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BIOECONOMY RESEARCH



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# Biogas in Norway and its role in the new circular bioeconomy

Joshua F. Cabell

Nordic Biogas Conference

Oslo, 10.04.2019

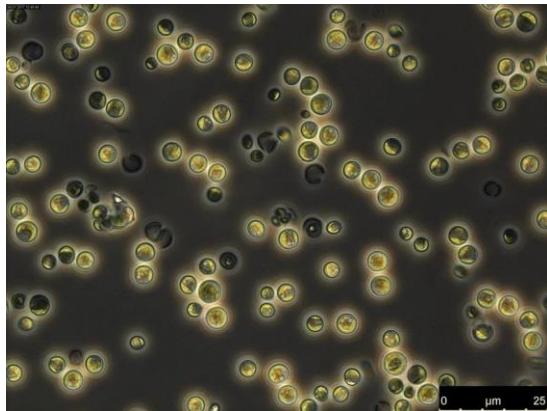
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One of Norway's largest research institutes

A stretched-out country  
with a varied growth  
season. 1700 km from  
Lindesnes til Nordkapp in  
a straight line, 2500 km by  
car.



# Bioeconomy is the transformation of biological resources...



Photos: Anette Tjomsland, Nina Elisabeth Nagy og Colorbox

...into useful products and services



# LINEAR VS CIRCULAR BIOECONOMY



## Linear economy

⇒ Sees resources as waste

## Circular

⇒ Sees waste as a resource

# EXAMPLES OF ADDING VALUE TO SECONDARY RESOURCES WITHIN THE «BLUE-GREEN» CIRCULAR BIOECONOMY

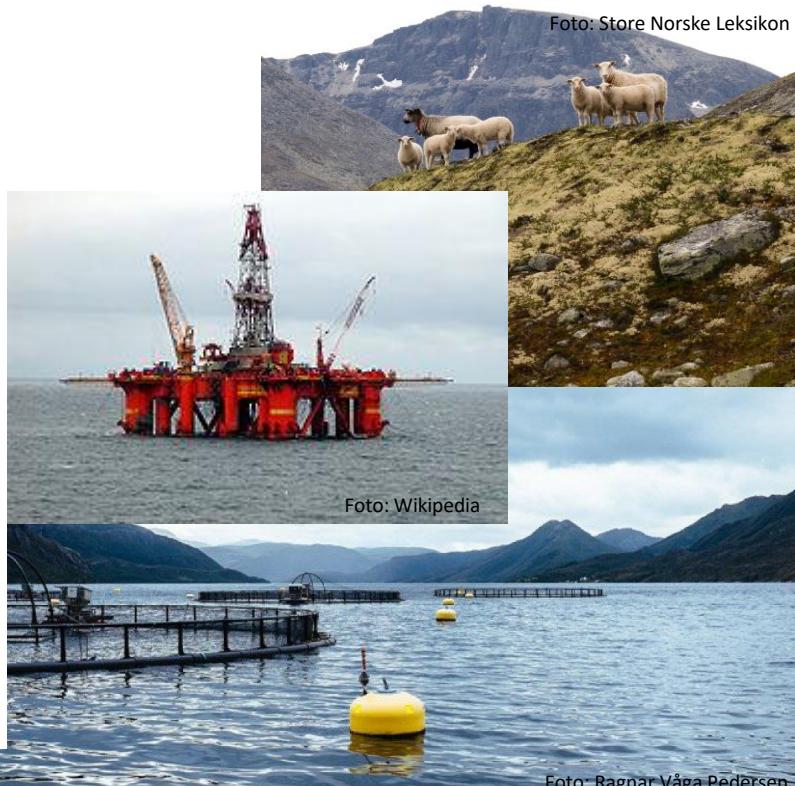
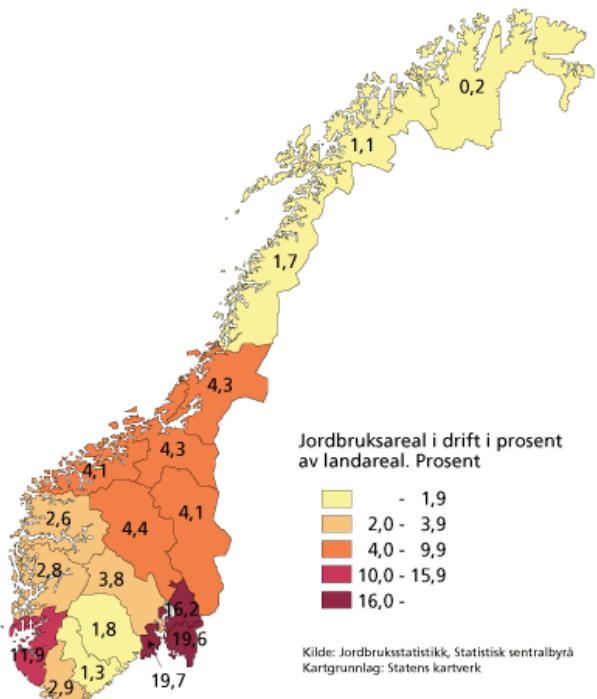
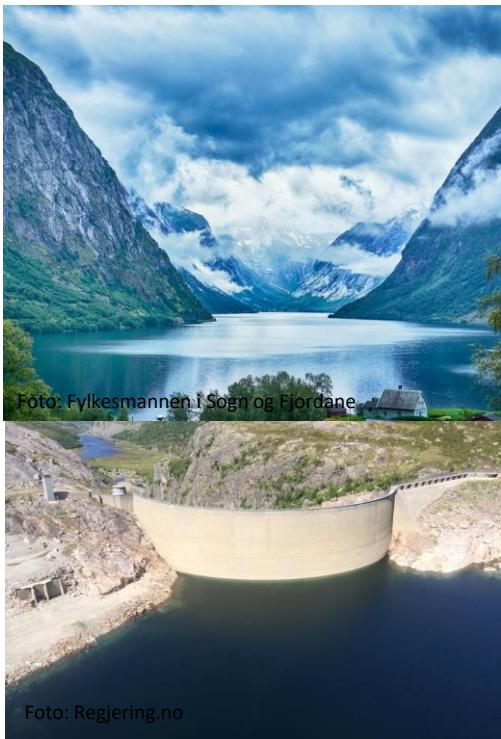


Foto: mikroalger fra  
<https://prosjektmikroalger.wordpress.com/2014/05/01/biopharma/>. Fiskefôr fra Anne-Eise Aakervik. Soya fra Brasil fra iStockphoto. Resten fra Nibio/Bioforsk

# What makes Norway unique?



# What *really* makes Norway unique (in a biogas context)?

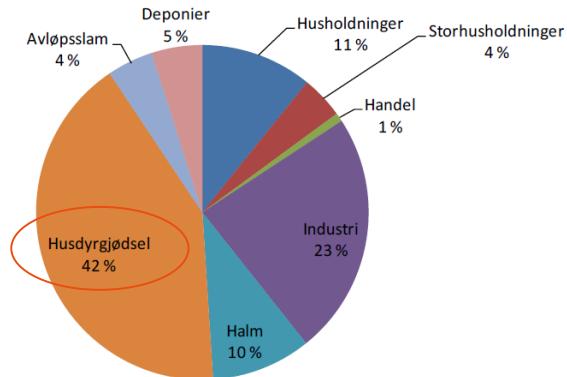


# Fish sludge, AD and the bioeconomy

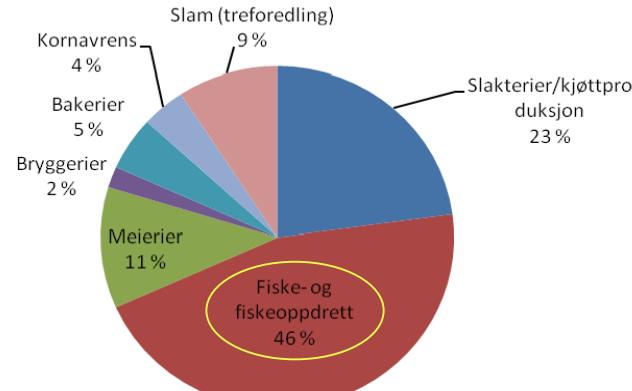


# Fish sludge + manure = a match made in heaven?

Fordeling av teoretisk energipotensial mellom ulike biogassressurser i Norge



Fordeling teoretisk energipotensial fra biogassressurser fra industri (~ 1400 GWh)



From: Raadal et al, 2008, *Potensialstudie for biogass i Norge*  
Østfoldforskning

# Co-digestion of fish sludge and manure

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**Reactor experiments on the co-digestion of salmon smolt sludge and dairy cattle manure**  
Opportunities and challenges for increased biogas production and improved nutrient cycling

**Justin Fossen Dahl**  
Institute of Animal  
Science, Norwegian  
University of Life Sciences

Fish sludge (feces and feed) is a waste product from Norway's salmon farming industry and is high in energy and nutrients. A study to test the feasibility of co-digesting sludge from a smolt hatchery with dairy cattle slurry in lab-scale anaerobic digesters was conducted with the goal of finding the optimal mixture for maximum gas production and a stable process.

**Background & objectives**  
Smolt hatcheries are located in areas where there is no agricultural land available for growing crops or raising animals. The most common method of disposal is stabilizing sludge in lagoons and spreading it onto nearby land, which may be agricultural land or fertilizer or delivered to a facility for centralized sludge facilities. Transport to these facilities is expensive and often requires specialized vehicles. (van Ginkel, 1992; Læren & Fossen, 2007; Gjermund, 2007). Fish sludge is energy rich and has a large potential for biogas production. This study aims to explore the potential of fish sludge to exploit its stable AD processes due to high concentrations of organic matter and the potential for high methane yields from long-chain fatty acids (LFA).

Salmon hatcheries are located on the west coast of Norway. Sludge is collected from hatcheries and transported and cattle slurry is abundant. Cattle slurry also has high biogas potential and is a good candidate for sole digestion and maintaining process stability. It was decided to co-digest sludge and cattle slurry to explore the potential of fish sludge as a feedstock for biogas production and explore feasibility for locating biogas facilities closer to the source of sludge. This study is part of a regional project investigating solutions for the disposal of sludge from salmon hatcheries and the potential for sludge in coastal regions.

**Materials & Methods**  
Biogas production time (GTT) in the two reactors was measured over 100 days. The first reactor received raw hatchery sludge harvested from 30 to 120 kg dry weight sludge per day. The second reactor received sludge harvested from 30 to 120 kg dry weight sludge. The concentration of VFA increased after reactor volume reached 100 mg/l. VFA levels increased to 100 mg/l and beyond, the sludge in the reactor was fed with slurry and the reactor was flushed with air. The second reactor received sludge, specific methane production increased to 0.25 Nm<sup>3</sup> m<sup>-3</sup> d<sup>-1</sup>. The concentration of VFA increased up to 100 mg/l. VFA levels remained low and the reactor was flushed with air. When the reactor was stopped when reactor volume reached 10% fish sludge. There were signs of inhibition.

**Results & Discussion**  
Biogas production time (GTT) in the two reactors was measured over 100 days. The first reactor received raw hatchery sludge harvested from 30 to 120 kg dry weight sludge per day. The second reactor received sludge harvested from 30 to 120 kg dry weight sludge. The concentration of VFA increased after reactor volume reached 100 mg/l. VFA levels increased to 100 mg/l and beyond, the sludge in the reactor was fed with slurry and the reactor was flushed with air. The second reactor received sludge, specific methane production increased to 0.25 Nm<sup>3</sup> m<sup>-3</sup> d<sup>-1</sup>. The concentration of VFA increased up to 100 mg/l. VFA levels remained low and the reactor was flushed with air. When the reactor was stopped when reactor volume reached 10% fish sludge. There were signs of inhibition.

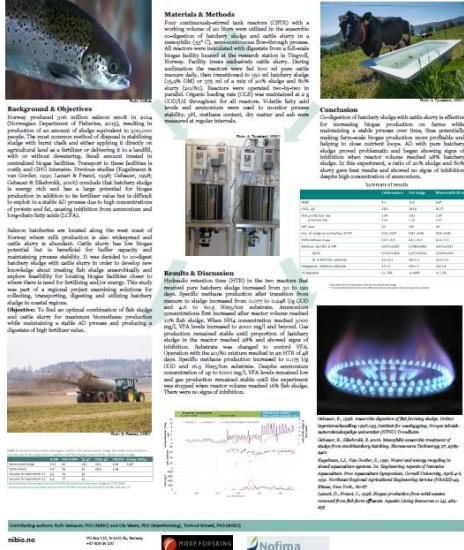
**Conclusion**  
Co-digestion of hatchery sludge with cattle slurry is effective for increasing biogas production on farm while maintaining the benefits of both sludges. The results indicate that mixing formulates higher production more predictable and better suited for industrial scale. Hatchery sludge and cattle slurry present problematic and biogas production signs of inhibition. In this experiment, a mix of sludge and slurry had a positive effect on the inhibition of biogas production due to inhibition despite high concentrations of ammonium.

**References**

**Contributing authors:** Justin Dahl, PhD (NMBU) and Ole Mærs, PhD (NMBU), Terje Skjelkvåle, PhD (NMBU)

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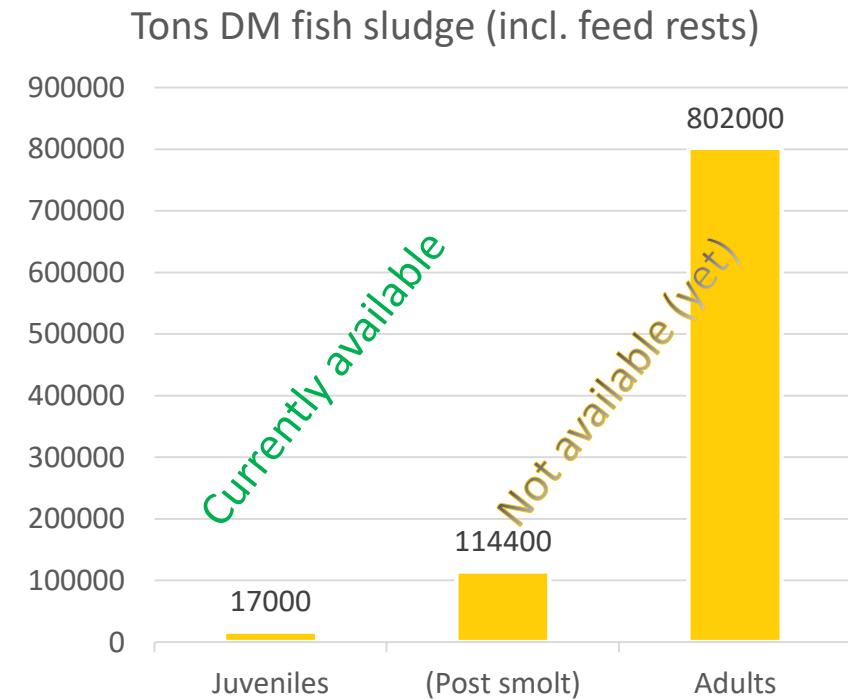
**PIKE** **PÖHLER** **Nofima**



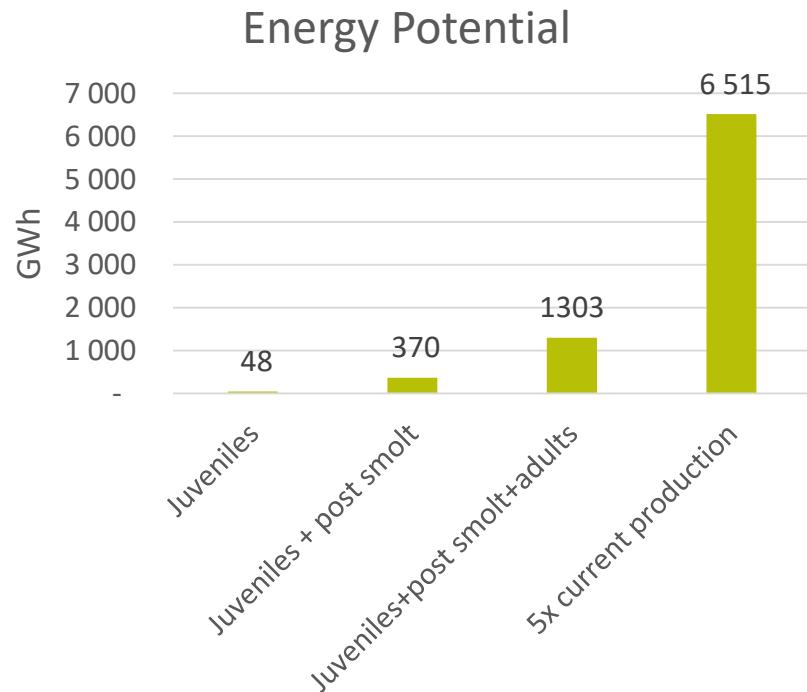
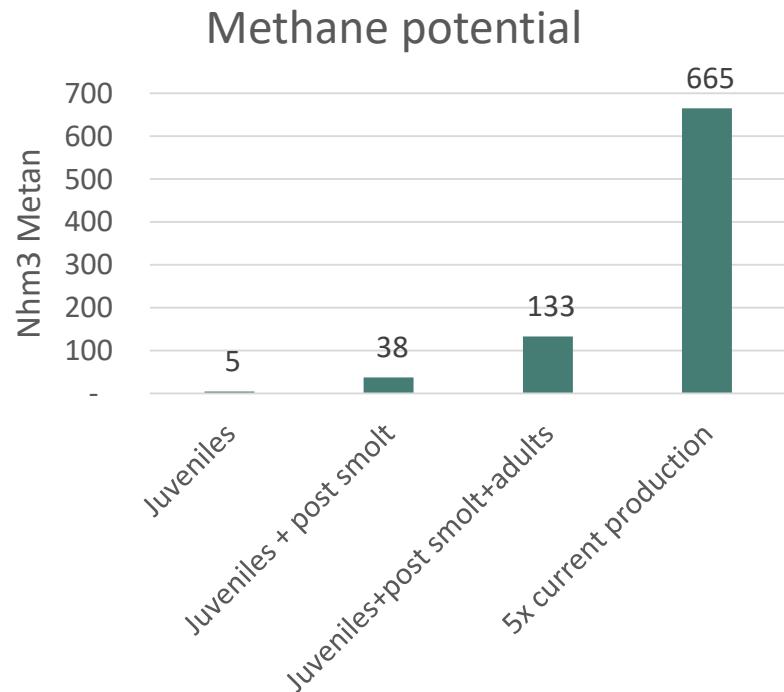
- Fish sludge high N – makes sole digestion problematic.
- Blend of 20% fish sludge and 80% almost 3X biomethane production with no sign of instability.
  - From 0,131 l/g VS to 0,304 l/g VS
- The same applies to fish silage (dead fish and off-cuts) – 20:80 ratio gave best results.
- Emerging technologies making sole digestion possible.

# How much fish sludge is produced in Norway?

- **304 million** salmon juveniles in 2018<sup>1</sup> (freshwater sludge, available)
- **1 331 000 ton** salmon in 2018<sup>1</sup> (marine sludge, currently unavailable)
- Goal of increasing production five-fold by 2050.
- An increasing amount will be land-based or within closed pens.

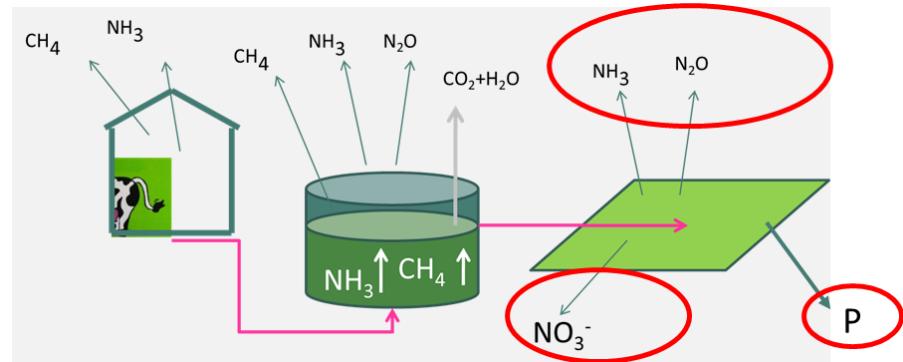


# Theoretical biogas potential of fish sludge



# Biogas isn't just about gas...

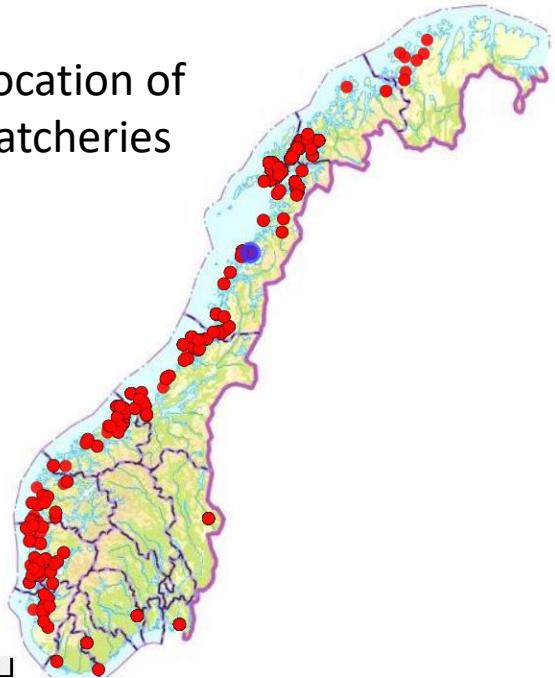
**Recycling of nutrients, reduced pollution, increased food production**



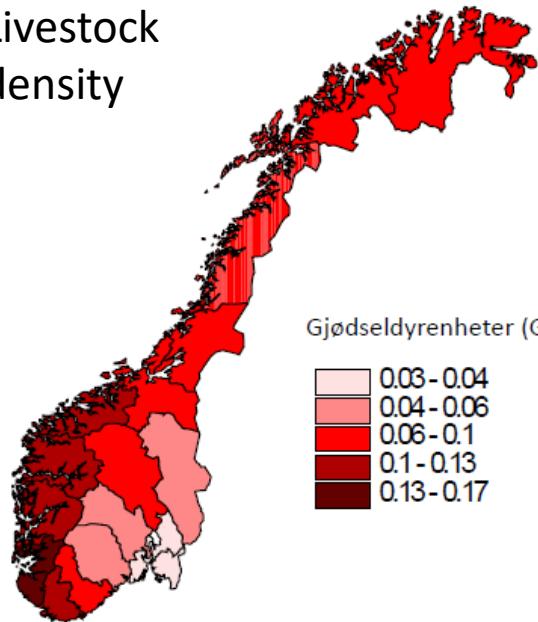
8-9000 tonn fosfor/år i fiskegjødsel<sub>1</sub>

# The challenge of P

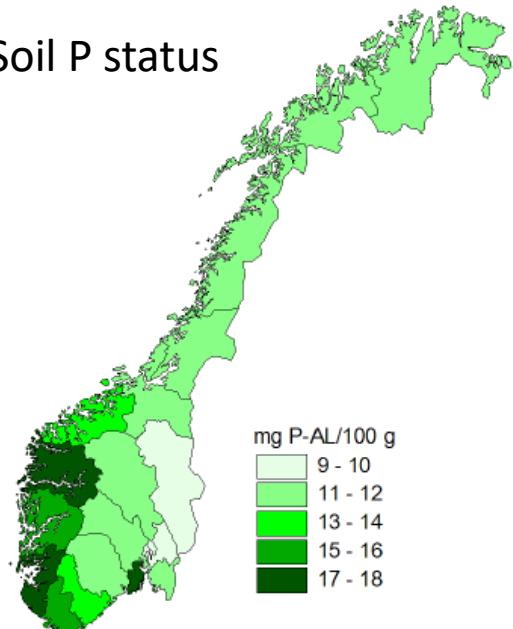
Location of hatcheries



Livestock density



Soil P status



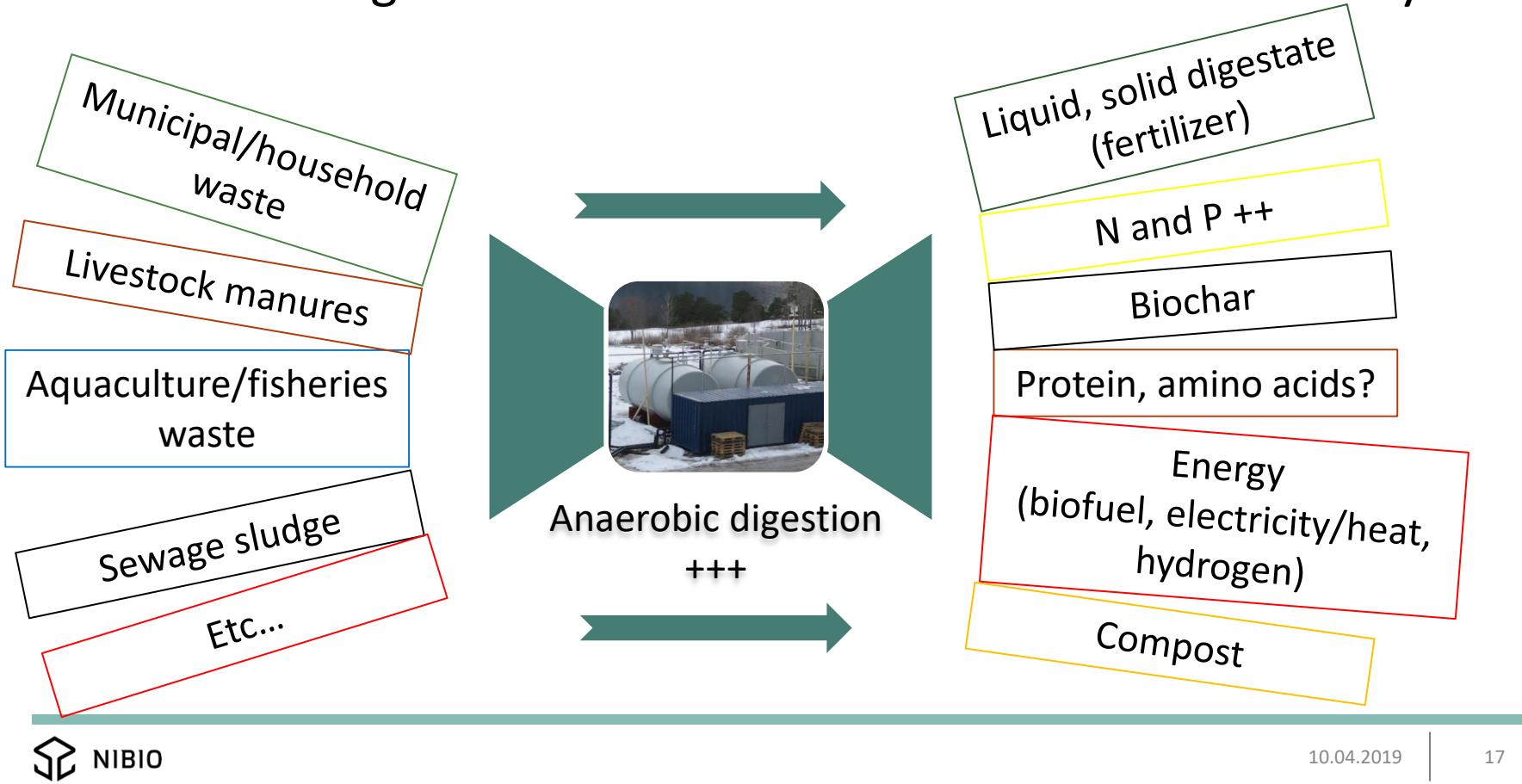
Source: Bechmann 2014

Source: Norwegian Fisheries Department

8-900 tons P released in the form of fish sludge per year.<sup>1</sup>

<sup>1</sup> Hamilton, H. A., Brod, E., Hanserud, O. S., Gracey, E. O., Vestrum, M. I., Bøen, A., Brattebø, H. (2016). Investigating Cross-Sectoral Synergies through Integrated Aquaculture, Fisheries, and Agriculture Phosphorus Assessments: A Case Study of Norway. *Journal of Industrial Ecology*, 20(4), 867-881. <https://doi.org/10.1111/jiec.12324>

# Anaerobic digestion: a hub in the circular bioeconomy



# Barriers to making circular bioeconomy a reality

- Regulatory and legislative
- Bioaccumulation (heavy metals, POP, dioxins), microplastic
- Antibiotic resistance, prions, pharmaceuticals
- Economics and market
- Logistics

AD can in combination with other processes address many of these challenges



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# Thank You!

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