CNH INDUSTRIAL

POWERED BY NATURE

Alistair Walshaw,
CNH Industrial
Innovation Alternative fuels & Drivelines

CLEAN ENERGY LEADER
Sustainable Efficient Technology

NEW HOLLAND AGRICULTURE

CNH Industrial

January 2022

T6 METHANE POWER
POWERED BY NATURE

One of the world's largest capital goods company

AGRICULTURE

Second largest manufacturer of agricultural machinery

CASE IH AGRICULTURE · STEYR TRAKTOREN · NEW HOLLAND AGRICULTURE

29	18	$14.7B
plants	R&D Centres	net sales in 2021

CONSTRUCTION

A global player in construction equipment

CASE CONSTRUCTION · NEW HOLLAND CONSTRUCTION

8	8	$3.1B
plants	R&D Centres	net sales in 2021

FINANCIAL SERVICES

Global financial services player supporting customers and dealers

CNH INDUSTRIAL CAPITAL

CNH INDUSTRIAL

The Farming Specialist

NEW HOLLAND AGRICULTURE

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TRACTORS

HARVESTERS

CONSTRUCTION RANGE FOR AGRICULTURE

SOIL MANAGEMENT

CROP MANAGEMENT

let's get it done.

NEW HOLLAND AGRICULTURE

CNH Industrial in the UK
Basildon Plant

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THEN & NOW

1964

THE SITE

- Area – 40 ha
- Building – 12.65 ha
- Personnel – 4000

THE PLANT

- Monorail – 2 km
- Forklift trucks – 31
- Incoming tonnage – 800 per day

THE PRODUCTION

- Models – 4
- Power range – 37 to 65 hp
- Components – Engines, front axles, hydraulic lift

THE CONSUMABLES

- Paint – 1800 l per day
- Oil – 37,000 l per day
- Boiler fuel – 4000 l oil per day
- Electricity – 20,000 KVA (max)
- Water – 2.7m l per day

2021

THE SITE

- Area – 40 ha
- Building – 12.65 ha
- Personnel – 585
- Iveco - 176

THE PLANT

- Monorail – 2 km
- Forklift trucks – 25
- Incoming tonnage – 1,100 per day
- Auto Guided Vehicles – 21

THE PRODUCTION

- Models – 21
- Power range – 100 to 300 hp
- Components – Sub assembly of armrests, hoods, roofs

THE CONSUMABLES

- Paint – 450 l per day
- Oil – 1000 l per day
- Boiler fuel – 9700 m3 gas per day
- Electricity – 46,500 kWh per day
- Water – 1.4 m l per day
- Air conditioning fluid – 200 kg per day

A Brief History of Agriculture and Impact on the World Today

What is it? - And frankly, why should anyone care?

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Hunter-Gatherer

Ancient Times

<10 M People

100% in Agriculture

Food Scarcity

Day to Day Living

Horse / Oxen & Plough

~4,000 BCE

<15 M People

90% in Agriculture (1800)

Development of Industry

Growth of Cities / Civilization

Early Tractors

1892 – Froelich, Iowa USA

Henry Ford 1917 (first mass produced)

1.1 B People

>50% in Agriculture (1900)
(40% in the USA)

Industrialized Nations

Global Expansion

Today

2021 – est 1.5 M produced annually

~7.9 B People

28% in Agriculture (Today)
(<1% in the USA)

Technology and Globalization

Interdependency

A Key Enabler to What World is Today!

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Fundamental Role to Play in a Sustainable Future

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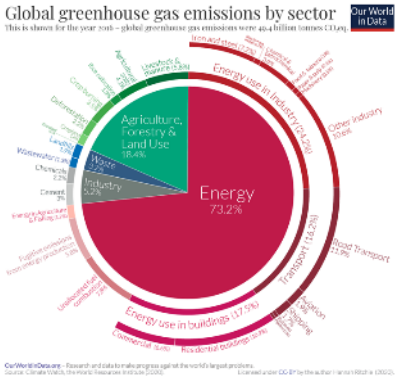
POPULATION	URBANIZATION	FOOD SCARCITY	CLIMATE CHANGE & BIODIVERSITY LOSS
POPULATION GROWTH: **+2B** people by 2050 **CHANGING DIETS:** **+10%** average calorie uptake	**RURAL EXODUS:** **1.5M** people move into urban areas each week **MEGACITIES:** **140** cities with > **3M** in habitants	**FIELD PRODUCTIVITY DECREASE** Soil compaction and inefficient farm management **AGRONOMIC PRACTICES** 15% yield loss from inadequate/incorrect fertilizer application	**The science is clear:** society must limit global warming to 1.5°C by the end of the century
GROWING FOOD DEMAND	**GROWING INFRASTUCTURE DEMAND**	**GROWING YIELD DEMAND**	**DECARBONIZATION DEMAND**



Getting more from less in a sustainable way

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Technology Roadmaps

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ROADMAP TOWARDS FULL AUTOMATION

Optimized machine utilization and labor efficiency

MACHINE AUTOMATION
Optimize and automate the usage of our products

AUTONOMOUS VEHICLES
Autonomous driving, remote monitoring, coordinated vehicle operation and robotics

DATA MANAGEMENT AND CONNECTED VEHICLES
Leverage data (machine and agronomy) to optimize operation

ROADMAP TOWARDS ZERO EMISSION

Optimized power usage and minimized environmental impact

ALTERNATIVE FUELS
Reduced greenhouse gas emission

MACHINE EFFICIENCY AND PRODUCTIVITY
Optimize power usage

ELECTRIFICATION
Electric-vehicle technologies in our products

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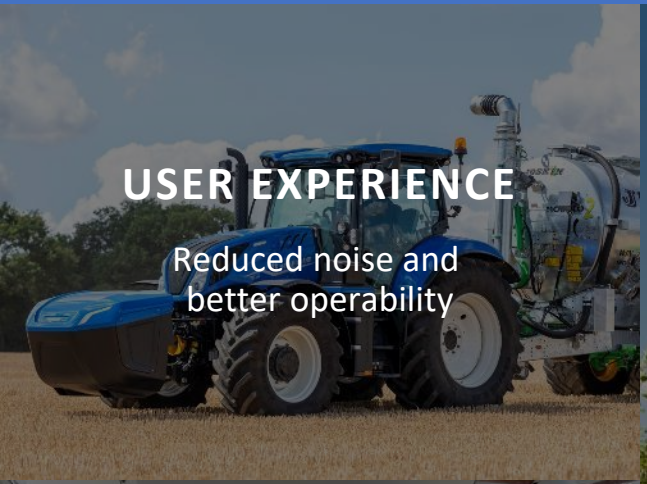
SUSTAINABILITY
Accelerating net zero path
along the value chain

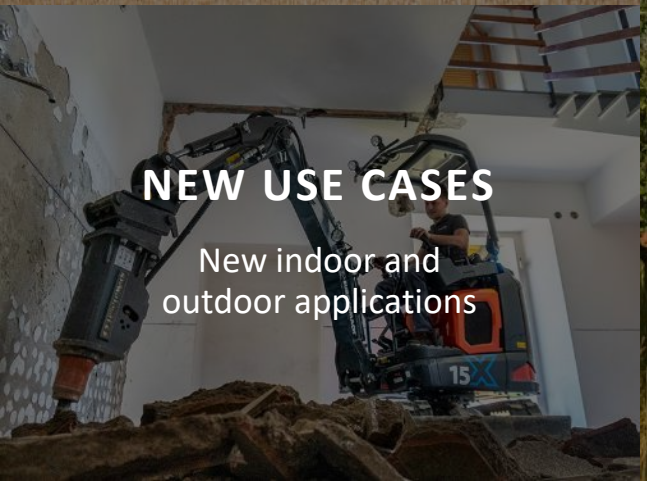
WHY ELECTRIFICATION & ALTERNATIVE FUELS MATTER

Creating value for customers



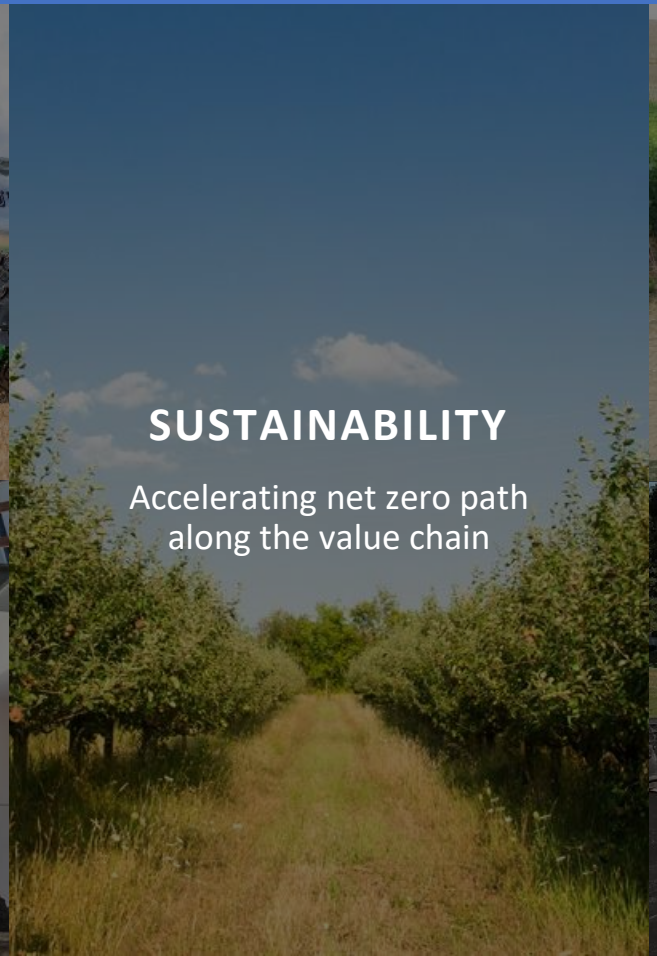
USER EXPERIENCE

Reduced noise and better operability



NEW USE CASES

New indoor and outdoor applications



SUSTAINABILITY

Accelerating net zero path along the value chain

FINANCIAL RETURN

Decreasing TCO, increasing productivity

REGULATION

Users preparing for emerging regulations

Alternative Fuel paths towards CO2 emission "reduction"

Comparison Vs. Diesel and Impact estimation on sample CNHi machine

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	Biodiesel (B20)	Renewable diesel (e.g., HVO, xTL)	Bio-DME	Bio-NG		Bio-Ethanol	Green Hydrogen Engine	Green Hydrogen Fuel Cell	BEV
CO_2 WTW emission*	-10%	-40%	-90%	-180%** *(from manure)*		-70%	-96%	-97%	-100% *(if renewable)*
Volumetric power density	Same as Diesel			Slightly lower than diesel (~ -10%)				-60%	Not applicable
								To add machine electrification (e.g., e-motor)	
				CNG	LNG				
Autonomy with same energy storage volume	-2%	-4%	-50%	-75%	-50%	-50%	-90%	-85%	-95%
Energy storage volume for same autonomy	same	same	~x2	~x4,5	~x2	~x2	~x9	~x6,5	~x14
Case Study: **T8.435** (GVW 18/24,5 tonne), Power System only*** weight for same autonomy	same	same	+20%	x2 (+2 tonne)	same	+10%	x3,5 (+4,5 tonne)	x3,3 (+4 tonne)	x8,5 (+13,2 tonne)

- **Biodiesel/renewable diesels as quick win** (ready to use); **NG** as **existing technology to be adapted to Off-Road**, using LNG storage for autonomy.
- **DME and ethanol**, with comparable benefits and impacts, **to be assessed** depending on fuel strategy / production.
- **Hydrogen-powered engines** as easier-to-adapt to exploit H2 without vehicle electrification; **Fuel Cells and Battery Electric** ensures **zero emission** but with **heavier impacts on machines** (storage size and weight)

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*Data from Concawe "JEC Well-to-Wheels study version 5" | **Fugitive methane capture from manure (CO2 absorption from atmosphere) | *** Energy storage+engine equivalent+ATS (driveline not considered)

ENERGY DENSITY IS A KEY CHALLENGE FOR ALL ALTERNATIVE FUELS

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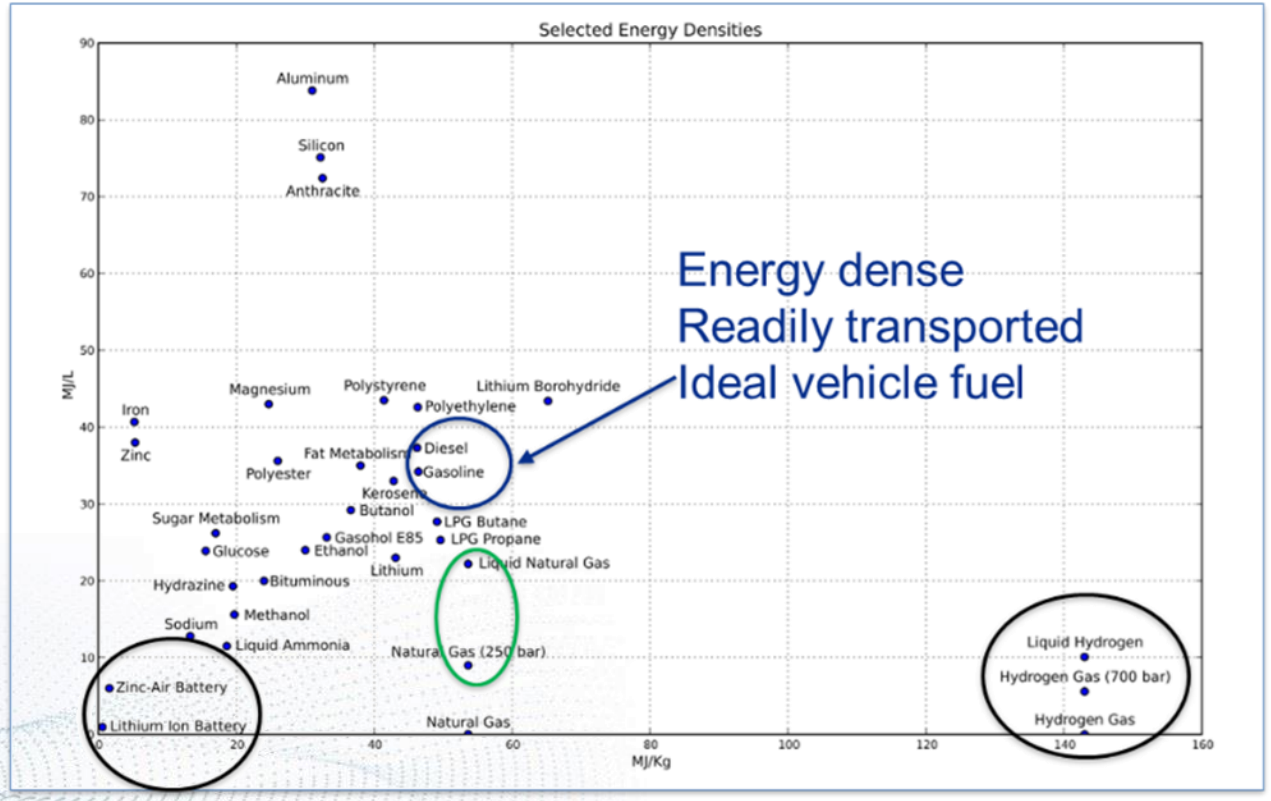
ENERGY / VOLUME



ENERGY / MASS

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Full electrification: technical readiness

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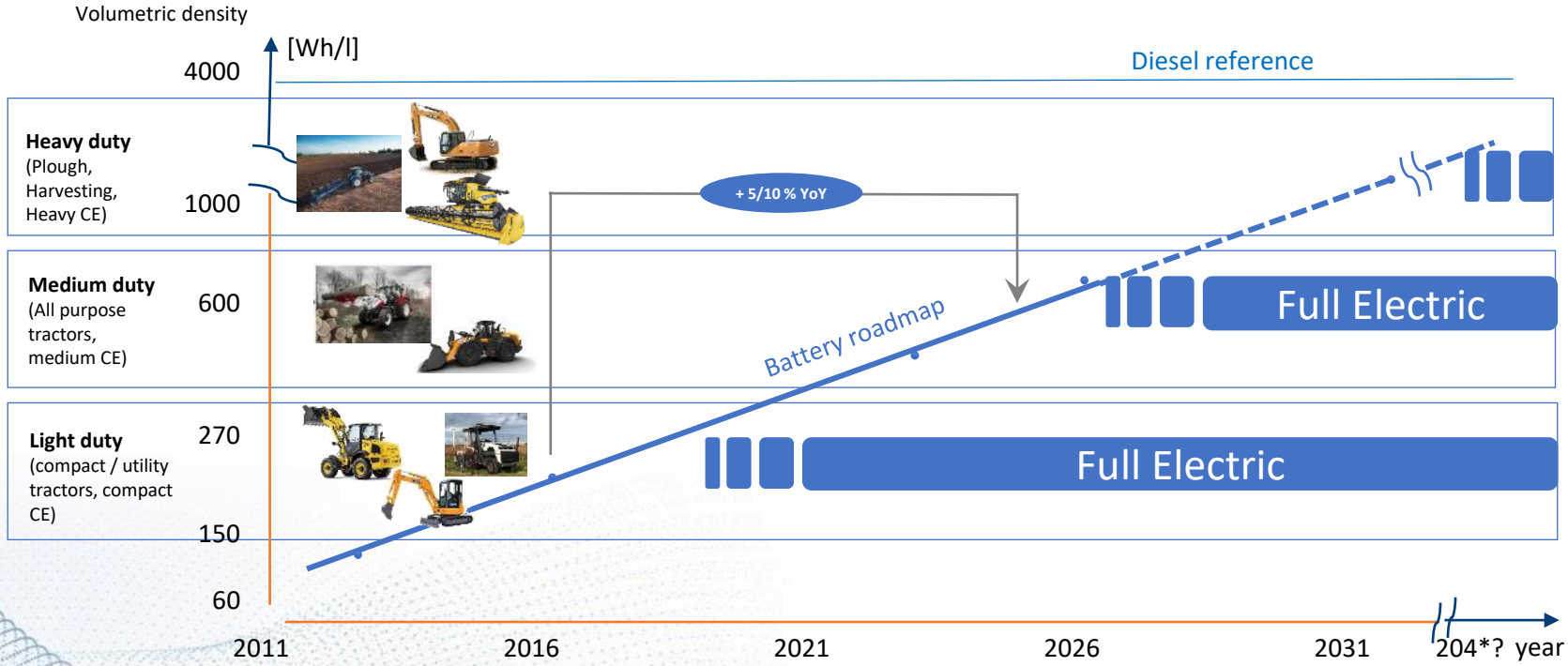
Battery roadmap drives the adoption curve



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Alternative fuel pathways

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<u>The “chicken and egg” logistical challenges faced by all alternative fuels</u>

It is hard to justify engineering and producing vehicles that would operate on a dedicated alternative fuel without have the fuel production and supply infrastructure in place

It is hard to justify building up a fuel production and distribution infrastructure without vehicles in place that can use the fuel.

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Refuelling Logistics

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- On large farms, the fuel comes to the tractor, not vice versa
- Being able to have mobile refuelling as well as high runtimes between refuelling is key for adoption

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New Holland the Clean Energy Leader® since 2006

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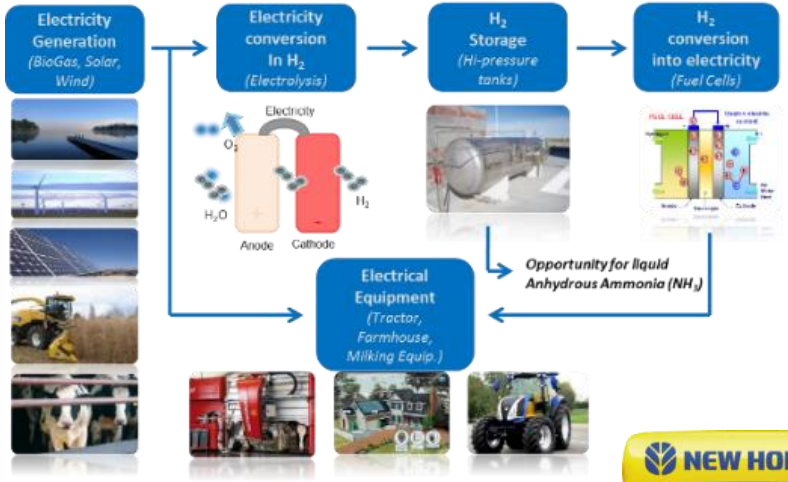
- 2009 Energy Independent Farm Vision

JULY 2006
THE BIRTH OF A NEW ERA
CLEAN ENERGY LEADER®
STRATEGY LAUNCHED

NOVEMBER 2007
100% BIODIESEL
ALL NEW HOLLAND ENGINES ARE
100% BIODIESEL COMPATIBLE

FEBRUARY 2009
ZERO EMISSION FUTURE
NH²™ HYDROGEN TRACTOR AND
ENERGY INDEPENDENT FARM™



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Dairy cow population in the UK

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Approximately 1.9 million UK Dairy cows

"Many" open slurry lagoons

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METHANE – A THREAT AND OPPORTUNITY

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POWERED BY NATURE

Methane is the second biggest man-made contributor to climate change, after CO2

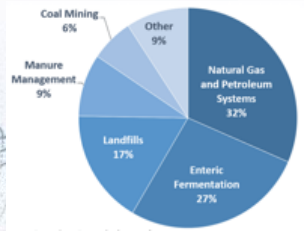
Capturing 1 kg of fugitive methane removes the equivalent of 86 kg of CO2 from the atmosphere (GWP20, IPPC AR6)

Accounts for 42% of near-term climate warming (over the next 20 years)

~360 million tons (60%) of methane released globally through human activities, 30% of this is through livestock farms

Methane is unique in that it's the only GHG that can power it's own capture and removal and then be used as a better then zero carbon green fuel

At COP26, (Oct 21), the US & EU announced the Global Methane Pledge in an attempt to keep global warming at 1.5 degrees Celsius.



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Atmospheric Methane

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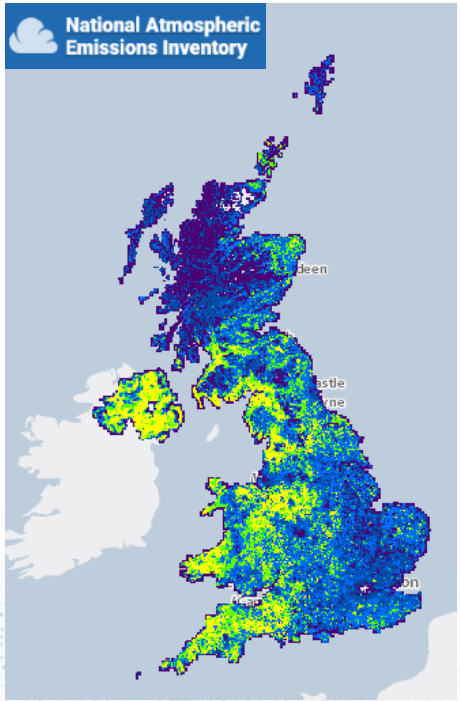
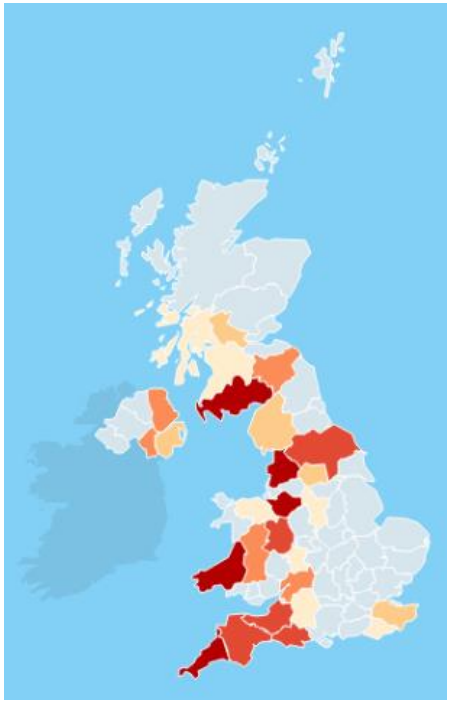
UK Methane Hotspots



UK Dairy Hotspots



Low concentration of Methane in atmosphere
High concentration of Methane in atmosphere

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New Holland the Clean Energy Leader® since 2006

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ALTERNATIVE FUELS HISTORY

JULY 2006
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ALL NEW HOLLAND ENGINES ARE
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FEBRUARY 2009
ZERO EMISSION FUTURE
NH2™ HYDROGEN TRACTOR AND
ENERGY INDEPENDENT FARM™

NOVEMBER 2011
INTELLIGENT VITICULTURE
ECOBRAUD AND SUSTAINABLE VITICULTURE
WIN A SILVER MEDAL AT AGRITECHNICA

SEPTEMBER 2012
A RENEWABLE ALLIANCE
STRATEGIC PARTNERSHIP WITH GROWTH
ENERGY TO PROMOTE ETHANOL

NOVEMBER 2013
THE NEW FRONTIER
1ST GENERATION T6 METHANE
POWER TRACTOR

JUNE 2015
INNOVATION THAT WORKS
2ND GENERATION
T6 METHANE POWER

NH DRIVE

AUGUST 2016
THE AGRICULTURE OF TOMORROW
NHDRIVE™ CONCEPT AUTONOMOUS TRACTOR,
UNVEILED AT FARM PROGRESS, USA.

AUGUST 2017
METHANE CONCEPT TRACTOR
REIMAGINES THE DESIGN AND REVEALS
A CONNECTED AND SUSTAINABLE FUTURE

NOVEMBER 2019
SUSTAINABLE TRACTOR OF THE YEAR
T6.180 METHANE POWER CONCEPT

FEBRUARY 2021
INDUSTRY FIRST E-SOURCE
AN ELECTRICAL GENERATOR TO
POWER ELECTRIFIED IMPLEMENTS

MARCH 2021
CNH INDUSTRIAL ACQUIRES A MINORITY STAKE IN BENNAMANN

Q4 2021
DELIVERY OF FIRST T6.180 METHANE POWER UNITS

ADVANCED PROPULSION CENTRE UK
LOW CARBON TRACTOR PROJECT

NEW HOLLAND AGRICULTURE

Methane Power tractor

T6 METHANE POWER
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Commercial Requirements

STANDARD DIESEL TRACTOR VS METHANE POWER

Power 180 hp	Same
Torque 740Nm	Same
Durability	Same
Service intervals	Same
Productivity	Same
Performance	Same
Running costs	Saving ??%
Sustainability credentials	Significantly better ?? %

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Gas Tractor Development

T6 METHANE POWER
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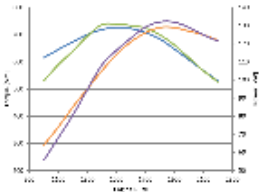
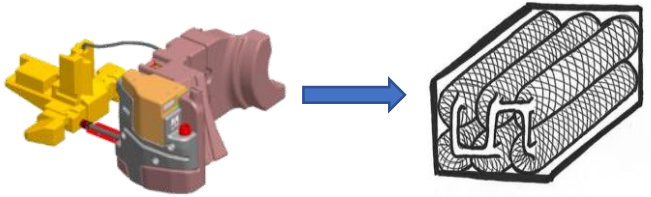
4 MAIN TECHNICAL CHALLENGES

Driveability



Gas Tank Development (high pressure composite)



Variable Fuel Quality (knock sensor)

High Exhaust Temperatures

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Natural Gas Leadership

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On- Road proven technology → Technology transfer → Off-road technology application

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ENGINE CONFIGURATION
CNG 6.7L NEF

T6 METHANE POWER
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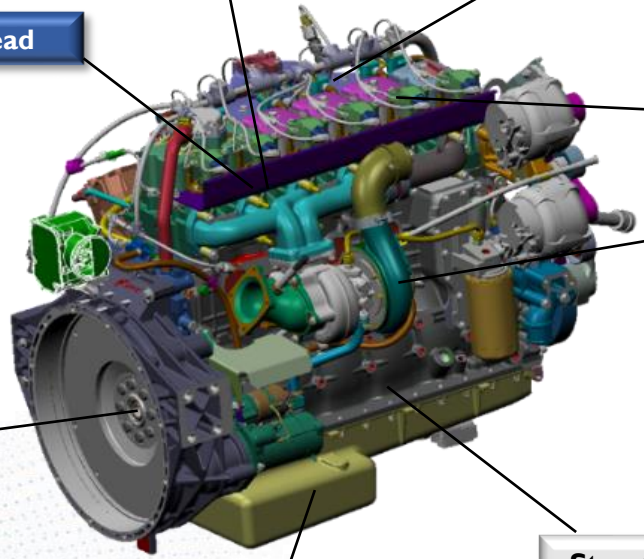
Maximize commonality with 6.7L NEF stage V Diesel development



- Pistons
- Ignition system
- Cylinder head
- Fuel Injection system
- Intake system
- Crankshaft
- Engine Control System (derived from diesel Stage V)
- Structural cylinder block
- Oil sump

New NEF NG Content

Carry over from NEF diesel

FPT POWERTRAIN TECHNOLOGIES

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FPT Industrial natural gas engines

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T6.180 METHANE POWER

Main features and benefits

- 100% methane gas engine with diesel-like performance
- CNG. LNG and bio-methane compatible
- Stoichiometric combustion strategy pioneered from 1995 for clean combustion and low emission
- Multipoint injection and proprietary model-based engine control (patent pending)
- Proprietary gas quality sensing software
- High performance materials for maximum reliability
- High resistance structural block and oil sump specifically designed for installation on tractors
- Reduced operating costs and low CO_2 emissions (Better than zero when operating with bio-methane)
- Simple 3-way catalyst for stage V emission compliance
- Lower noise and vibration compared to Diesel (5 db)

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Simplified exhaust aftertreatment

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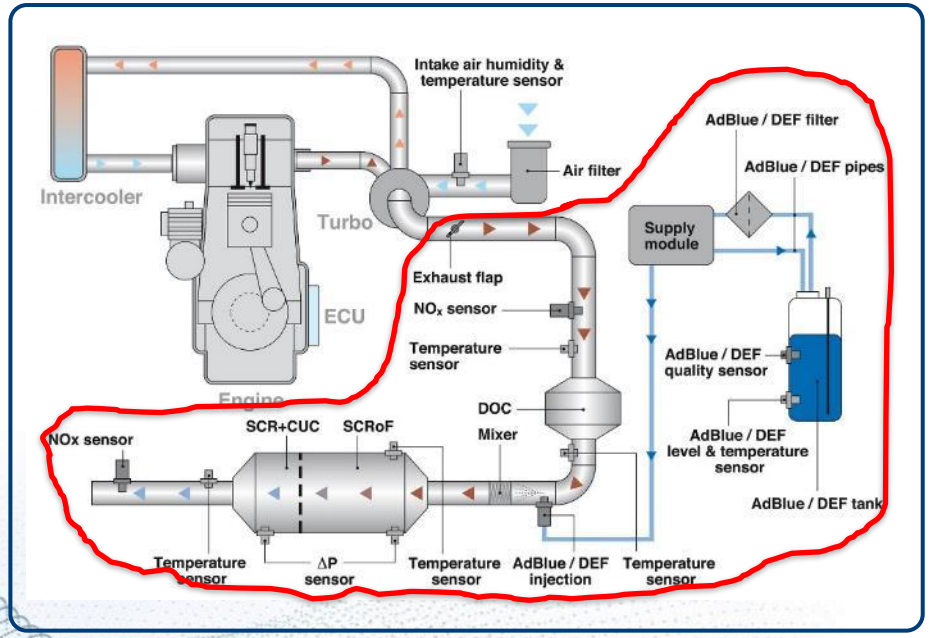
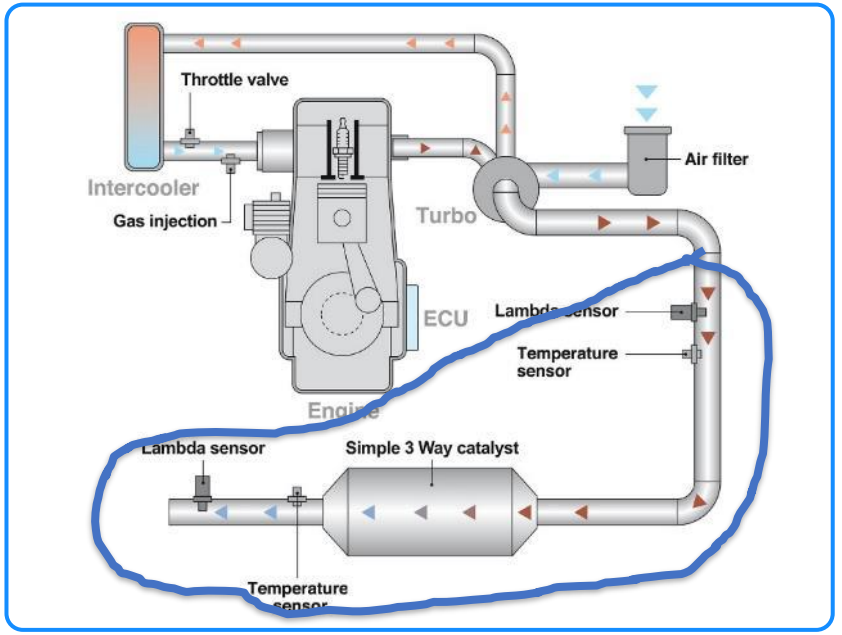
DIESEL STAGE V



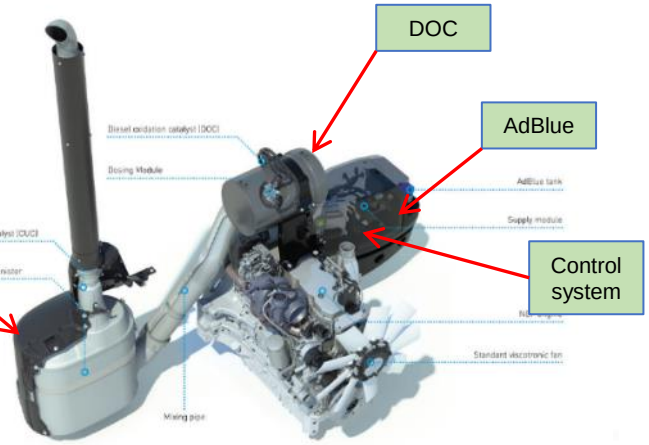
METHANE TRACTOR



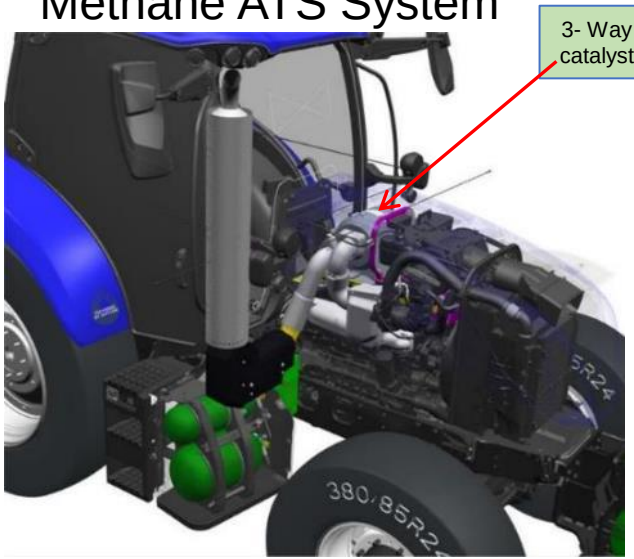
Eminox
zircotec GROUP
NEW HOLLAND AGRICULTURE

Heat management

Stage V Diesel ATS System



Methane ATS System



Gas powered engines operate with extremely high exhaust gas temperatures when compared with current diesel technology

800+ deg C versus 550 deg C

Space availability in the tractor for the exhaust after treatment system (ATS) is heavily constrained by the machines construction and operating requirements– Legal exhaust touch temperature limit is <80 deg C

Fuel Tank Development

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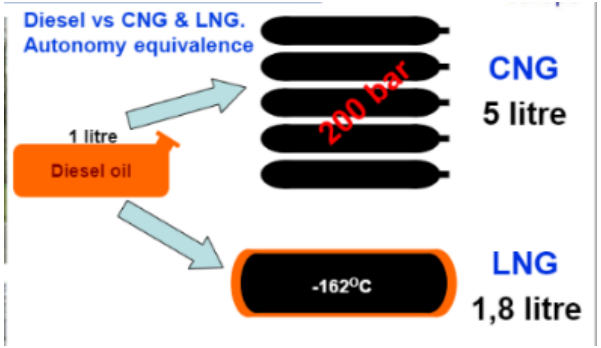
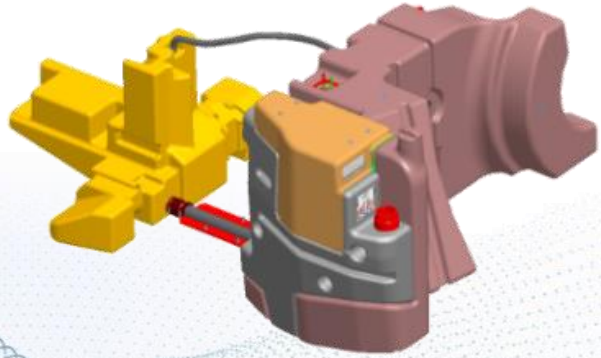
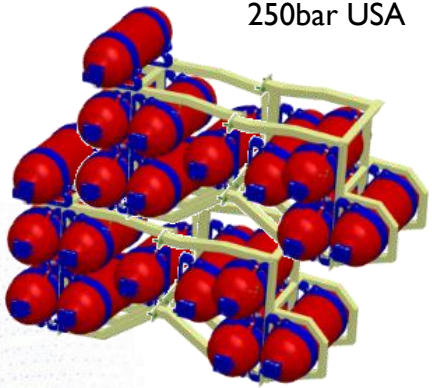
• VEHICLE AUTONOMY





150 litres Diesel

CNG
Compressed to 200bar Europe
250bar USA



750 litres of CNG methane

LNG
Cyrogenic storage @ -162° C
Tank vent off considerations

270 litres of LNG methane

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Novel CNG Tank Comparison

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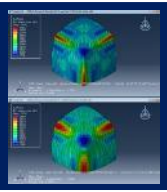
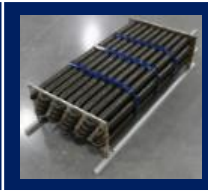
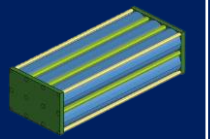
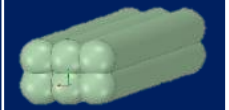
Concept	Standard Cylinder	Conformable composite	Intestinal	Casting	Nested Pipe	DDLT
						
Capacity (LHS only)	144L	N/A	208L	230L	199L	206L
Approximate Development Time	1 year	?? year	2 years	2 years	3 years	3.5 years
TRL	9	0	4	4	1	1
Approximate System Cost	High compared with Diesel	N/A	Increase in cost compared with current off shelf	Increase in cost compared with current off shelf Likely lower cost than Intestinal solution	Cost for development and qualification greater than £3million	Cost for development and qualification greater than £3million

- Regardless of tank design it is difficult to fit the required CNG volume within the existing diesel tank package
- The complex shape of the existing diesel tank package prevents the use of long, straight, large diameter tanks which would maximise CNG storage

NEW HOLLAND AGRICULTURE

Fuel Tank Development

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460 litre CNG compressed to 200bar
190 litres on vehicle,
270 litres range extender

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Emissions legislation

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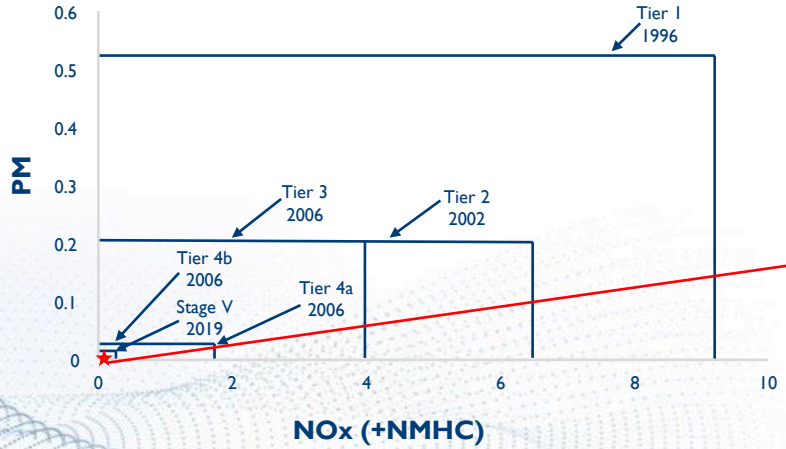
POWERED BY NATURE

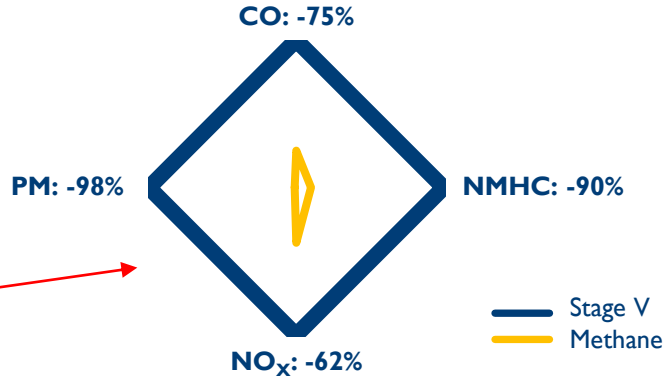
The impact of Methane technology vs Emission legislation

Before emissions legislation



By developing a tractor running on methane, we have changed the game

Compared to Stage V Emisions



CO_2: -10% (not part of Stage V legislation)

NEW HOLLAND AGRICULTURE

Methane Power tractor

T6 METHANE POWER
POWERED BY NATURE

Vehicle achievements

STANDARD DIESEL TRACTOR VS METHANE POWER

Power 180 hp	Same
Torque 740Nm	Same
Durability	Same
Service intervals	Same
Productivity	Same
Performance	Same
Running costs	Saving 30%
Sustainability credentials	CO2 equivalent (fossil fuel) Tank to Wheel ~10 % Well to Wheel ~11 %

NEW HOLLAND AGRICULTURE

Environmental Impact View

T6 METHANE POWER
POWERED BY NATURE

WELL TO WHEEL

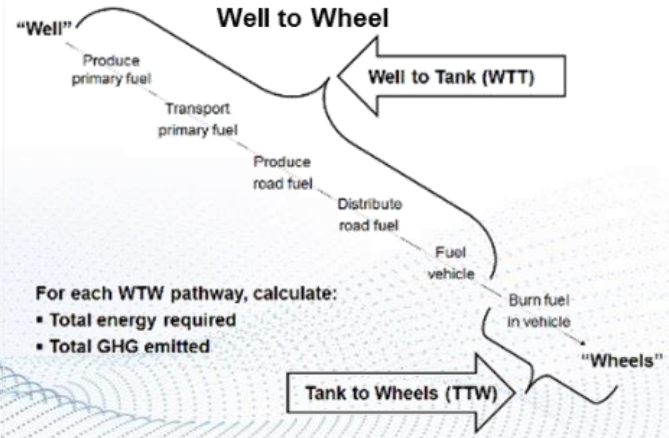
Natural Gas vs Diesel

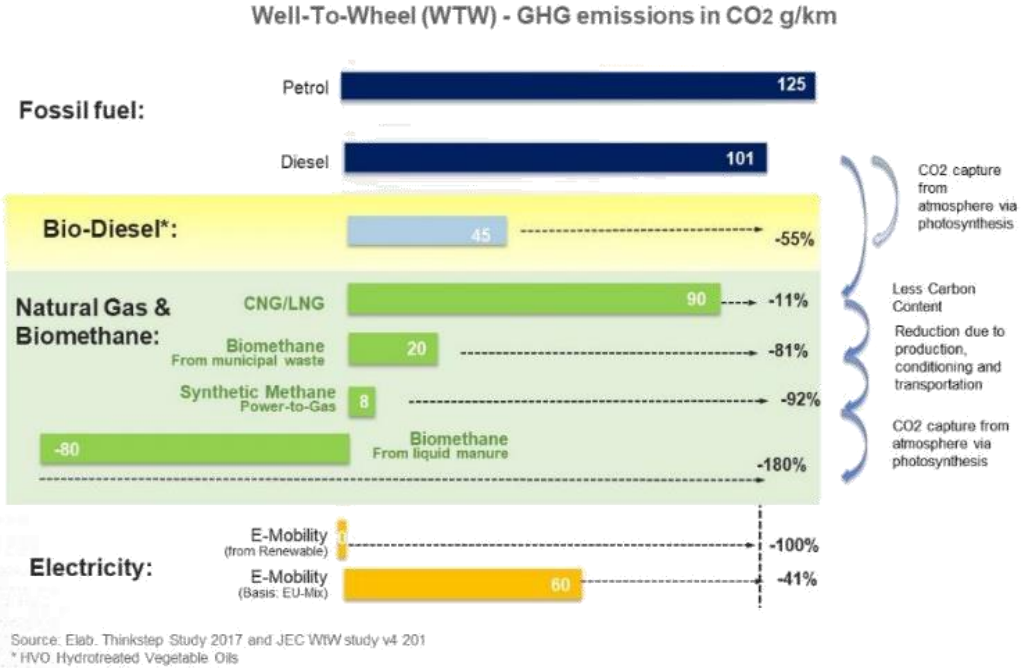
Tank to Wheel (TTW)

- **Non-Renewable** Natural Gas has a significant reduction in CO_2 emissions vs Diesel (~11%)

Well to Tank (WTT)

- **Renewable sources of Gas reduce CO2 emissions even further vs Diesel**
  - Between ~ 80% - 180% reduction depending on the source





Source: Elab. Thinkstep Study 2017 and JEC WtW study v4 201
* HVO Hydrotreated Vegetable Oils

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.. Solving an Environmental Problem Profitably

T6 METHANE POWER
POWERED BY NATURE

Slurry from a 130 cows farm emits 40,000kg of methane

This is releasing ~3.5K Tonnes of CO_2 annually

The Challenge

Create a business model that manages to turn an inconvenient waste and a powerful greenhouse gas into a clean vehicle fuel helping to slow down climate change and make some £/$/€ for **all** parties in the process!

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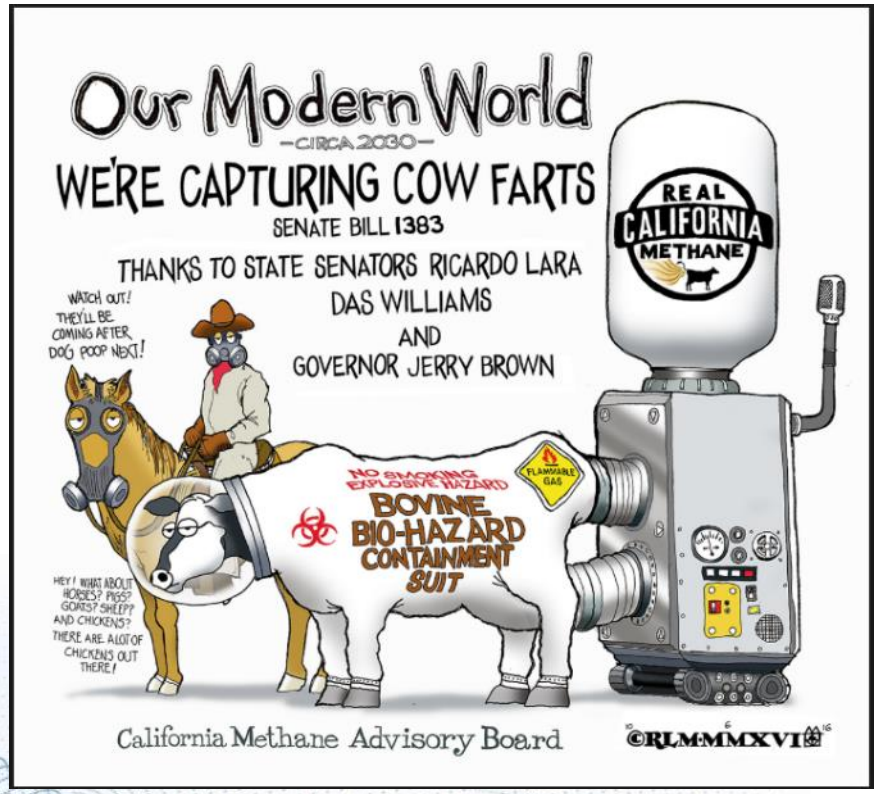
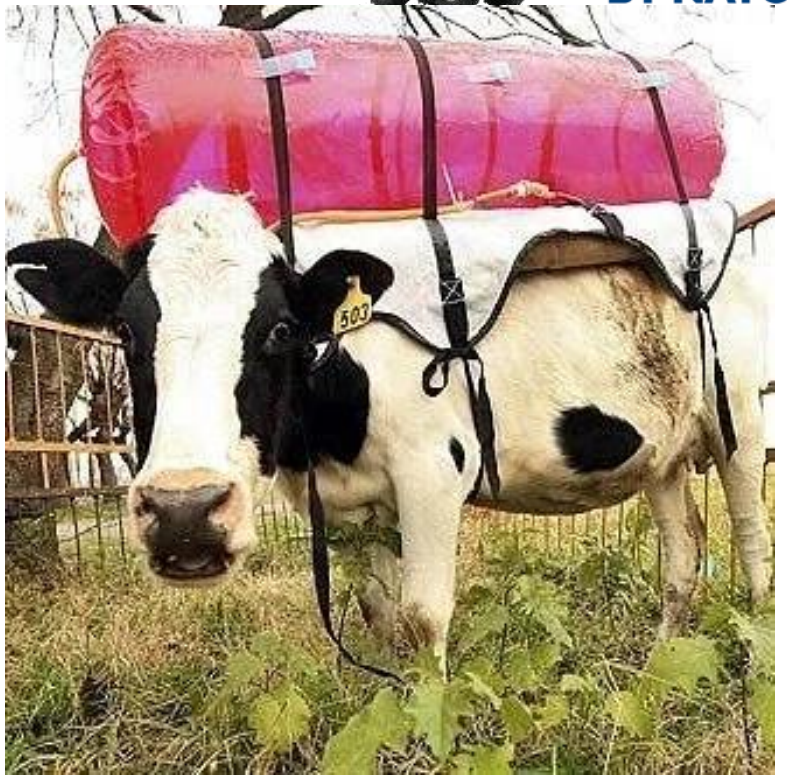
Quick Google Search …..?

T6 METHANE POWER
POWERED BY NATURE





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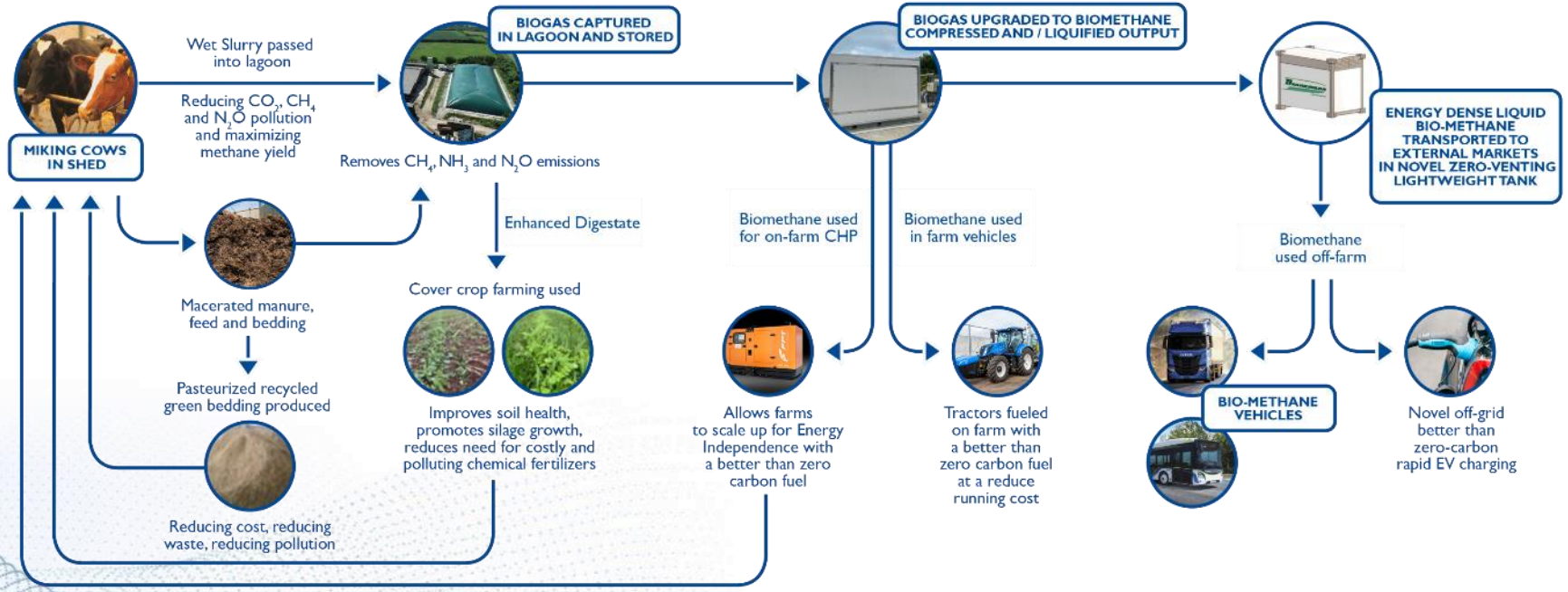
Energy Independent Farm℠ Dairy Farm

T6 METHANE POWER
POWERED BY NATURE

How the Bennamann system works



FPT POWERTRAIN TECHNOLOGIES
Bennamann
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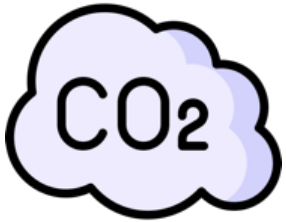
BENEFITS OF CAPTURING & REPURPOSING LIVESTOCK METHANE AS FUEL

T6 METHANE POWER
POWERED BY NATURE

150 cows
(housed 7¾ months of the year)

33.5 Tonnes of methane emitted from an uncovered lagoon annually



2,883 tonnes of CO2 equivalent emissions pa (GWP 20)

95 UK households annual carbon footprints

28.7 Tonnes of methane after processing
(some methane is used for energy)

=

44,400 l of Diesel equivalent
OR
155 MWh electricity + 260 MWh heat pa

=

1 methane tractor (90 hour / month)
AND
1,500 milking hours / year (50 kWh peak)

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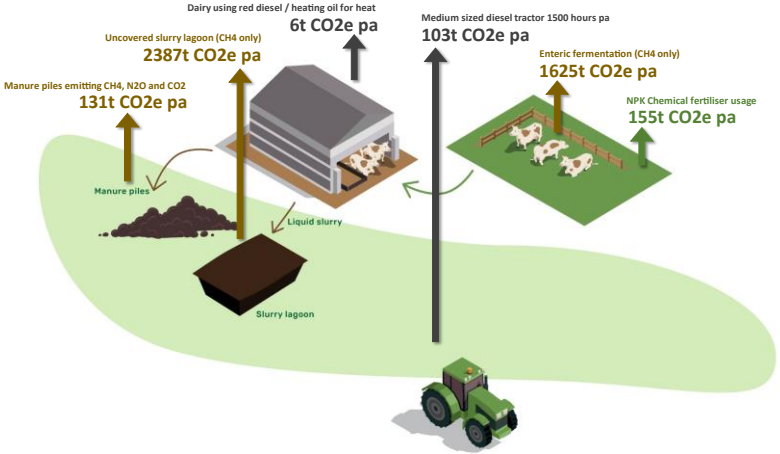
Dairy Farm CO2e Emissions Today & Tomorrow

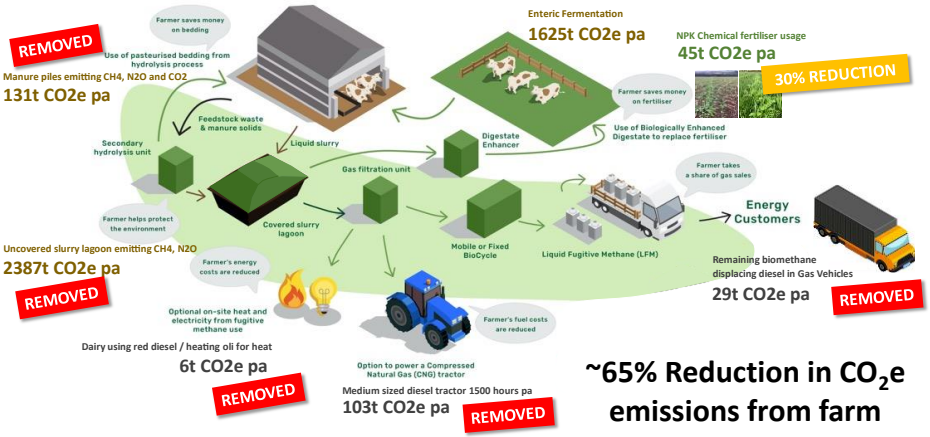
T6 METHANE POWER
POWERED BY NATURE

Before and After Energy Independent Farm℠ Implementation

CO_2e Output 150 Cow UK Dairy Farm - BEFORE



CO_2e Output 150 Cow UK Dairy Farm - AFTER



~65% Reduction in CO_2e emissions from farm

FARM CO_2e OUTPUT (kg CH4 GWP20 86kg CO_2e)	~4400 tCO_2e pa	→	TOTAL METHANE CO_2e REDUCTION (86kg CO_2e)	~2500 tCO_2e pa	+	CO_2e REDUCTION REUSING METHANE	~290 tCO_2e pa	=	TOTAL CO_2e REDUCTION (86kg CO_2e)	~2800 tCO_2e pa

~65% Reduction in methane CO_2e emissions on farm

140 UK household carbon footprints

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Why use a Methane Powered tractor, it still has an ICE?

T6 METHANE POWER
POWERED BY NATURE

FUGITIVE METHANE SUSTAINABILITY EFFECT

86kg CO_2e / kg CH_4 **- 97%** **2.75kg CO_2e / kg CH_4**

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Potential Customers: EU focus

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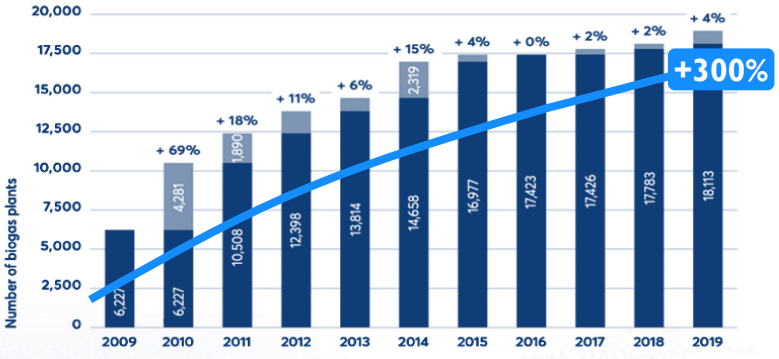
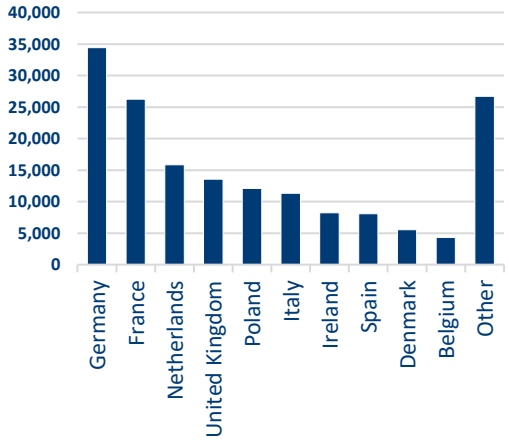
EU Biogas Plants



Existing plants
New plants

- **EBA Statistical Report 2020**
- Development of the number of biogas plants in Europe, 2009-2019

EU Dairy Farms



Eurostat survey 2018

Total number of holdings – Number of cattle +50

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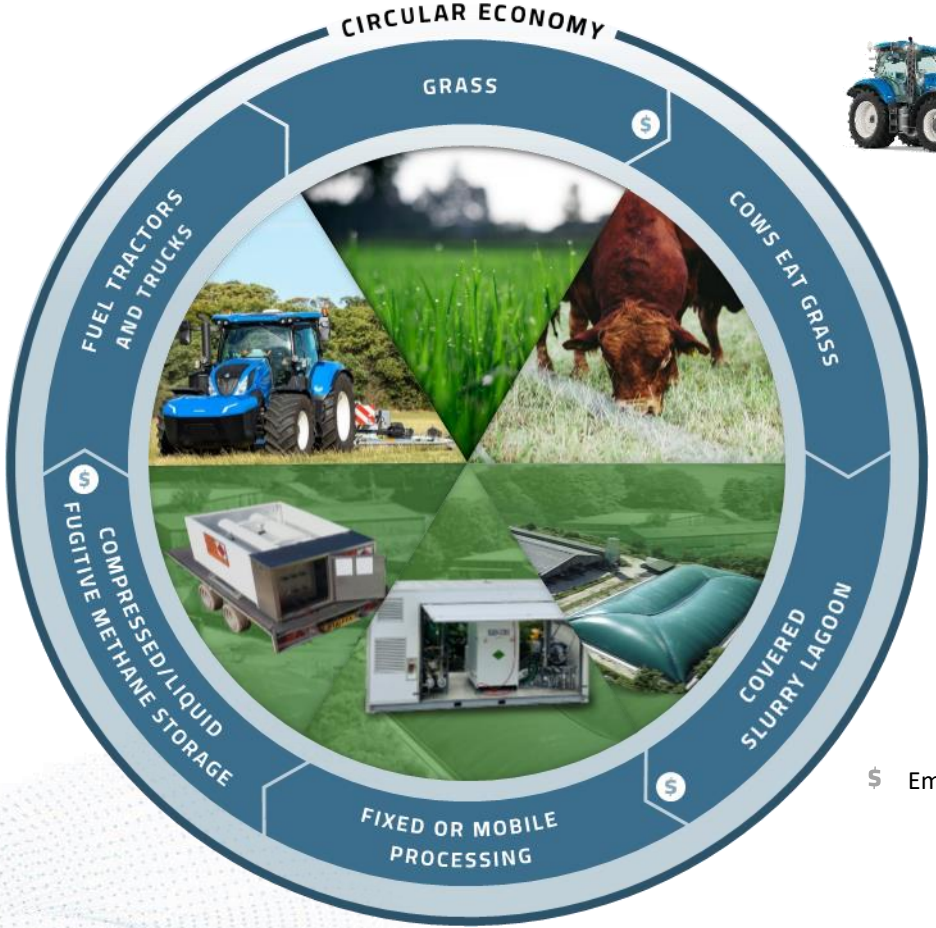
Enabling the circular economy in agriculture generating energy from waste



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$ Emerging revenue streams

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T6.180 METHANE POWER

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At Work Today

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T6 METHANE POWER

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CNH INDUSTRIAL

THANK YOU

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