Institution of Agricultural Engineers Landwards Conference 2021

Future Fuels in Agriculture

Wednesday 3 November 2021

Dr Chris Mann, Co-founder, Chairman & CTO

Delivering a Local Clean Energy Revolution











Florida radio piece about exploding lawn clippings was the epiphany

ERDF Project Energy Independent Farming has developed a profitable and sustainable local scale production and distribution of liquid fugitive methane from agricultural waste streams

Cornish Company has grown to nearly 30 staff – engineering, scientific and commercial teams recruited locally. Expected to double workforce over next 36 months

Novel approach creates rural jobs, reduces rural fuel bills, provides a solution to fuel poverty

UK Exports income through delivering a local clean energy revolution globally!

Based at the Aerohub, Newquay and our development farm near Truro. Custom manufacturing facility under construction at Chynoweth

Fantastic support from Cornwall Council & Cormac, and other local Cornish organisations, Duchy College, National trust, Cornwall Wildlife trust, The Environment Agency, University of Exeter

In March 2021 Case New Holland Industries acquired a minority stake in Bennamann















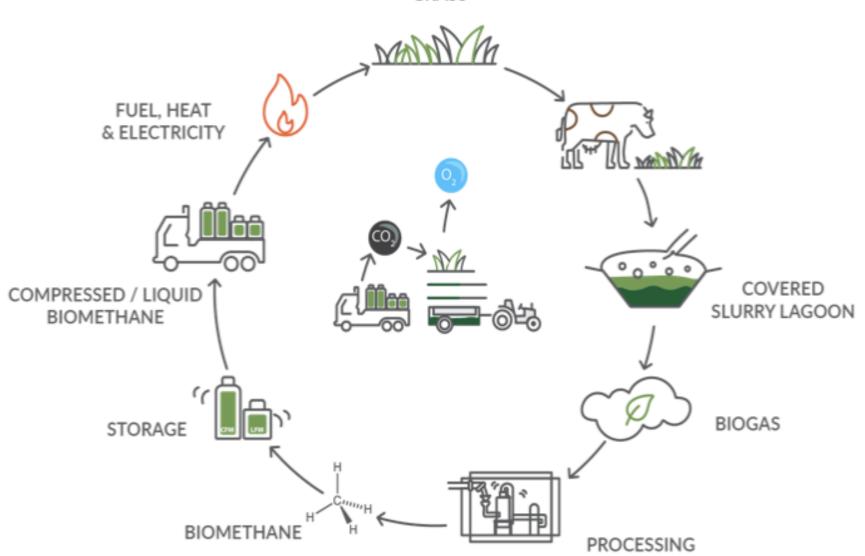


THE BENNAMANN CYCLE - CAPTURING & REPURPOSING FUGITIVE METHANE





GRASS





The Bennamann Challenge

Efficiently manage an inconvenient waste turning a powerful greenhouse gas into a clean vehicle fuel helping to slow down climate change and make some £\$€ for <u>all</u> parties in the process!







- Slurry lagoons on diary farms act as a collector and concentrator of waste biomass
 - A typical dairy farm produces much more fugitive methane than it can use Bennamann collects excess, sells and shares the profit
- A New Holland gas tractor running on fugitive methane takes the equivalent of 680 cars off the road annually
- Typical 150 head dairy farm produces 40,000kg of fugitive methane and is worth £10,000 – £15,000 in cash and operational savings to the farm
- The equivalent carbon saving is 3440 tonnes

FUGITIVE METHANE – THE CHALLENGE AND THE OPPORTUNITY



Geophysical prope		al properties	GWP-weighted share of global GHG emissions in 2010			
Kyoto gases	Atmospheric lifetime (year)	Instantaneous forcing (W/m²/ppb)	SAR (Kyoto)	WGI (20 and 100 year from AR5 & 500 year from AR4)		
			100 years	20 years	100 years	500 years
CO ₂	various	1.37 x 10 ⁻⁵	76 %	52 %	73 %	88 %
CH ₄	12.4	3.63 x 10 ⁻⁴	16 %	42 %	20 %	7 %
N ₂ O	121	3.00 x 10 ⁻³	6.2 %	3.6 %	5.0 %	3.5 %
F-gases:			2.0 %	2.3 %	2.2 %	1.8 %
HFC-134a	13.4	0.16	0.5 %	0.9 %	0.4%	0.2 %
HFC-23	222	0.18	0.4 %	0.3 %	0.4 %	0.5 %
CF ₄	50,000	0.09	0.1 %	0.1 %	0.1 %	0.2 %
SF ₆	3,200	0.57	0.3 %	0.2 %	0.3 %	0.5 %
NF ₃ *	500	0.20	not applicable	0.0 %	0.0 %	0.0 %
Other F-gases **	various	various	0.7 %	0.9 %	0.8 %	0.4%

MINIMISING MANMADE FUGITIVE METHANE EMISSIONS WILL HELP SLOW THE ONSET OF NEAR-TERM CLIMATE CHANGE

METHANE IS A FUEL THAT CAN DIRECTLY REPLACE ALL FOSSIL FUELS, FURTHER REDUCING IT'S GLOBAL WARMING IMPACT

- Over 20 years a methane molecule absorbs and traps heat 86 times more efficiently than CO2
- Capturing 1 kg of fugitive methane effectively removes the equivalent of 86 kg of CO2 from atmosphere
- Methane is unique in that it's the only GHG that can power it's own capture and removal and then some!
- Captured fugitive methane offers an 86 fold GWP benefit over 'carbon neutral' feedstock derived biofuels
- Capturing fugitive methane <u>now</u> offers the potential to slow down the early onset of global warming

METHANE IS RESPONSIBLE FOR 42% OF NEAR-TERM GLOBAL WARMING (IPCC 5th Assessment Report)

^{*} NF₃ was added for the second commitment period of the Kyoto period, NF₃ is included here but contributes much less than 0.1%.

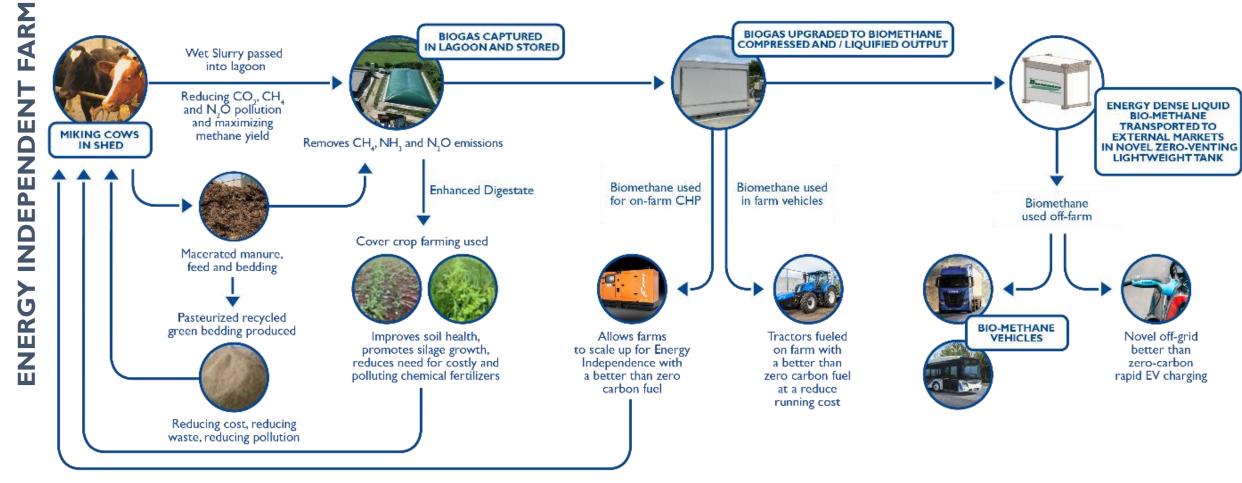
Other HFCs, PFCs and SF₆ included in the Kyoto Protocol's first commitment period. For more details see the Glossary (Annex I).





Energy Independent FarmsM Dairy Farm

How the Bennamann system works







WHY BENNAMANN IS DIFFERENT?



CONVENTIONAL ANAEROBIC DIGESTER OPERATION

- High capital, overhead & running costs
- Relies on subsidy to achieve profitability
- Requires grid connection (gas or electricity)
- Often need for methane to be flared
- Questionable environmental benefits?
 - Any biomethane loss degrades or eradicates carbon neutrality
 - Feedstock cropping often relies on diesel and natural gas derived fertilisers



H2S REMOVAL AND STORAGEOF FUGITIVE METHANE

BIOCYCLE - MOBILE METHANE PROCESSING PLANT VISITS TO PROCESS AND REMOVE VEHICLE GRADE FUGITIVE METHANE BY ROAD

LOGISTICS AND SALES HAS NO NEED FOR ELECTRICITY OR GAS GRID CONNECITON TO DERIVE PROFITABILITY

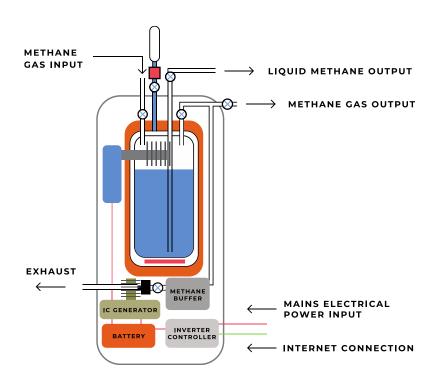
Bennamann's disruptive products and services provide a farmer a new recurring revenue stream and the means to manage and store slurry and digestate, capture and repurpose fugitive methane, manage rainwater, protect the environment, comply with regulations (Clean Air Strategy around NH_4 , NO_x etc.,), freeing farmers to what they do best - FARM

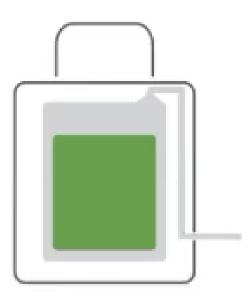




The enabling technology – Zero Venting Liquid Methane Storage

- As a liquid, methane takes up less than <u>1/600th the volume</u>
- Liquid methane can then be transported by road
- Liquid methane is collected from remote sites with no reliance on electricity or gas grid connection





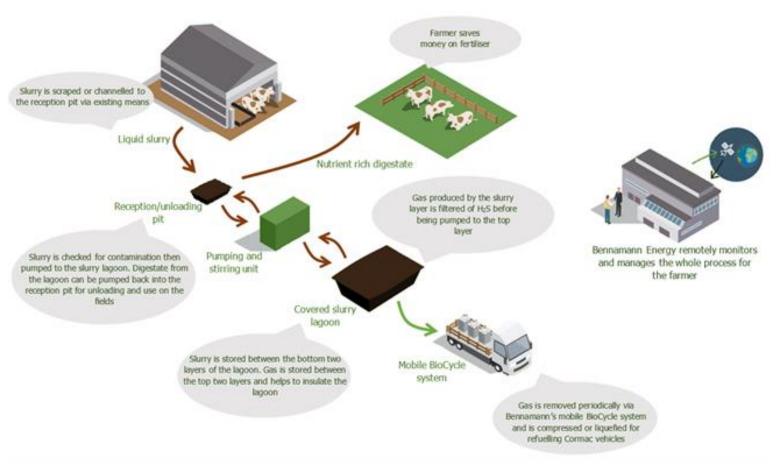
13 patent families: lagoon, liquid methane storage, fuel systems and IoT enabled energy networks

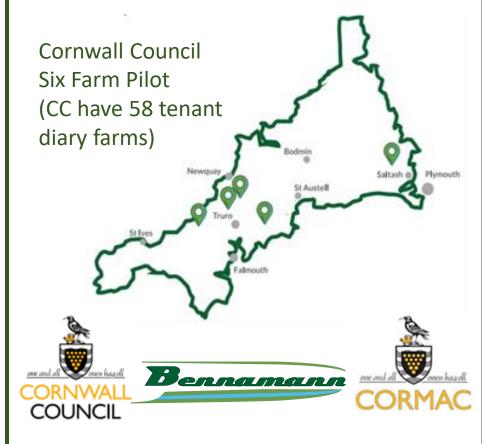
Bennamann **BENNAMANN – FUGITIVE METHANE SOLUTION OVERVIEW (AGRICULTURE)** First Biologically Enhanced Digestate trial successful run – more following Farmer saves money CFM version of BioCycle **Proof of Concept** on bedding Commissioning underway planned Q2 2022 Prototype Inventor MST built Use of pasteurised bedding from ready for thermal load testing hydrolysis process Farmer saves money on fertiliser Gas trucks Use of Biologically Enhanced Digestate to replace fertiliser & manure solids Digestate Liquid slurry Secondary Enhancer hydrolysis unit Farmer takes Gas filtration unit a share of gas sales Off grid EV charging Energy **7** Customers Farmer helps protect Covered slurry the environment lagoon Mobile or Fixed Liquid Fugitive Methane (LFM) BioCycle Farmer's energy costs are reduced Residential, leisure and industrial natural gas & propane replacement Optional on-site heat and Farmer's fuel costs New build lagoon solution deployed electricity from fugitive methane use are reduced Bennamann Energy remotely Retrofit concept Option to power a Compressed monitors and manages the Natural Gas (CNG) tractor in development whole process for the farmer Gas filtration system CHP / EV Charging solution now now built and deployed Compressed bio-methane being underway with FPT etc

delivered now to paying customers















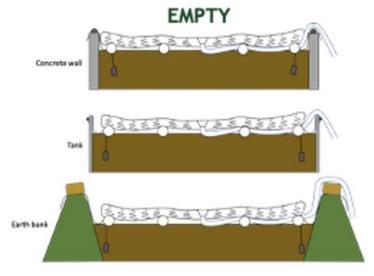


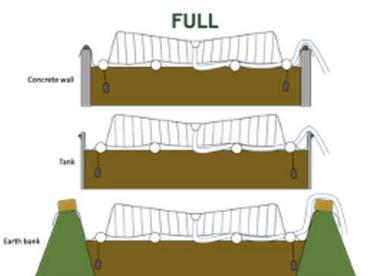






OPTION 2 - RETROFIT LAGOON COVER, RAINWATER HANDLING AND & FUGITIVE METHANE STORE

















Cornwall Council Farm No. 1: Trenance – now live! Capturing \approx 100kg of fugitive methane / day equivalent to \approx 2.4 tons CO₂ / day



BioCycle – Fugitive methane upgrading





Scalable

IoT Remote control and monitoring for logistics network



Benganan

BIOLOGICALLY ENHANCED DIGESTATE SUPPORTING REGEN FARMING



We take the AD digestate and do second stage aerobic and microbial processing

Less damaging and costly then chemical fertilisers

Removes significant carbon footprint relating to processing and distributing chemical fertilisers

Easier to handle with less environmental risk than "raw digestate"

No specialized equipment required

More economic, all developed on the farmer's site

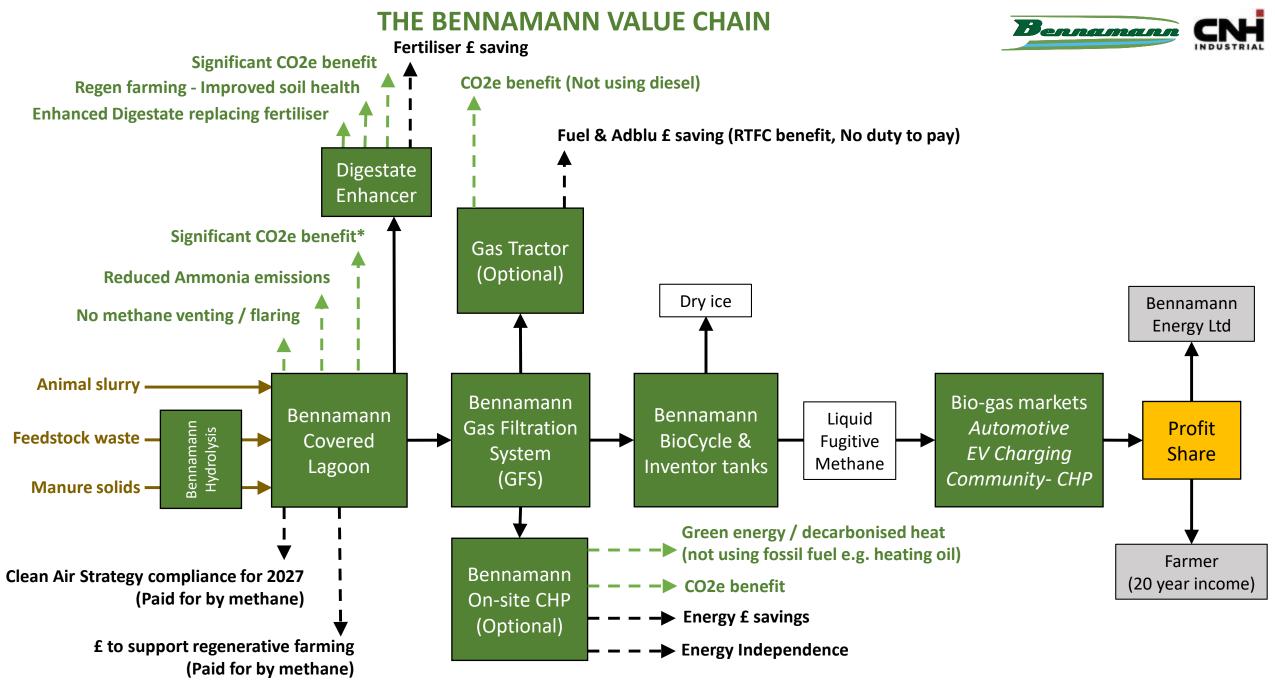
Significant beneficial results in terms of rates of growth and soil compaction



Conventional cover crop establishment on maize stubble. Sown 5th Oct. Picture taken 17th Jan. (104 days)



Cover crop established using B.E.D. system. Sown 1st Oct, picture 11th Nov (42 Days)



Dairy Farm CO₂e Emissions Today & Tomorrow



Before and After Energy Independent Farm™ Implementation

CO₂e Output 150 Cow UK Dairy Farm - BEFORE

Dairy using red diesel / heating oil for heat 6t CO2e pa 103t CO2e pa

CO₂e Output 150 Cow UK Dairy Farm - AFTER



~65% Reduction in CO₂e emissions from farm

FARM CO₂e OUTPUT (kg CH4 GWP20 86kg CO₂e) ~4400 tCO₂e pa



TOTAL METHANE CO₂e REDUCTION (86kg CO₂e)

~2500 tCO₂e pa CO₂e REDUCTION REUSING METHANE ~290 tCO₂e pa

=

TOTAL CO₂e REDUCTION (86kg CO₂e)

~2800 tCO₂e pa



~60% Reduction in methane CO₂e emissions on farm

140 UK household carbon footprints



MARKET FOR LIQUID FUGITIVE METHANE – HIGH POWERED MOBILE ELETRCI VEHICLE FAST CHARGERS

By 2030, EVs could account for 69% of car sales and 57% of LCV sales [KPMG Mobility 2030,2019].

UK Gov also recently marked their intent for 2030.

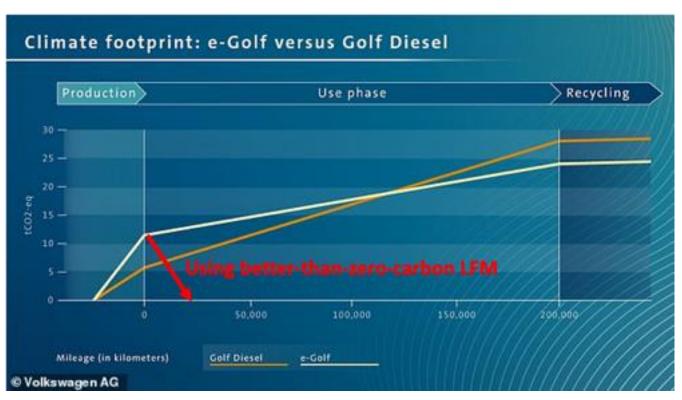
A current barrier to high speed EV charging is the cost / availability of infrastructure.

Bennamann's novel off-grid fugitive methane EV charging technology will address this.

1 kg of methane in our efficient design of generator / EV will produce 6.2kWh of electricity. So 6 kg of fugitive methane will fully charge an average family electric car

This approach makes 1kg even more profitable then NGV gas market

Powering an EV with a better-than-zero carbon footprint will speed up the paying down of the carbon debt built into an EV (which is higher than it's fossil fuel powered equivalent).



Charging an e-Golf with LFM and recognising the 86kg CO2e / kg CH4 benefit at this point, would breakeven on the carbon debt in around 6,000km or ~20 charges (a fraction of the 115,000km current breakeven point).

SUMMARY



By focusing on the capture of existing fugitive methane emissions from agriculture and grass waste there is a window of opportunity to slow climate change and make money in the process

The arrival of New Holland methane tractor coupled with the Bennamann system removes agricultures reliance on fossil fuels and offers energy independence to farmers

Exploitation of farm waste through the capture of methane provides a financially sustainable route for farms and rural communities to be become net carbon negative

Creates rural jobs, reduces rural fuel bills and fuel poverty and delivers export income

Cornwall spends approximately £1 billion pounds annually on energy imports.

Liquid biomethane can play a crucial role in the long term energy storage that requirement to fill the gap left by intermittent renewables such as wind and solar

Mobile electric vehicle chargers fuelled by liquid methane can provide fast charge capability at remote and busy locations without little need for significant infrastructure upgrades