

Decarbonizing the Oil Field

Evolution vs Revolution

Ian Norton



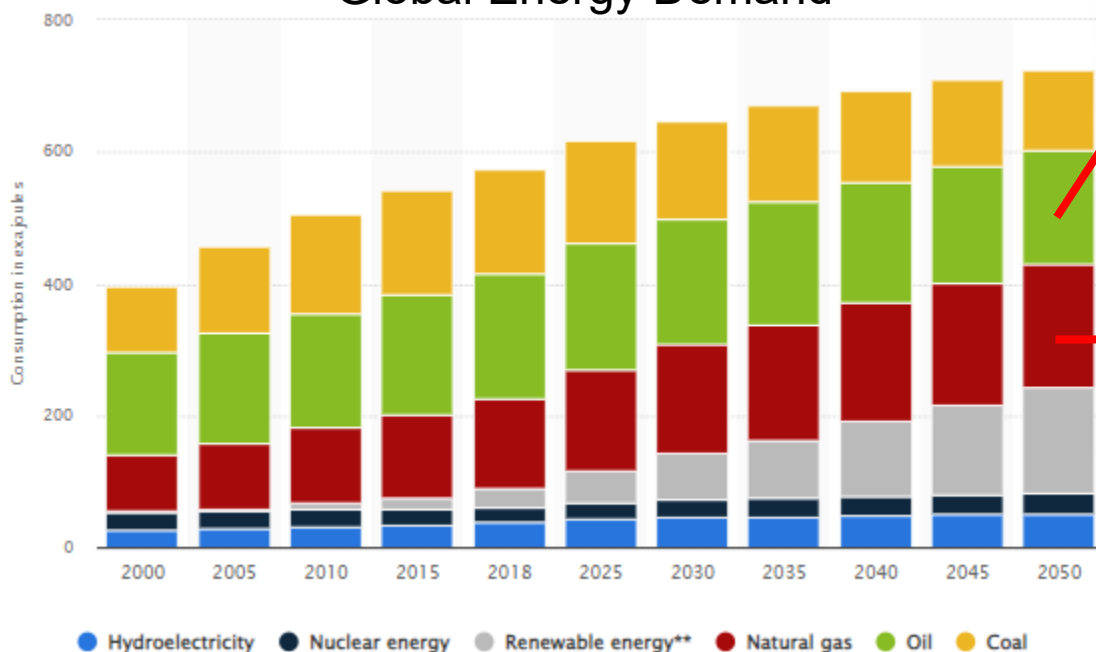
FOR
A WORLD
THAT'S
ALWAYS ON™



Global Energy Demand

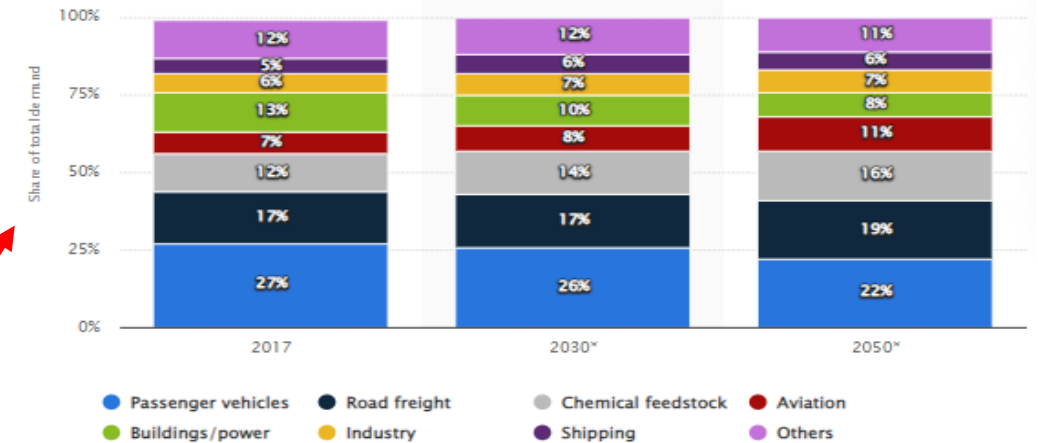
- Global energy demand is expected to continue to grow through 2050.
- Oil and Natural Gas will continue to be a significant contributor to the global energy mix, however most of the increase will come from renewables, with coal showing the largest decline.

Global Energy Demand

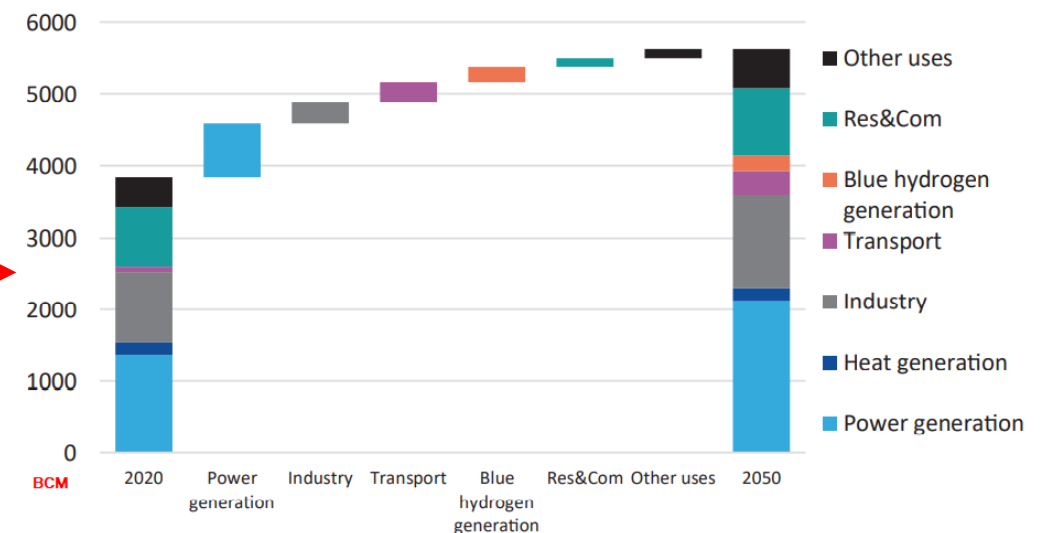


The contribution of passenger vehicles to the overall global oil demand will drop slightly from 27% in 2017 to 22% in 2050.

Distribution of Global Oil Demand



Distribution of Global Natural Gas Demand



Significant growth of power generation provided by natural gas

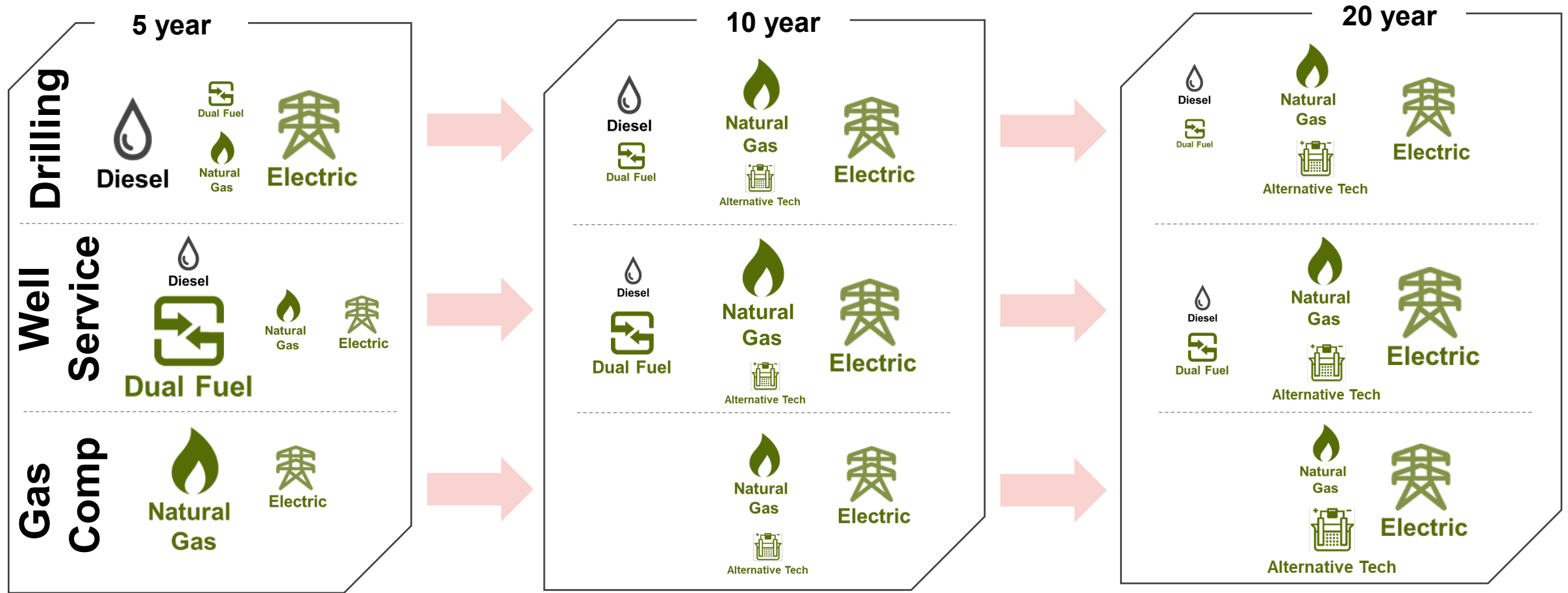
Market Technology Roadmap

Power Source/ Hardware

Diesel – I.C.E

Natural Gas – I.C.E or Turbine

Dual Fuel – I.C.E



Fuels in the Upstream

Incumbent

Immature

Future

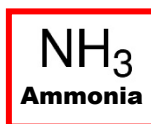
Liquid



Diesel

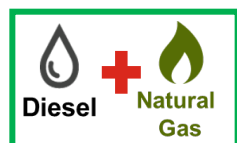


HVO

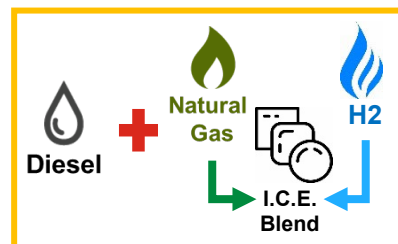


Ammonia

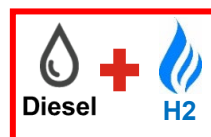
Dual Fuel



Diesel + Natural Gas



Diesel + Natural Gas + H2
I.C.E. Blend

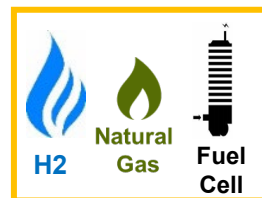


Diesel + H2

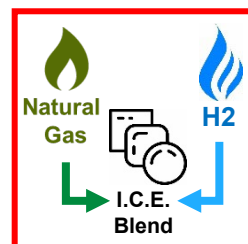
Gaseous



Natural Gas

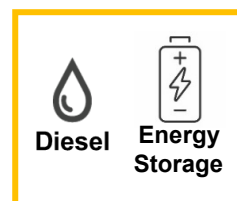


H2 + Natural Gas
Fuel Cell

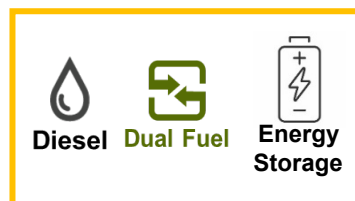


Natural Gas + H2
I.C.E. Blend

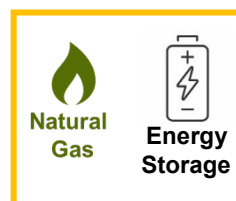
Hybrid



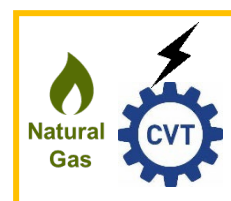
Diesel + Energy Storage



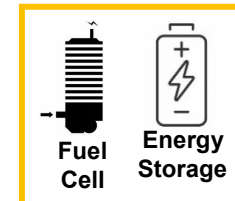
Diesel + Dual Fuel + Energy Storage



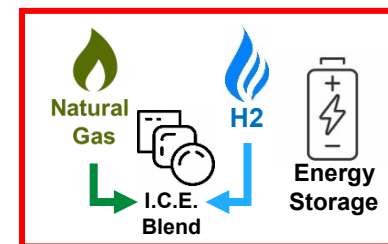
Natural Gas + Energy Storage



Natural Gas + CVT



Fuel Cell + Energy Storage



Natural Gas + H2 + Energy Storage
I.C.E. Blend



H2 I.C.E. + Energy Storage



Electric

Optional

Optional

Reducing well to wheels emissions

BY INNOVATION OF THE ENERGY SOURCES AND THE POWER SOLUTIONS



Future Product Trends (Alternative Fuel/Electrification)

To continue to help customers reduce fuel costs/TCO and emissions reduction, the industry is exploring different Fuels and also different Power Sources - Hardware that could achieve these goals, mainly utilizing alternative fuel and electrification

Alternative Fuel

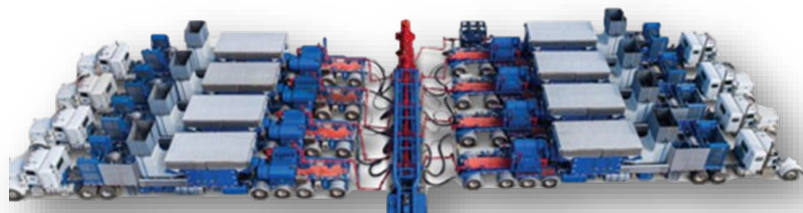
*Dual fuel technologies
(NG or H₂)*



*Alt Fuel (HVO, H₂, NG) blending
as means to reduce emissions*



*NG / turbine
direct drive*



Electrification

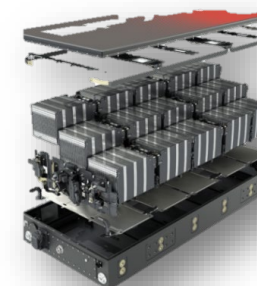
*Gas gensets for
electric frac*



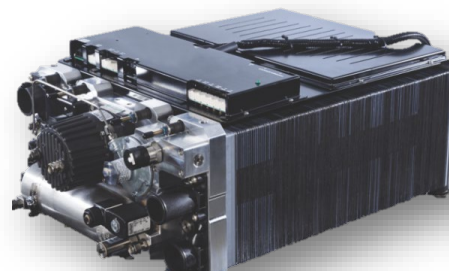
*H₂ blending for eFrac as
mean to reduce emissions*



Energy Storage






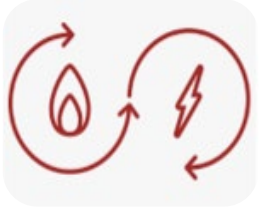


*Fuel cell technology (for
hotel loads currently!)*



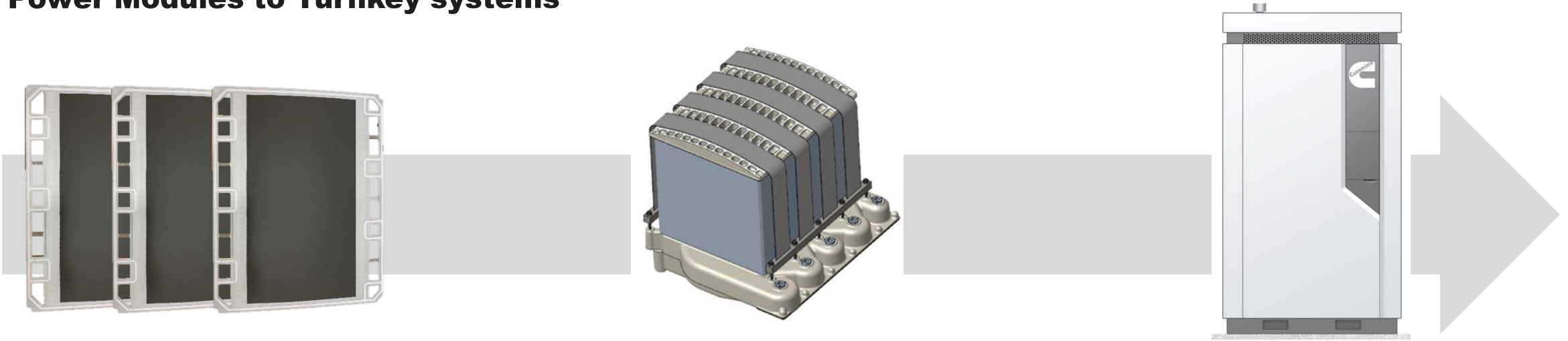
SOFC & PEMFC - ELECTRIFICATION

SOLID OXIDE FUEL CELLS & PROTON EXCHANGE MEMBRANE FUEL CELLS

	Applications	Resiliency & Security	Electrical Efficiency	Fuel Flexibility	Emissions	CHP/CCHP Options
SOFC	 <ul style="list-style-type: none"> Continuous Power Grid-connected Off-grid 	 <p>As high as 99.999% uptime</p>	 <p>50% (BoL: 60%)</p>	 <ul style="list-style-type: none"> NG Propane H₂ Blended NG Biogas, NH₃ H₂ 	 <ul style="list-style-type: none"> No combustion No PM No So_x Trace levels of No_x 	 <p>>80% overall efficiency</p>
PEMFC	<ul style="list-style-type: none"> Peak Shaving Grid Firming Renewable Integration Stand-by 	<p>As high as 99.999% uptime</p>	<p>45% (BoL: 55%)</p>	<p>H₂ (99.999% Pure)</p>	<p>NO Emissions</p>	<p>N/A</p>

SOFC Components

Power Modules to Turnkey systems



SOFC SINGLE CELL

- Additively manufactured electrolyte and anode
- Stainless steel support
- Cathode
- Ceramic electrolyte

FUEL CELL STACK

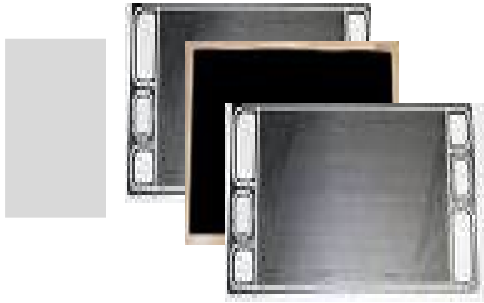
- Multiple cells layered
- Gas distribution manifold
- Current leads

FUEL CELL SYSTEM

- Fuel management
- Air management
- Embedded Control hardware and software
- Thermal management
- Start up system
- Power electronics
- AC power output

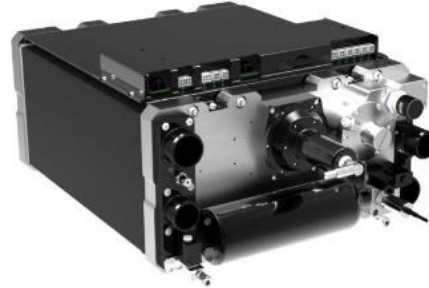
PEM Components

Fuel Cells to Power Racks



PEM SINGLE CELL

- MEA - Membrane Electrolyte Assembly
- Bipolar plates
- Gas diffusion layer
- Gaskets



POWER MODULE

- Multiple cells layered
- End plates
- Tie rods
- Spring washers
- Bus bar interfaces
- Fuel cell voltage monitor
- Electronic Control Unit



FUEL CELL RACK

- Power Modules
- Fuel management
- Air management
- Water management
- Gas conditioning
- Coolant pump and control
- Control hardware and software

Additional BOP Required

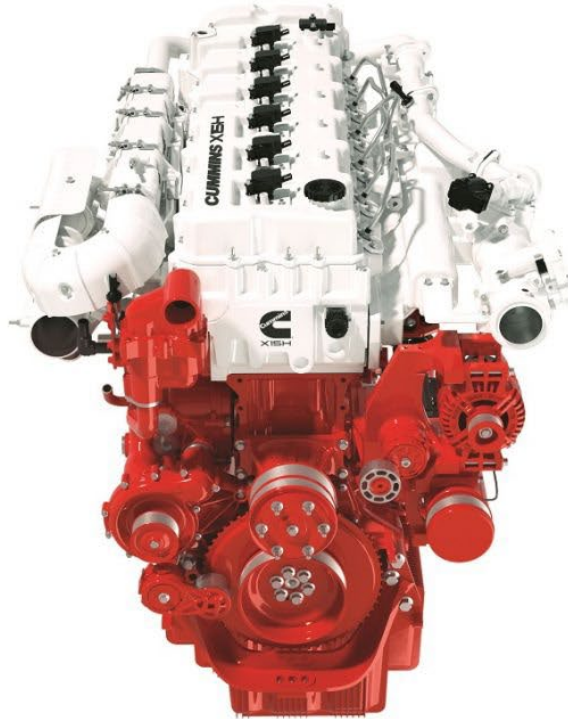
Power conditioning; Hybrid energy storage; Hybrid control hardware and software; H2 storage

A Fuel Agnostic Future – Alternate Fuels

Common X15 architecture below the head.
Reliable | Durable | Scale | Commonality



Natural Gas



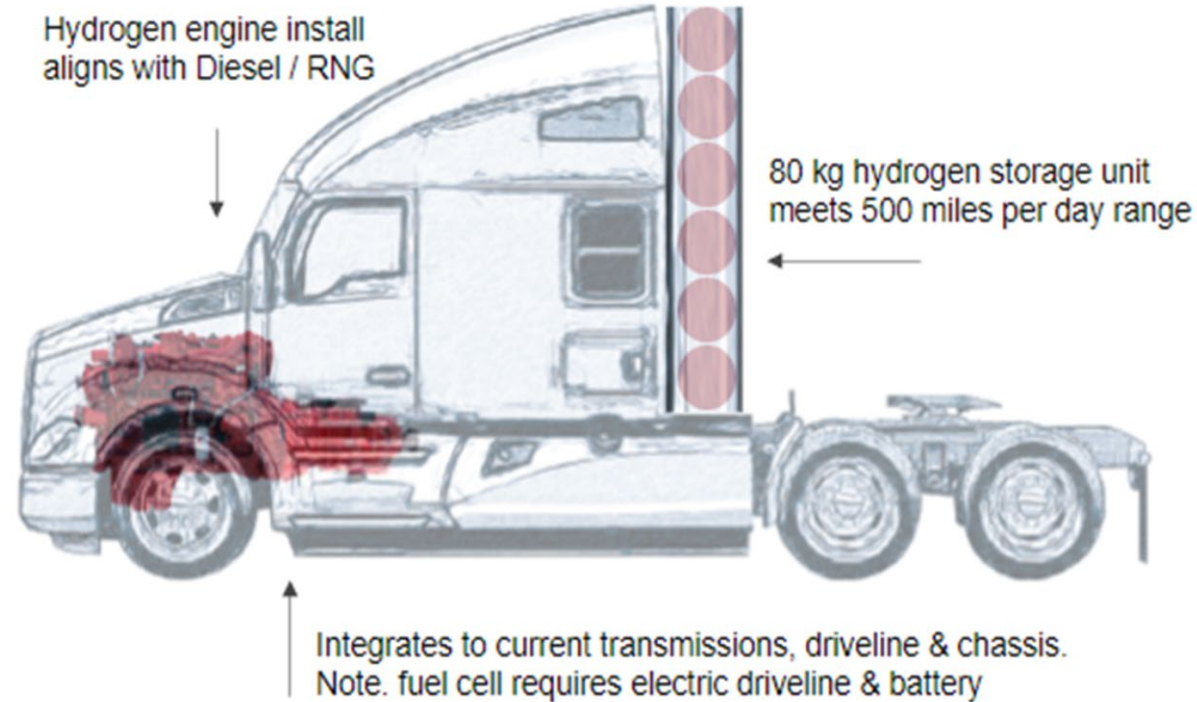
Hydrogen



Diesel

The H2 Internal Combustion Engine

Familiar



A Class 8 sleeper cab Hydrogen Engine powered vehicle will generate 144 fewer metric tons of CO₂/year and 1,437 fewer metric tons of CO₂ over its lifetime vs. the same diesel-powered vehicle*.

**WINNING
TOGETHER
IN A WORLD
THAT'S
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ON.**

