



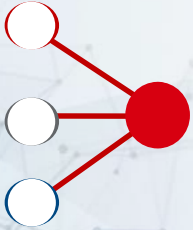
Wabtec Overview

DoE: Liquid Hydrogen Technologies Workshop February 2022

Presented by: Dr. Gladys Anyenya (Engineering Lead- Fuel Cell Development)

WABTEC

Global leader
in freight and transit
rail technologies



+50 COUNTRIES

~25K EMPLOYEES

FREIGHT: 67%

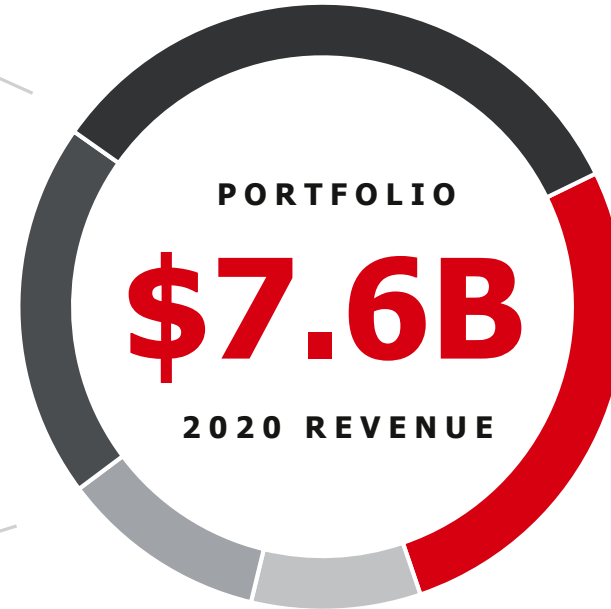
TRANSIT: 33%

27%
Freight Services

20%
Freight Equipment

11%
Components

9%
Digital Electronics



33%
Transit

MARKET
~60%
Aftermarket

GEOGRAPHY
~60% Non-U.S.
Revenues

WABTEC

Rail is well-positioned to tackle world's freight challenges

RAIL VS TRUCKS TODAY

The freight rail network is already considered the largest, safest, and greenest means of transporting goods throughout the world.

TODAY



CARBON REDUCTION

5x less carbon emissions per ton-mile



SAFER

22x fewer deaths and injuries per year than trucking



MORE EFFICIENT

3-4x more fuel efficient than trucking

50% SHIFT TO RAIL

~5 BILLION
gallons of fuel eliminated / year

~60 MILLION
5x less carbon emissions per ton-mile

~18 MILLION
fewer truckload trips / year

~14 MILLION
fewer injuries or deaths from truck accidents / year

WABTEC

Changing the course on emissions

Wabtec is leading the charge to a low- to zero-emissions rail network with heavy-haul battery-electric locomotives

1st

100%
BATTERY-ELECTRIC
LOCOMOTIVE
WORLDWIDE

7MWh

MORE THAN
7MWH
CAPACITY

30%

UP TO 30%
FUEL & EMISSIONS
SAVINGS



WABTEC

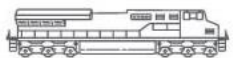
Roadmap to Carbon-zero Locomotives

HYDROGEN AVAILABILITY

GREY H2

BLUE H2

GREEN H2



Diesel-Electric
(Bio-Diesel and Renewable Diesel)

TODAY



Battery-Electric
Operating in Consist



Battery-Electric
Lead

LOCOMOTIVE CARBON
EMISSIONS



Hydrogen
Fuel Cell

2015

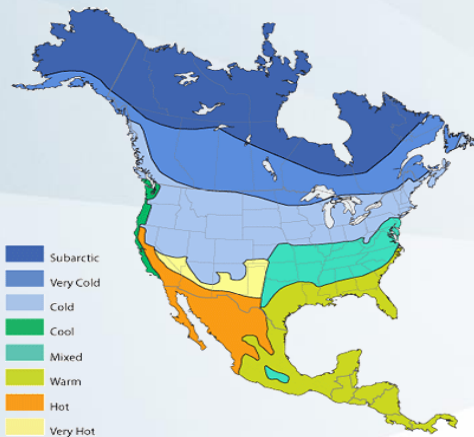
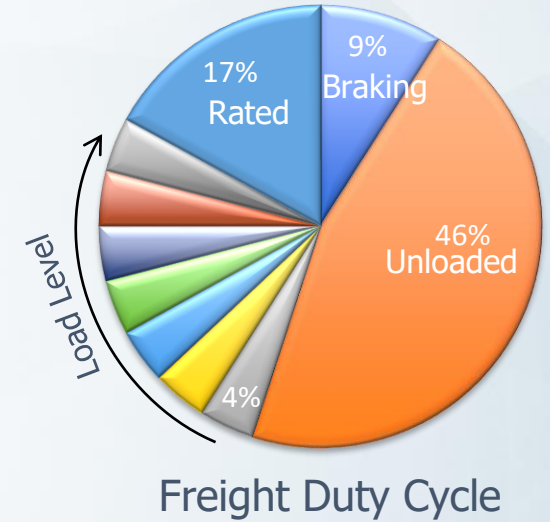
2020

ZERO
CARBON 2030

Locomotive Operation

Aggressive Duty Cycle

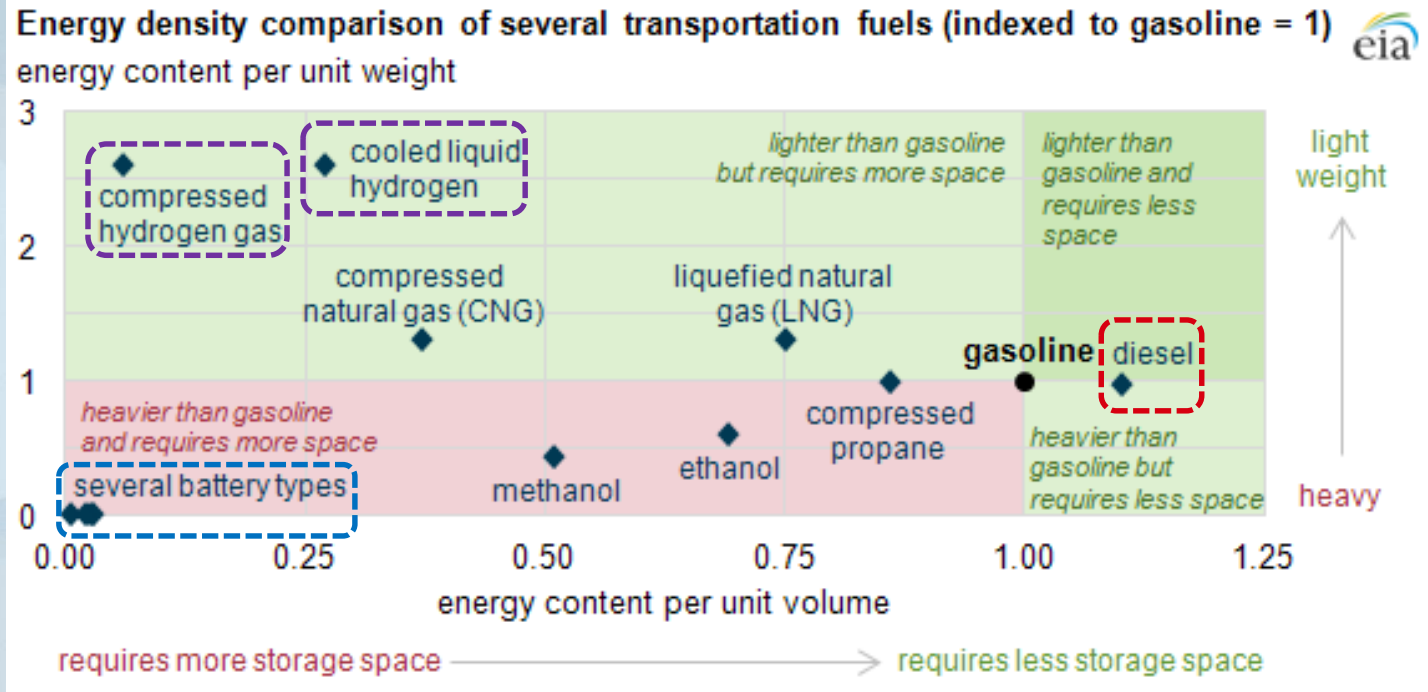
MWh/Yr : **3500-4000**
Power (kW) : **~3300**
Loco Operation : **30+ Yrs.**
Rated Power : **17%+ usage**
Daily Uptime : **80%+**
Diesel used/yr : **~250,000 gals**
Refuel freq. : **~1 week/fill**



Temperature : **-40°F to >120°F**
Altitude : **0 to 10,000+ ft**

Extreme Conditions

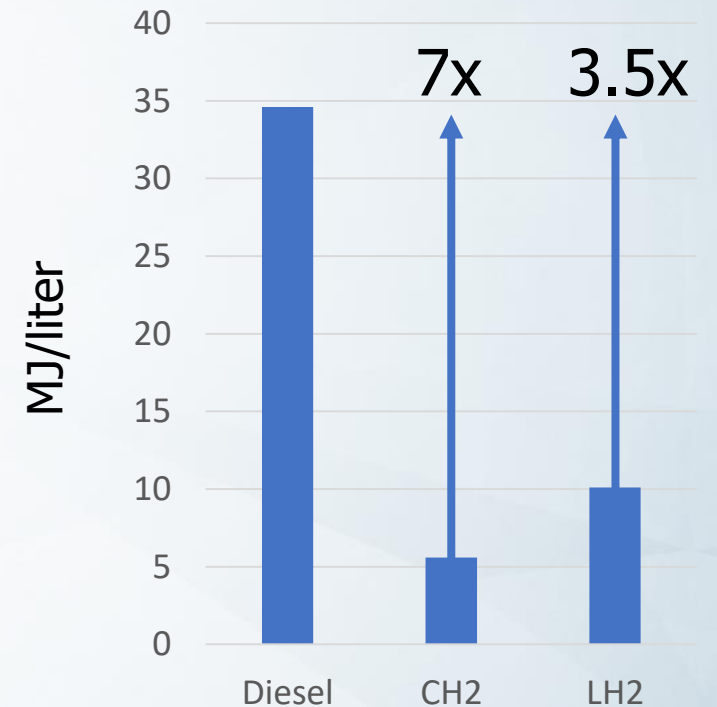
Energy Density walk



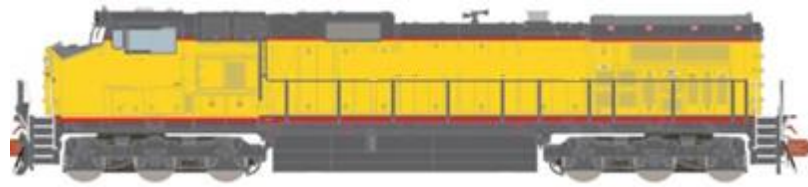
Diesel

~70 MWh per 5,000 gal tank

Energy Density Comparison

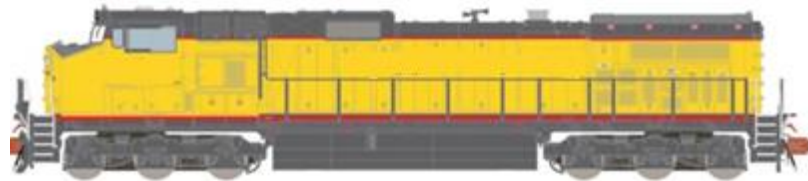


Required volume of liquified hydrogen is approximately 3x that of diesel fuel for same range



Diesel

5,000 gallons



5,000 gallons

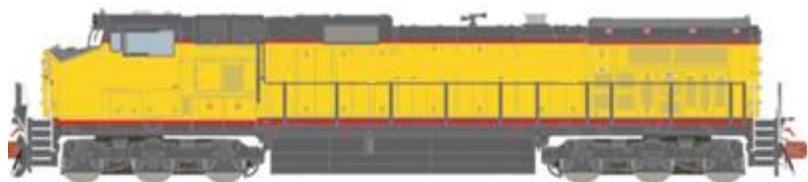


20,000 gallons



20,000 gallons

Compressed
(350 bar / 5,000 psi)



5,000 gallons



20,000 gallons



5,000 gal

Compressed
(700 bar / 10,000 psi)



5,000 gallons



10,000 gal

Liquid
(-423 °F, ~2 bar / 25 psi)

WABTEC

LNG on the rails provides a precursor to LH2

Wabtec's NextFuel™ kit has the ability to burn gaseous natural gas which is conditioned & supplied to the locomotive from a tender of liquified natural gas (LNG) or compressed natural gas (CNG).

The lessons learned in LNG tender development are crucial to a hydrogen tender design.



Potential barriers to adoption of hydrogen for rail

Scalable designs for higher power density

Operating hours/charging cycle life

Wear and tear from harsh rail operating conditions

Fuel cell components reliability

Extreme environmental conditions

Aggressive cooling system design requirements

Rail's aggressive duty cycle

Fuel cell-battery hybridization strategy

On-board hydrogen storage limitations for long range

Hydrogen system safety uncertainty

Alternative hydrogen storage solutions with higher energy density

Refueling time

Defueling system for service and maintenance

Refueling stations on the rail network

Hydrogen transfer over coupling components

Lack of financial commitment from rail stakeholders

Expertise and knowledge of rail stakeholders

Immature hydrogen and fuel cell supply chain

Regulatory approval/permitting structures

First responder/public reservations

