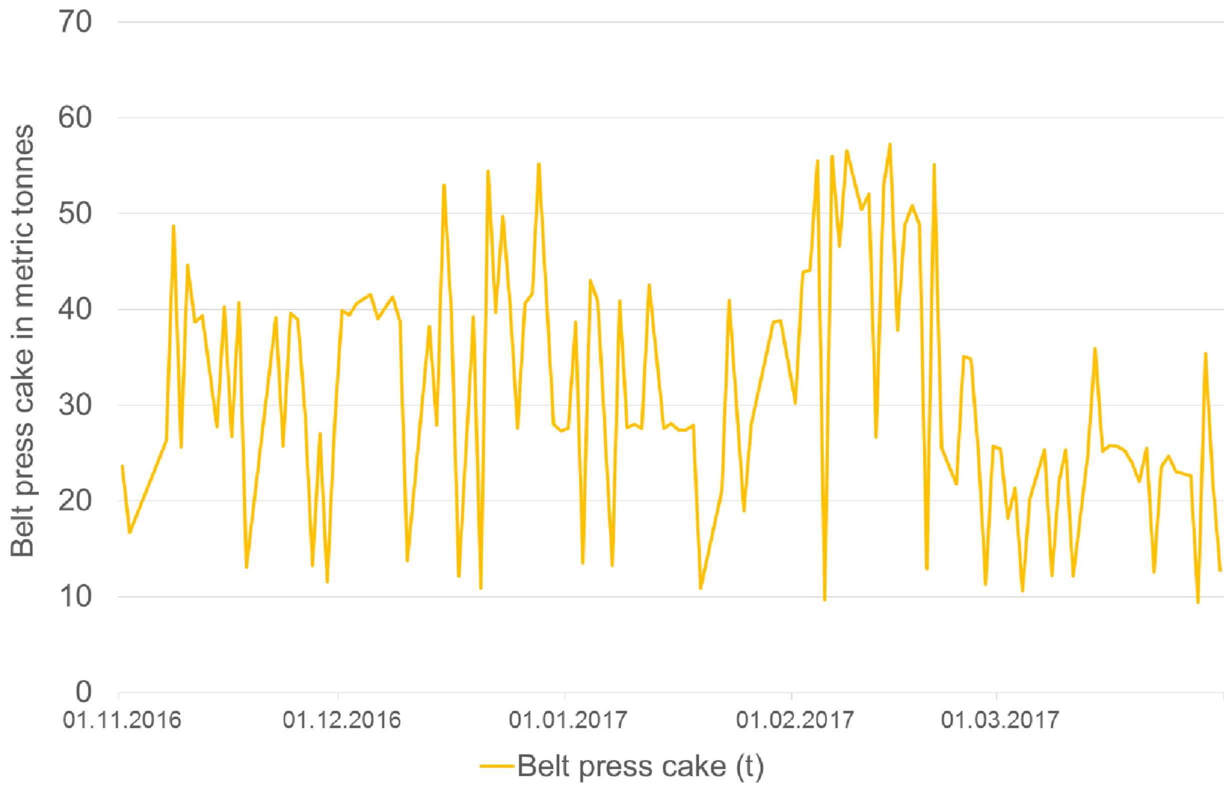
Developing a calculation model for determining the impact of methane reduction measures on GHG emissions

- Based on onsite measurements, a functional relationship for every pond between the GHG and carbon content of the organic matter in the POME ponds
  - And/or other parameters that are easy to assess by the palm oil mill
- The relationship can then be applied for different methane reduction set-ups at oil mills for determining GHG emissions
- Two measurement sequences are required,
  - the first one to set the baseline (without the belt press being in operation),
  - the second one with stationary operation of the belt-press

Field research: Case study mill in Perak, Malaysia

- 730 t FFB d^{-1}
- 156 t CPO d^{-1}
- 27.3 t belt press cake d^{-1}
- 5 anaerobic POME ponds





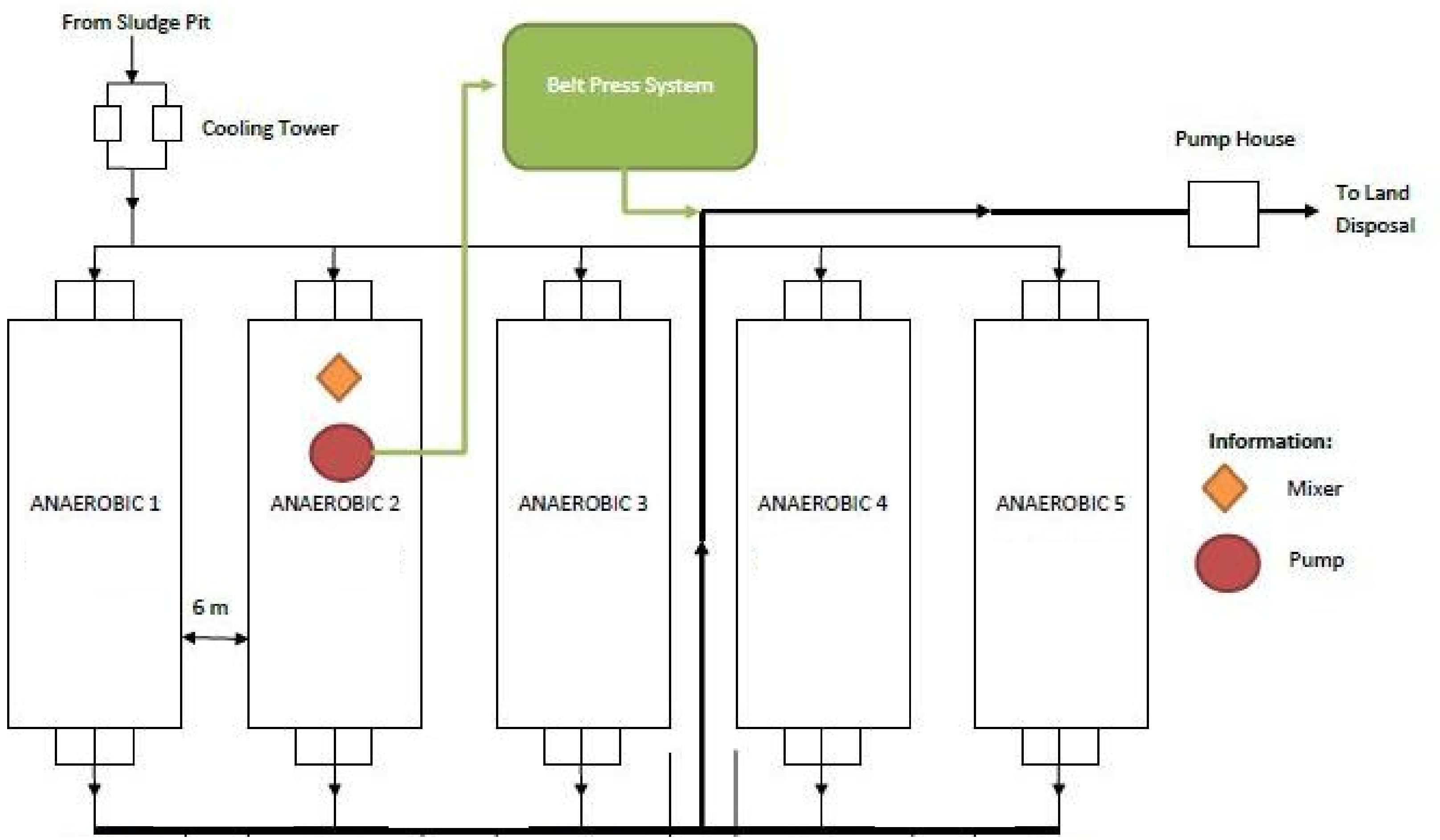
Solid separation

- The belt press system was installed in pond 1, to where it was moved 3 weeks prior the measurements from pond 2, where it had been in use from October to December.

Baseline

- Other “baseline” mill in Indonesia and the Malaysian “case study” mill ponds without solid separation
- The baseline mill appeared to have a very different production profile than assumed and it had an effect on comparability
- The best comparison was achieved with anaerobic ponds in the “case study” mill without solid separation

POME treatment plant layout of the Case study mill

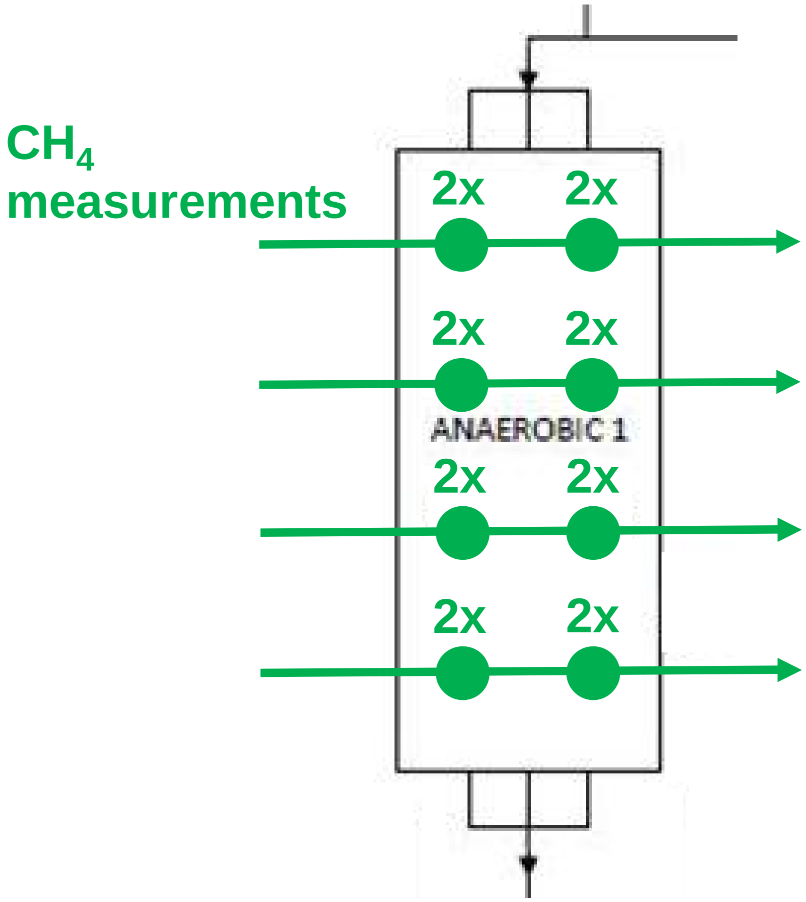


Slurry pump was moved to anaerobic pond 1 three weeks before CH_4 measurements.

Anaerobic ponds 1 and 2 of the case study mill with belt press, cooling tower in the background

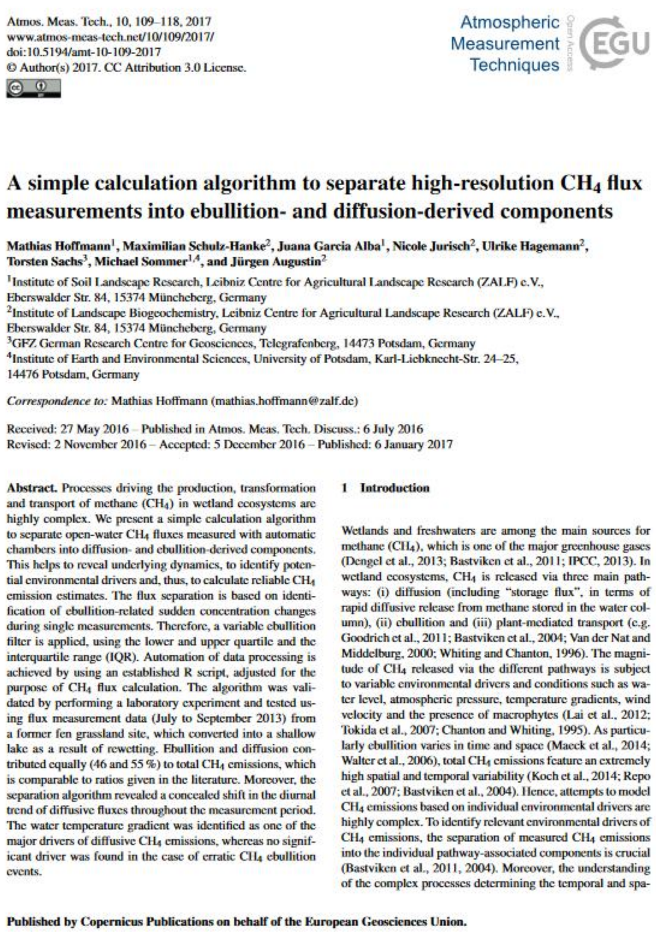
Design of measurement setup

- Ponds are measured in four transects on a daily rotational mode for CH_4 focusing on those with belt press "background"
  - I.e. one CH_4-measurement rotation for all ponds took 9 days
- Every transect has two measuring points, repeated twice
- Chamber closure time is five minutes
- During February more detailed transects were taken in order to identify edge effects
  - Change: Increase of measuring points (3) and reduced chamber closure time (1 min)



On-site measurements

CH_4 emissions are calculated using a version of a methane flux calculation tool developed by Hoffmann et. al (2017)



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Atmospheric Measurement Techniques
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A simple calculation algorithm to separate high-resolution CH_4 flux measurements into ebullition- and diffusion-derived components

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Abstract. Processes driving the production, transformation and transport of methane (CH_4) in wetland ecosystems are highly complex. We present a simple calculation algorithm to separate open-water CH_4 fluxes measured with automatic chambers into diffusion- and ebullition-derived components. This helps to reveal underlying dynamics, to identify potential environmental drivers and, thus, to calculate reliable CH_4 emission estimates. The flux separation is based on identification of ebullition-related sudden concentration changes during single measurements. Therefore, a variable ebullition filter is applied, using the lower and upper quartile and the interquartile range (IQR). Automation of data processing is achieved by using an established R script, adjusted for the purpose of CH_4 flux calculation. The algorithm was validated by performing a laboratory experiment and tested using flux measurement data (July to September 2013) from a former fen grassland site, which converted into a shallow lake as a result of rewetting. Ebullition and diffusion contributed equally (46 and 55 %) to total CH_4 emissions, which is comparable to ratios given in the literature. Moreover, the separation algorithm revealed a concealed shift in the diurnal trend of diffusive fluxes throughout the measurement period. The water temperature gradient was identified as one of the major drivers of diffusive CH_4 emissions, whereas no significant driver was found in the case of erratic CH_4 ebullition events.

1 Introduction

Wetlands and freshwaters are among the main sources for methane (CH_4), which is one of the major greenhouse gases (Dengel et al., 2013; Bastviken et al., 2011; IPCC, 2013). In wetland ecosystems, CH_4 is released via three main pathways: (i) diffusion (including "storage flux", in terms of rapid diffusive release from methane stored in the water column), (ii) ebullition and (iii) plant-mediated transport (e.g. Goodrich et al., 2011; Bastviken et al., 2004; Van der Nat and Middelburg, 2000; Whiting and Chanton, 1996). The magnitude of CH_4 released via the different pathways is subject to variable environmental drivers and conditions such as water level, atmospheric pressure, temperature gradients, wind velocity and the presence of macrophytes (Lai et al., 2012; Tokida et al., 2007; Chanton and Whiting, 1995). As particularly ebullition varies in time and space (Maeck et al., 2014; Walter et al., 2006), total CH_4 emissions feature an extremely high spatial and temporal variability (Koch et al., 2014; Repo et al., 2007; Bastviken et al., 2004). Hence, attempts to model CH_4 emissions based on individual environmental drivers are highly complex. To identify relevant environmental drivers of CH_4 emissions, the separation of measured CH_4 emissions into the individual pathway-associated components is crucial (Bastviken et al., 2011, 2004). Moreover, the understanding of the complex processes determining the temporal and spa-

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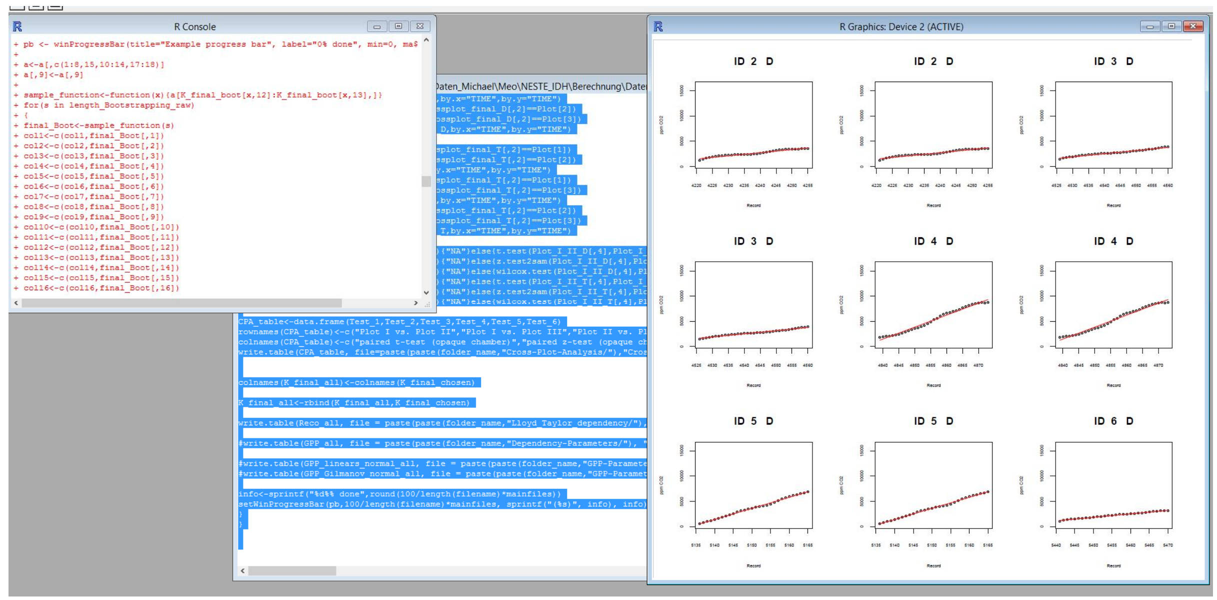


Assessing the CH_4 emission is based on identifying the increase of gas concentration over time within the chamber volume

$$r_{CH_4}[\mu g \times C \times m^{-2} \times h^{-1}] = \frac{M[g \times mol^{-1}] \times P[Pa] \times V[m^3] \times dv[ppm(v)] \times f_1}{R[m^3 \times Pa \times K^{-1} \times mol^{-1}] \times T[K] \times t[h] \times A[m^2]}$$

r_{CH_4} : *Gas flux (e.g. CH_4)*

M : *molar mass*

P : *barometric pressure*

V : *chamber headspace (volume)*

R : *constant*

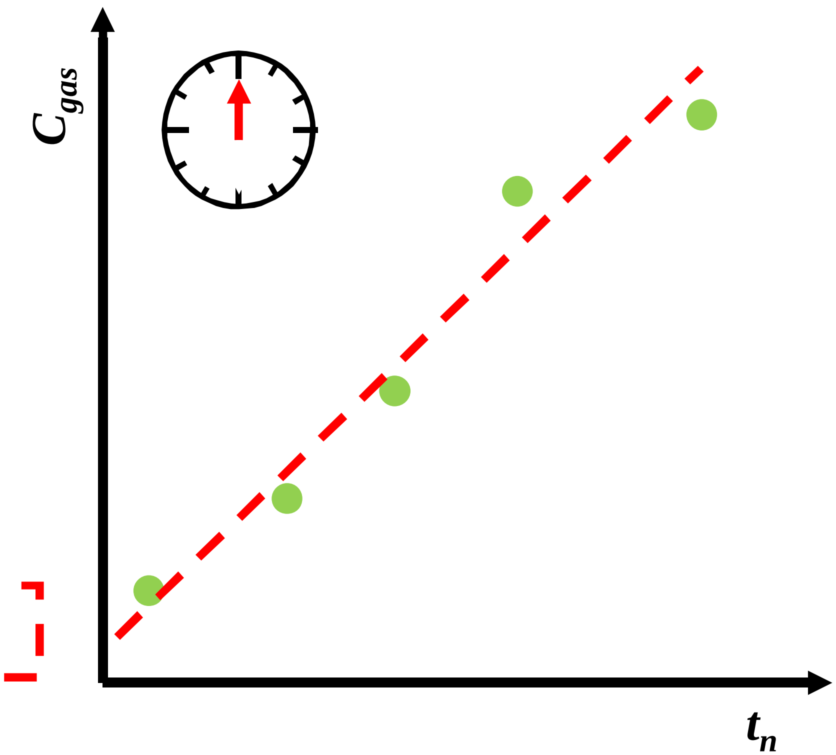
T : *temperature*

t : *time*

A : *size of observed area*

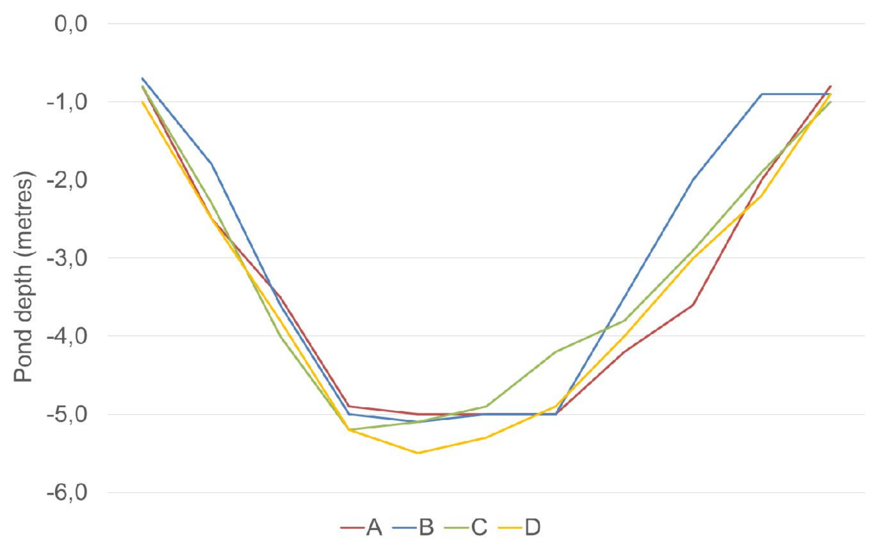
f_1 : *elementary part of observed gas molecule*

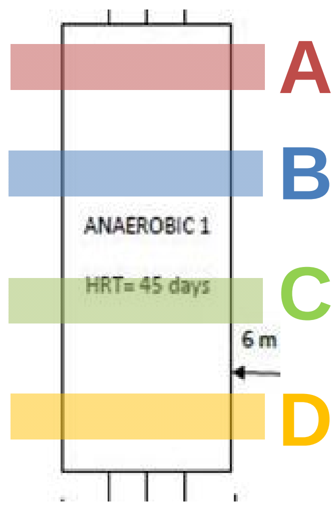
dv : *observed slope of gas concentration c_{gas} over time t_n*



Design of measurement setup

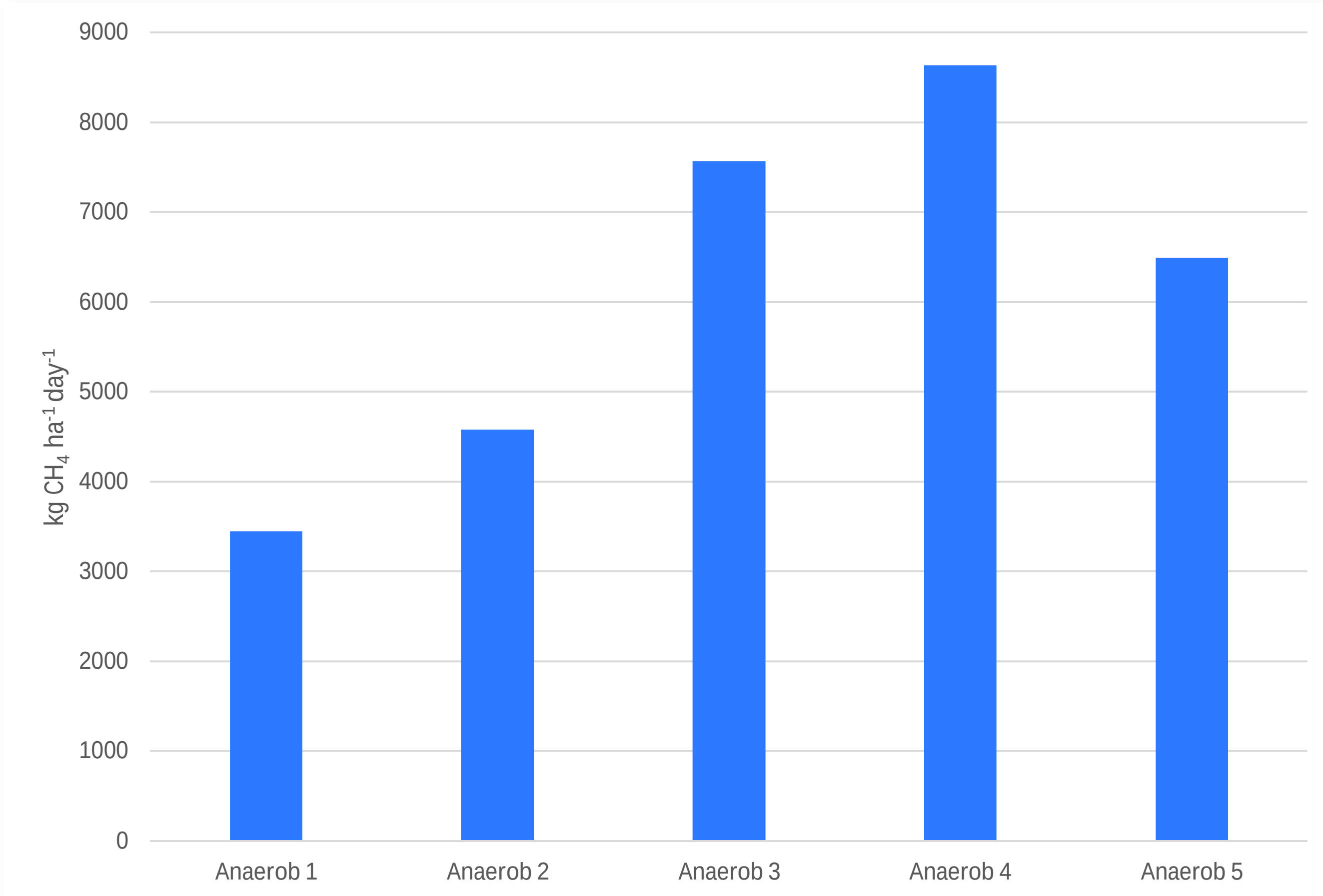
- For the day of CH_4-measurement of each pond, COD_{Cr} (Chemical Oxygen Demand) samples were taken from 3 different depths close to inlet and outlet of the ponds (= 6 COD samples per day)
- Water temperatures were recorded with logging devices every 30 minutes in three to four different depths over several days in each pond
- TOC (Total organic carbon) and dry matter sampling was done in raw effluent inlet, final discharge (outlet) and the belt press cake
- Pond profile was measured





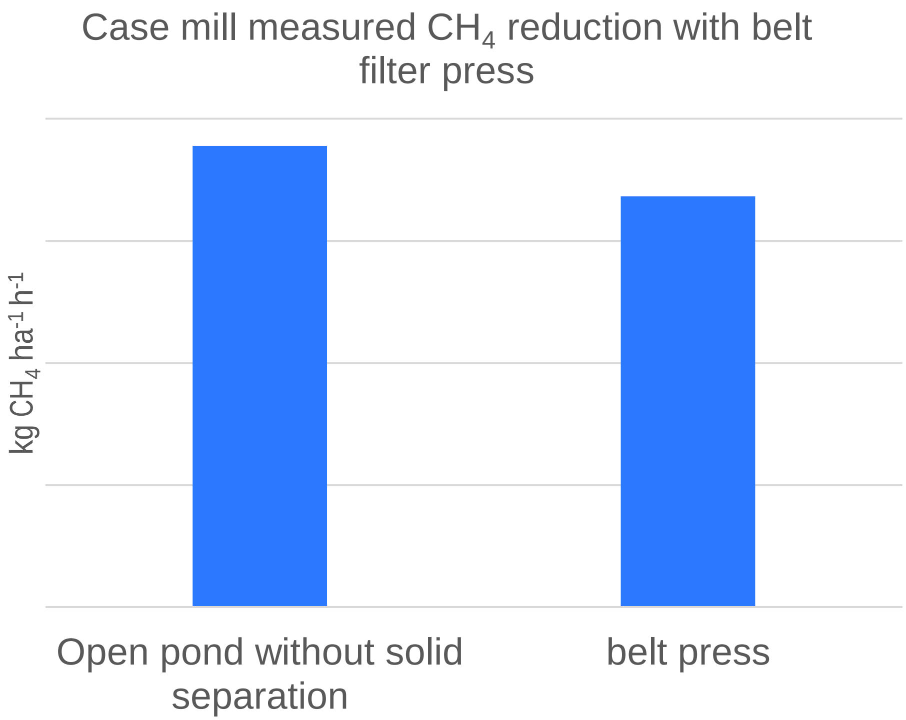
Measurement results

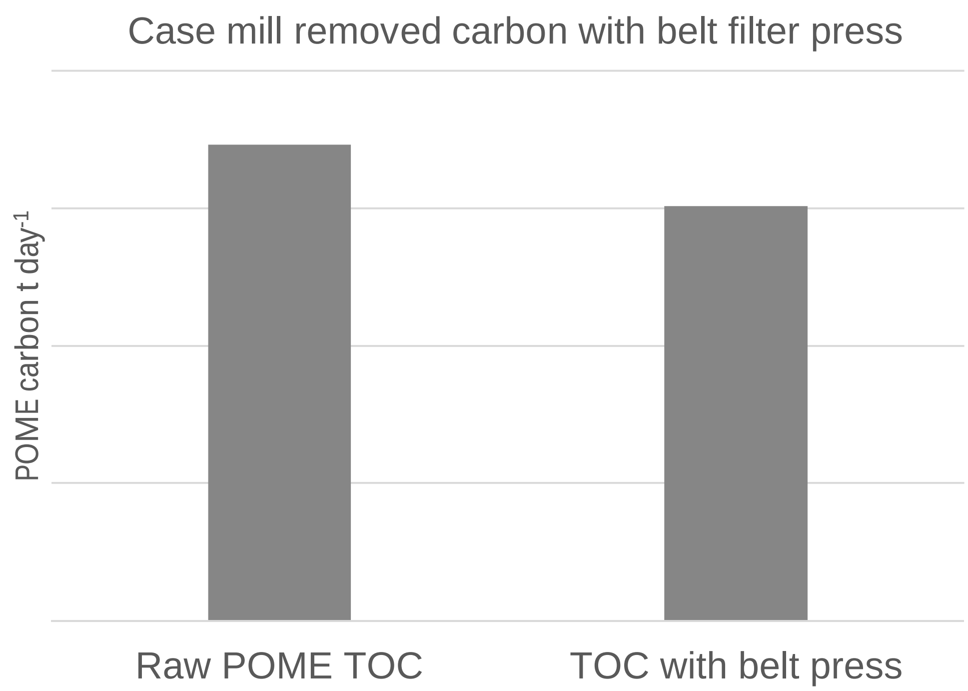
- Average CH_4 emissions for each pond show that pond 1 with belt filter press system had significantly lower emissions than ponds 3, 4 and 5
- Pond 2 is considered to remain in intermediate state between solid separation and open pond
- TOC measurements gave an average of 3.25 % of carbon in belt press cake



- COD values show decreasing trend for surface values from pond inlet to pond outlet in first ponds
- Water and air temperatures remained stable

The measurement showed similar reduction with 1 belt press in both CH_4 emissions and carbon





Content

Carbon content can be used in estimating reduced emissions

- TOC measurements gave an average of 3.25 % of carbon in belt press cake
- This results in 890 kg d^{-1} removed carbon with belt filter press in the case study mill, with belt press cake production of 27 t d^{-1}
- GHG (CO_{2e}) formation factor for removed carbon
  - *Molecular weight of CH_4 =16.04*
  - *Molecular weight of carbon = 12.01*
  - *Methane correction factor from IPCC wastewater methodology* = 0.8*
  - *IPCC uncertainty factor** = 0.94*
  - *Methane global warming potential converted to CO_{2e} (as defined in RED) = 23*
- Removed carbon converted to avoided CO_{2e} emissions with a GHG factor of 23.1:

$$CO_{2e} emission\ reduction_{beltfilterpress}\,(t) = Carbon\ content_{beltfilterpress}(t) * \frac{16}{12} * 0.8 * 0.94 * 23$$

à The case study mill‘s daily GHG reduction with belt filter press is 20.6 t CO_{2e}

- Equals to 0.13 $kgCO_{2e}$/kgCPO with production of 156 t CPO d^{-1}
- Annual reduced emissions of approx. 5300 t CO_{2e}

*UNFCCC IPCC: CDM AMS-III.H. Small-scale Methodology Methane recovery in wastewater treatment. Version 18.0.
**UNFCCC IPCC 2003: Greenhouse gas inventories and additional information submitted by Parties included in Annex I Reporting, accounting and review requirements relating to the second commitment period of the Kyoto Protocol

Based on the findings from this study, an enhanced GHG calculation would allow for the inclusion of emission from oil mills with belt press

- This study showed that the carbon content of the organic material that was removed by a belt press installation from POME ponds, relates to the mass of methane that is avoided, compared to a baseline open pond system
- Thus, it is recommended to include an GHG emission factor for palm oil mills that are using an operating belt press installation within their waste water treatment plant
- This emission factor shall be deduced from the baseline open pond emission factor

$$EF_{belt\ press}\left(\frac{kg\ CO_{2e}}{kg\ CPO}\right) =$$

$$EF_{open\ ponds}\left(\frac{kg\ CO_{2e}}{kg\ CPO}\right) - \frac{Carbon\ content_{Belt\ press\ cake} * annual\ average\ belt\ press\ cake\ production\ (t)}{annual\ average\ CPO\ production\ (t)} * 23.1$$

With 23.1 as conversion factor for carbon to GHG

- ISCC emission factor for open ponds is 0.51 kg CO_{2e} / kg CPO
- The final emission factor is stongly dependable on the amount of belt filter cake produced.
- For using a belt press EF, actual carbon content values from lab analysis and average annual average of belt press cake – CPO ratio is required.

Content

Belt filter press is a valid system in GHG prevention

- Current estimate of emissions from WWTP in processing only refers to closed ponds or open pond treatment without GHG avoidance. This study shows that also a belt filter press significantly reduces the formation of methane emissions.
- Belt filter press is a cost-effective solution for POME treatment

  à Reduced need for dredging and operation shutdown

  à Frees land area for other use from dredging

  à Organic fertilizer: decreases need for purchased fertilizer

  à Investment costs significantly lower than with methane capture

Save the planet and secure your profits

Please watch for the article submitted in October by T. Haatainen, A. Enström, et al.

Thoughts for possible future studies / uncertainties

- Other solid separation technologies
- Other sectors‘ waste water treatment plants
- Organic carbon analysis:
  - Comparison of different methods: TOC, COD_{Cr}, dry matter & ash content, others?
  - Variance per sector / per mill: possible to find a stable emission factor based on only amount and dry matter of cake?
- Inlet & outlet POME 24 h mixed sample feasibility compared to press cake sampling
- Longer history of belt press use in pond(s) to be studied, in continuous mode
- Gas measurements for 24 hour days, 7 day weeks and whole year

Suggest to use factor for press cake carbon amount to GHG for now and to deepen research

Please let us hear the good news when you hear a company goes for solid separation:
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