

**IAgrE Landwards Conference 2021** 

Electricity and Hydrogen – Potential future energy sources for agricultural machines

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- Motivation and Ag-industry characteristics
- BEV use in agri-industry
- Hydrogen as fuel FC and ICE
- Challenges in vehicle installation
- Summary and conclusions





# INTERGOVERNMENTAL PANEL ON Climate change

IPCC PRESS RELEASE

9 August 2021

#### Climate change widespread, rapid, and intensifying – IPCC

GENEVA, Aug 9 – Scientists are observing changes in the Earth's climate in every region and across the whole climate system, according to the latest Intergovernmental Panel on Climate Change (IPCC) Report, released today. Many of the changes observed in the climate are unprecedented in thousands, if not hundreds of thousands of years, and some of the changes already set in motion—such as continued sea level rise—are irreversible over hundreds to thousands of years.

However, strong and sustained reductions in emissions of carbon dioxide (CO<sub>2</sub>) and other greenhouse gases would limit climate change. While benefits for air quality would come quickly, it could take 20-30 years to see global temperatures stabilize, according to the IPCC Working Group I report, *Climate Change 2021: the Physical Science Basis*, approved on Friday by 195 member governments of the IPCC, through a virtual approval session that was held over two weeks starting on July 26.



# **NRMM EMISSION REGULATIONS BY FAR**

So far NRMM emission legislation has focused on  $NO_x$ - and particulate reduction





## FORECAST GLOBAL EMISSION REGULATION ~ 2028 to 2030





### **FUTURE EUROPE NONROAD REGULATION**





What do we know about coming regulation by now:

- In Service Monitoring 2020 2024
- **EU comission will have review** on Stage IV regulation by 2026



In Service Monitoring (ISM) testing



# IS THERE A SILVER BULLET ENERGY SOLUTION?







### **OPTIONS FOR FUTURE FUEL STRATEGIES**





BIOMETHANE



SYNFUEL





# **INDUSTRY COMPLEXITY**





























# **INDUSTRY COMPLEXITY**

There is no single solution to cover whole machine range



- Small machines have most potential for full electrification
- Larger machines have very high power need
- All machines could benefit from hybridization



**E-Flywheel** 



Electricity storage



E-Turbo / booster





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#### **RATIONALE ELECTRIFICATION** WHY? THE MAJOR DRIVERS

Cost of Compliance

EMISSIONS: CO2, NOx, PM, ...

Machine Operation

Source

PRECISE AUTOMATION



Wow Effect, Noise, Architecture



 $\langle \boldsymbol{\varsigma} \rangle$ 

# **RATIONALE ELECTRIFICATION**

#### Swarm technology







TABLET







### **OFF-ROAD TECHNOLOGY IN THE FUTURE**







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# **HYDROGEN COMBUSTION ENGINE (H<sub>2</sub> ICE)**



- Modern ICE can be converted to run with hydrogen, biomethane or ethanol
- Design changes required specially on piston and cylinder head -area
- Supports global platform approach by enabling traditional powertrain architecture
- Multifuel capability
- Efficiency on similar with diesel
- Emits water vapor and small amount of particulates
- Best efficiency at high loads





# **HYDROGEN FUEL CELL**



- Very quiet
- Limited amount of moving parts
- Requires large water coolers
- Most likely offered only limited market areas
- Efficiency best at part load
- Emits only water
- Makes most sense to use with full electric driveline





### HYDROGEN FUEL CELL



#### Sir William Robert Grove



William Robert Orove
11 July 1811
Swansea, Wales
1 August 1896 (aged 85)
London





# **HYDROGEN INFRA**



- Planned hydrogen infra does not support its usage on off-road machinery
- Local production is an option but requires significant investment from farmer / machine operator







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# **ENERGY SOURCE COMPARISON**

	Typical operation duty cycle tractor, 8 hours operation (average engine load 100 kW)				
	Diesel (fuel)		Hydrogen ICE (fuel, 350bar)	Hydrogen FC (fuel, 350bar)	BEV (Li-Ion battery)
	Weight				
kg	152 kg		53 kg	43 kg	4.100 kg
	Volume				
	179		3.200 I	2.600 I	3.400 l
	Cost (energy per day)				
E	213€		~240 €	~200€	129€
*	Energy storage cost				
E	<1 k€		30 k€	25 k€	150 k€





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# **SUMMARY**

- Agri vehicles challenges on future fuels differ from onroad
- H<sub>2</sub> and BEV needs are driven by potential future regulation
- BEV would offer benefits battery energy density far too low still
- Hybridization is step forward but don't provide Zero emissions
- High voltages will change machinery service dramatically
- Infrastructure and vehicle gas tanks are biggest obstacles in H<sub>2</sub>-transition
- Maintaining ICE would give flexibility to use liquid and gaseous fuels
- Still need of mechanical power for implements
- The Silverbullet for future does not exist yet







