

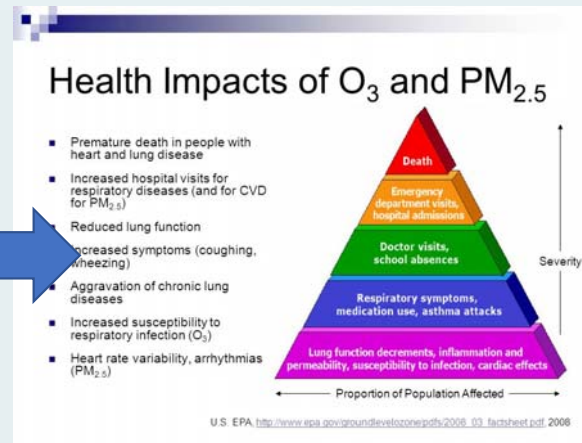
2019 BIC National Conference – Moving People
Moving to hydrogen: the benefits for bus and coach
20 November 2019

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Adjunct Associate Professor – QUT IFE | Director - AHC



HEALTH CONCERNS OVER PM_{2.5} DRIVING ZERO-EMISSION BUSES

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Municipal governments around the world are moving to zero-emission buses due to PM_{2.5} health impacts

BATTERY ELECTRIC AND FUEL CELL ELECTRIC BUSES CO-EXIST

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This is not a Beta versus VHS discussion over again – battery electric and fuel cell electric buses co-exist

BATTERY ELECTRIC BUSES FOR AIRPORTS/INTRA-CITY

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Battery electric buses have worked well in airport/intra-city deployments but have range and capacity limits

FUEL CELL ELECTRIC BUSES/COACHES FOR PERIURBAN/INTERCITY

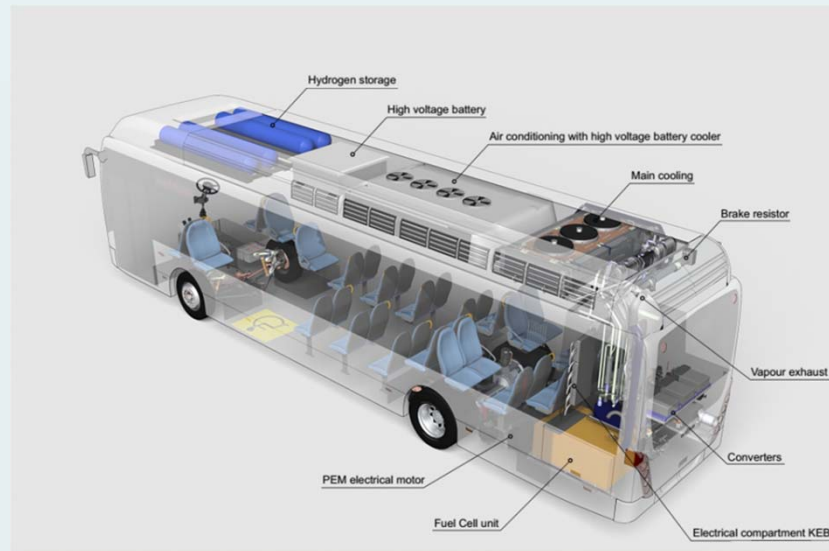
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Fuel cell electric buses work better in periurban/intercity without range, capacity or topography limits

SO WHAT IS A FUEL CELL ELECTRIC BUS?

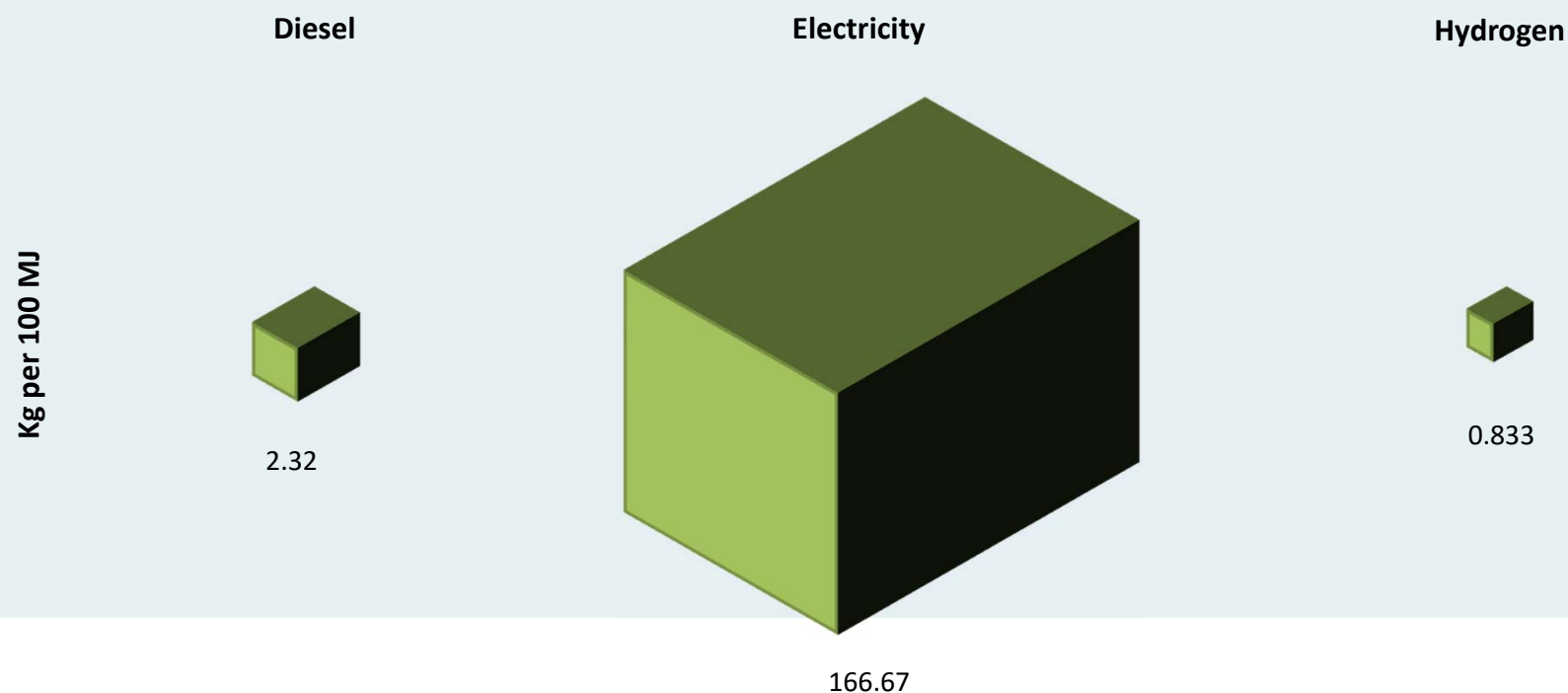
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A fuel cell electric bus is the same as a battery electric bus only with a smaller battery, hydrogen tanks and FC

HIGHER ENERGY DENSITY OF HYDROGEN = GREATER RANGE & PAX

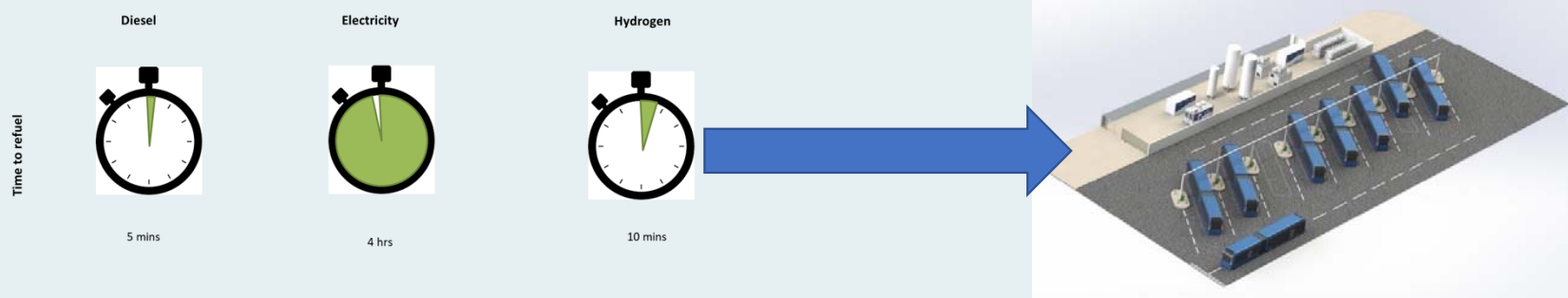
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Typical fuel cell electric bus range is between 400km to 500km and can be configured to suit operator

FUEL CELL ELECTRIC BUS REFUELLING TIME SIMILAR TO DIESEL

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Typical fuel cell electric bus refuelling time in minutes rather than hours with greater layout flexibility

FUEL CELL ELECTRIC BUSES OPERATE IN PALM SPRINGS AND OSLO

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Fuel cell electric buses operating reliably from -30C to +50C with consistent performance across all seasons

FUEL CELL ELECTRIC BUSES = 1:1 REPLACEMENT OF DIESEL/CNG

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Fuel cell electric buses offer route flexibility via 1:1 replacement of diesel/CNG buses with no roadside chargers

FUEL CELL ELECTRIC BUS MAINTENANCE OPERATIONS

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Fuel cell electric bus maintenance operations are relatively easy to establish and similar to CNG requirements

FUEL CELL ELECTRIC BUSES OFFER FIELD PROVEN DURABILITY

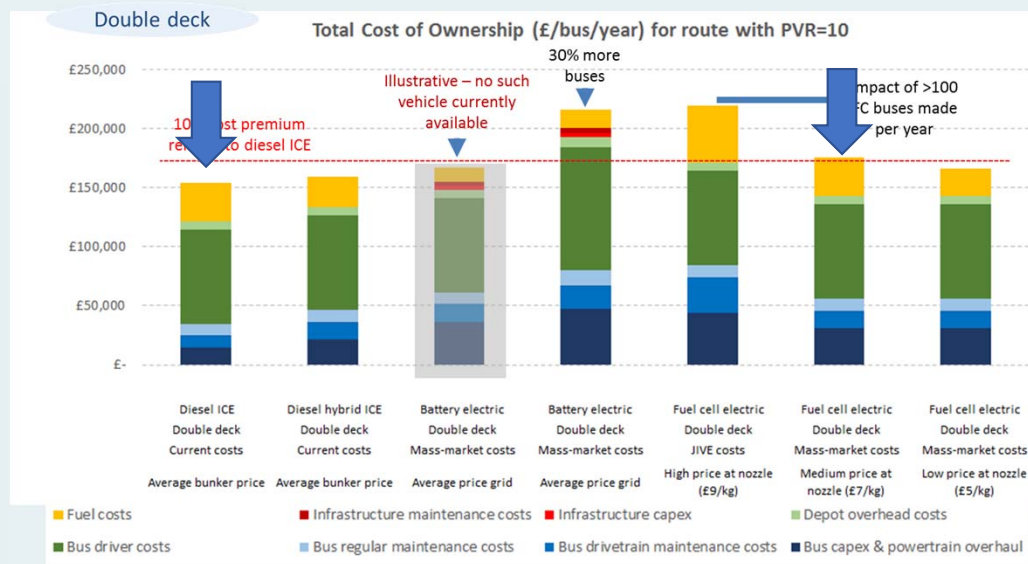
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Fuel cell electric buses have over 13m km of passenger service with 30,000+ hr FC stack durability over 15 years

FUEL CELL ELECTRIC BUS ECONOMICS COMPARABLE TO DIESEL ICE

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Fuel cell electric buses offer total cost of ownership (TCO) approaching diesel ICE at 100+ fleet scale

FUEL CELL ELECTRIC BUS RENEWABLE HYDROGEN FUEL SOURCES

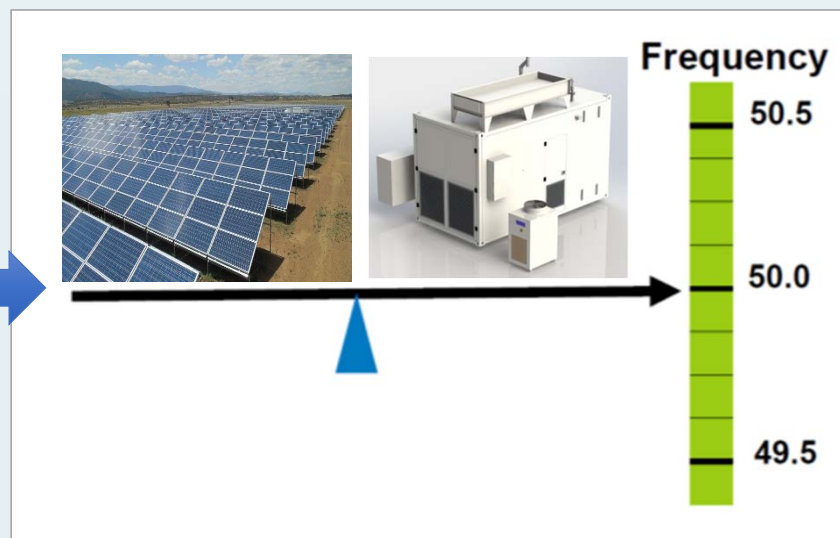
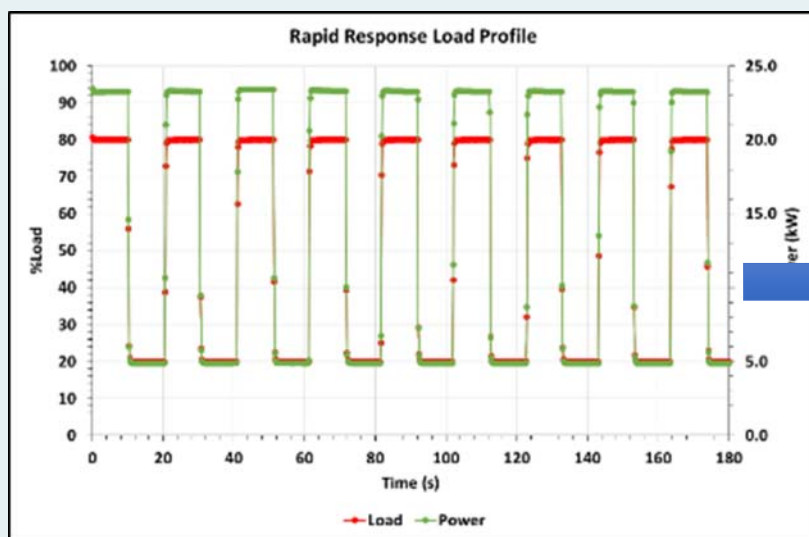
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Fuel cell electric buses can be easily supplied with renewable hydrogen fuel from centralised or site production

FUEL CELL ELECTRIC BUS INCREMENTAL REVENUES & LOWER \$/KG

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Use of rapid response PEM electrolyzers for site fuel production allows for incremental grid services revenues

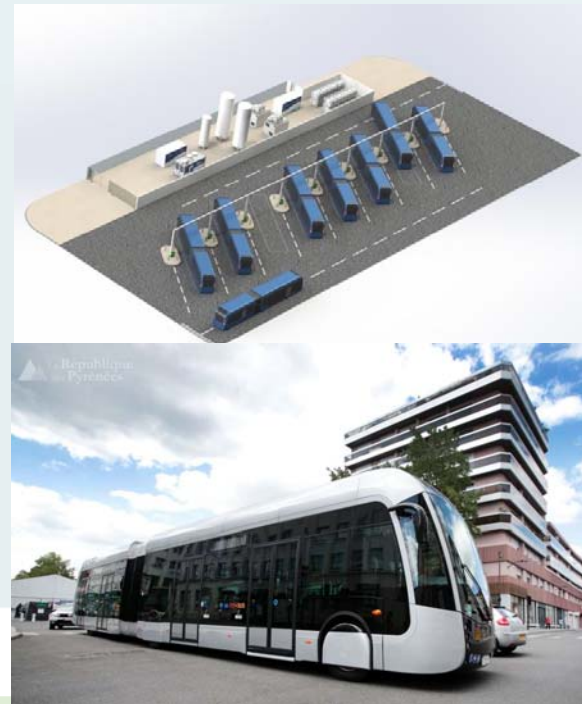
FUEL CELL ELECTRIC BUS RECENT DEPLOYMENT - FRANCE

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Pau 0.7MW ITM electrolyser | ~270kg/24hrs

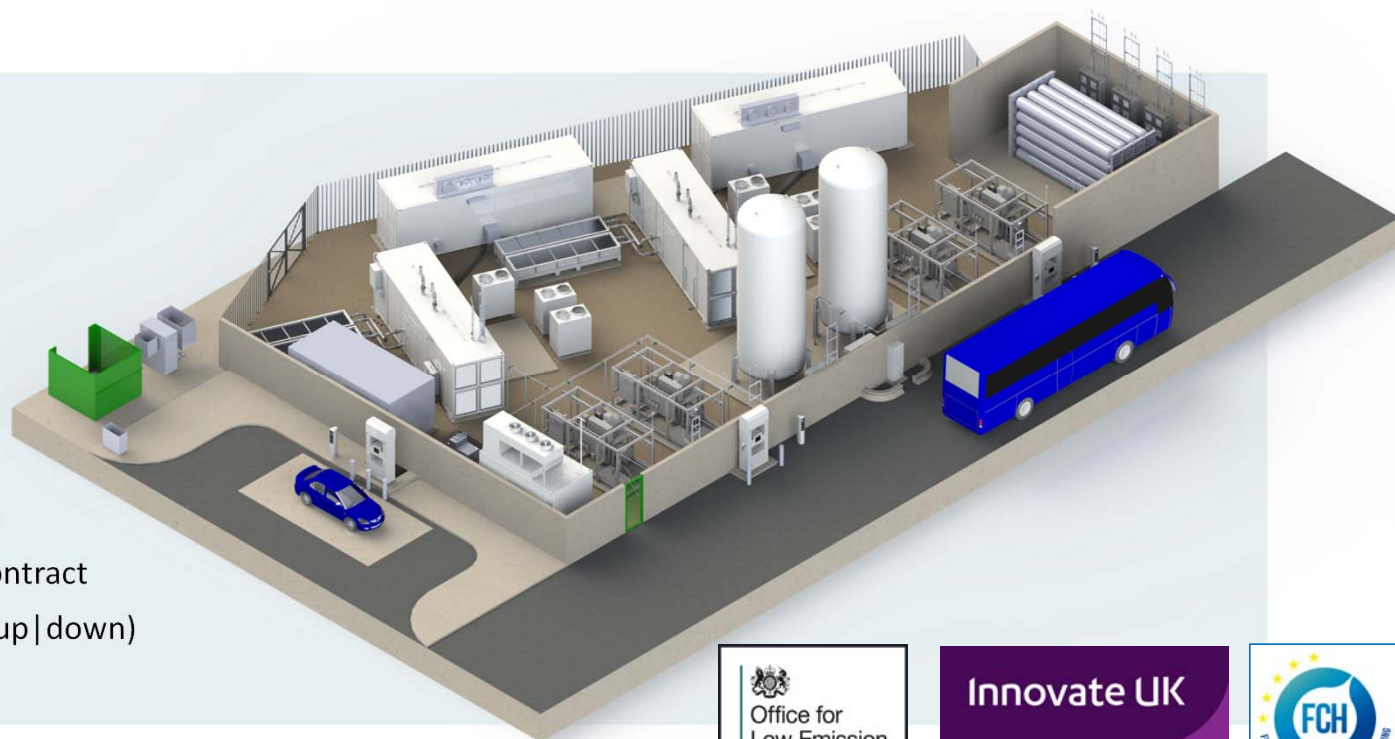
- First French 18m bus project
- 6+2 buses @ up to 36kg/bus per day
- Led by Engie | GNVert
- SMTU Public Transport | owner operator of bus
- Supported by FCH JU
- Linde Storage Compressing & Dispensing equipment
- Operational 2019



Fuel cell electric buses powered by renewable hydrogen in pristine tourist region

Birmingham Bus Project

- 3MW of rapid response electrolysis
- 350bar bus refueller
- 350 and 700 bar public refueller
- Opening Q2 2020 for cars and buses
- 3MW of FCDM combined with RE contract
- EFR trials (simultaneous 1 sec. turn up|down)



Innovate UK



Fuel cell electric buses and cars refuelled via 350/700 bar system with grid services revenue to lower \$/kg

FUEL CELL ELECTRIC BUS OPTIONS OFFERED BY MAJOR OEM'S

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Fuel cell electric buses are now offered as a standard option in major OEM electric platform portfolios

FUEL CELL ELECTRIC BUS FUTURE DEVELOPMENTS

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Forecast weight and cost reduction in fuel cell stacks will allow progress to luxury fuel cell electric coaches