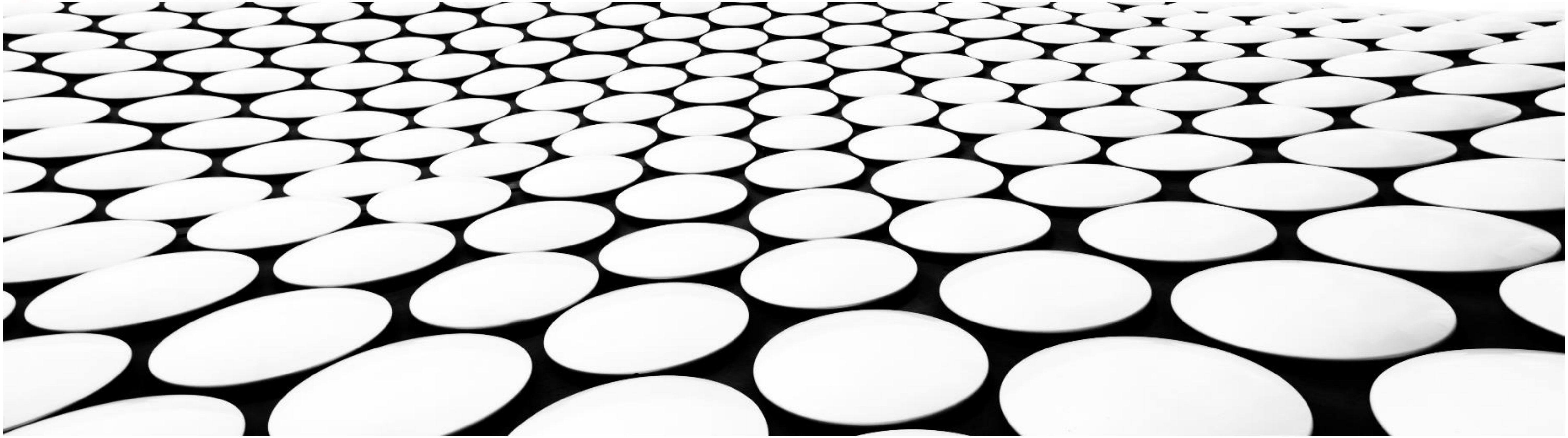
California Hydrogen Business Council



CHBC BRIEFING: HYDROGEN RAIL PROJECT SHOWCASE

MAY 19, 2021

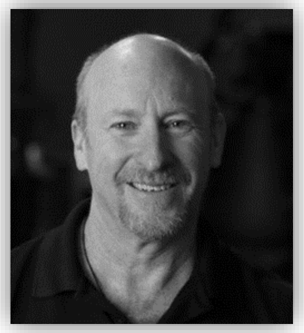
WEBINAR SPEAKERS

Cory Shumaker
Development Specialist
California Hydrogen Business Council

Lynn Harris
Senior Consultant - Sustainable Motive Power & Zero-Emission Technologies
DB Engineering and Consulting USA

Tim Sasseen
Market Development Manager, US
Ballard Power Systems

Carrie Schindler
Director of Transit and Rail
San Bernardino County Transportation Authority



Mike Hart
CEO
Sierra Railroad / Sierra Energy

Momoko Tamaoki
Office Chief, Equipment and Assets
Caltrans

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PROGRAM SPONSORS

BALLARD®

SoCalGas

A Sempra Energy utility®

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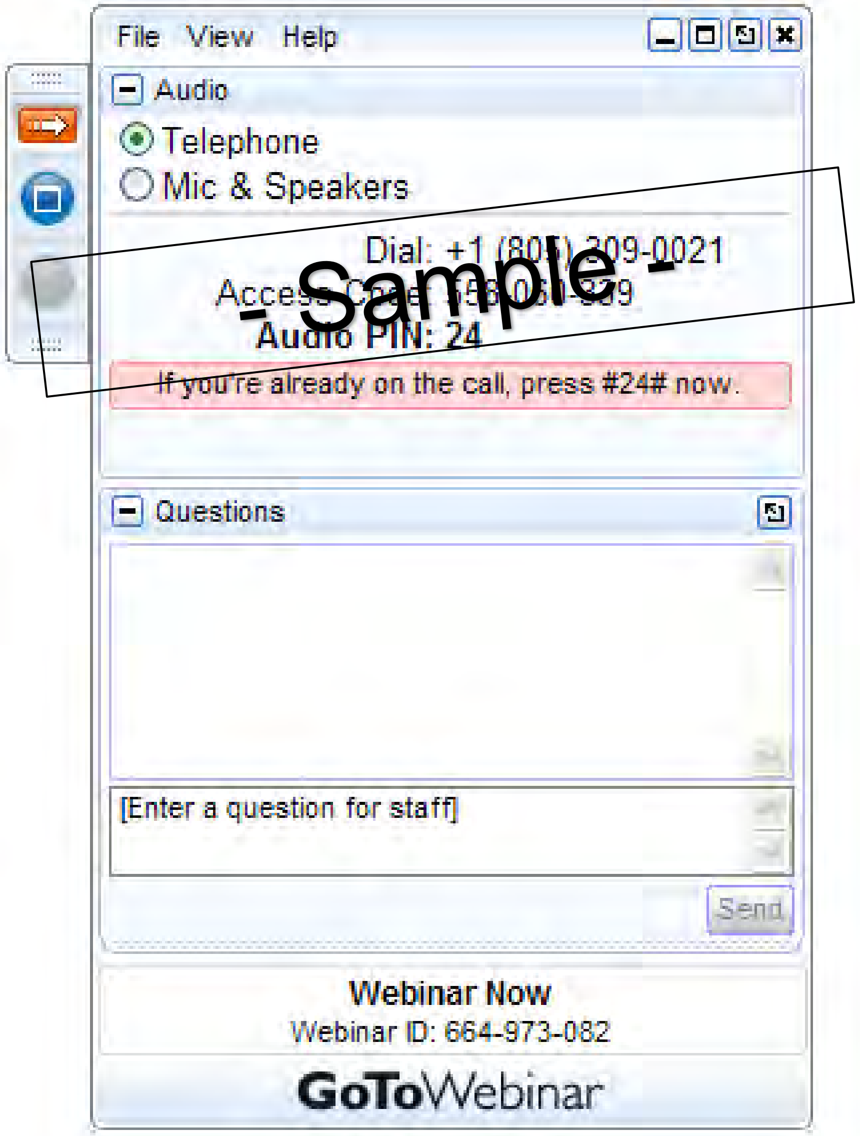
  - Dial-In: Use the Audio Panel (right side of screen) to see dial-in instructions. Call-in separately with your telephone.
- Question & Answers
  - Ask questions using the **Questions Panel** on the right side of your screen.
- Recording & Slides
  - The recording of the webinar and the slides will be available after the event. Registrants will be notified by email.
- Troubleshooting
  - Contact Peter Thompson | pthompson@californiahydrogen.org



ADVOCACY

GOODS MOVEMENT, HEAVY-DUTY TRANSPORT, AND CLEAN PORTS

PUBLIC TRANSPORTATION

ENERGY STORAGE AND RENEWABLE HYDROGEN

CALIFORNIA HYDROGEN BUSINESS COUNCIL

- **Our Vision:**
  - CHBC is committed to advancing the commercialization of hydrogen in the energy and transportation sectors to achieve California's climate, air quality, and decarbonization goals.
- **Our Mission:**
  - Provide clear value to our members and serve as an indispensable and leading voice in promoting the use of hydrogen in the utility and transportation sectors in California and beyond.
- **Our Principals:**
  - Leadership, Integrity, Teamwork and Inclusion.
- **Our Objectives:**
  - Enhance market commercialization through effective advocacy and education of policymakers and policy influencers
  - Be "the" trusted "go to" resource on Hydrogen and Fuel Cell technology for policymakers and policy influencers
  - Accelerate market growth via networking opportunities and information exchange for the industry and its customers

OUR MEMBERS

Platinum

- BALLARD
- BAKER BOTTS
- Bay Area Air Quality Management District
- Cummins
- MITSUBISHI POWER
- Ørsted
- PG&E
- PLUG POWER
- SDGE — A Sempra Energy utility
- SoCalGas — A Sempra Energy utility

Gold

- AC Transit
- Bloomenergy
- CHART — Cooler By Design.
- Dominion Energy
- element MARKETS
- IRD — IRD Fuel Cells LLC
- Linde
- nel
- PARSONS
- POWERTAP HYDROGEN
- NIKOLA
- South Coast AQMD
- Sumitomo Corporation
- SUMITOMO ELECTRIC
- TOYOTA — Let's Go Places
- US Gain

Silver

Innovator

California Performance Engineering Inc

EcoNavitas

MRS Enterprises

Planet Hydrogen

Sheldon Research and Consulting

Starworks

Terrella Energy Systems Ltd.

Versallis Tech Services LLC

Zero Carbon Energy Solutions

VALUE IN MEMBERSHIP

- Active representation in all relevant California policy making venues
- A trusted and knowledgeable industry resource
- Access to policymakers, policy influencers and industry
- Track record of success
- Platform for industry collaboration
- Learn more: www.californiahydrogen.org

BECOME A MEMBER AND MAKE A DIFFERENCE
TOGETHER WE CAN INFLUENCE PUBLIC POLICY AND GROW YOUR BOTTOM LINE

NEXT UP:

Lynn Harris
Senior Consultant - Sustainable Motive Power & Zero-Emission Technologies
DB Engineering and Consulting USA

Hydrogen Business Council

Current Global Landscape of Motivations Behind Hydrogen and Fuel Cells for Rail Applications

Lynn Harris | DB Engineering & Consulting USA Inc. | Lynn.harris@deutschebahn.com | May 19, 2021

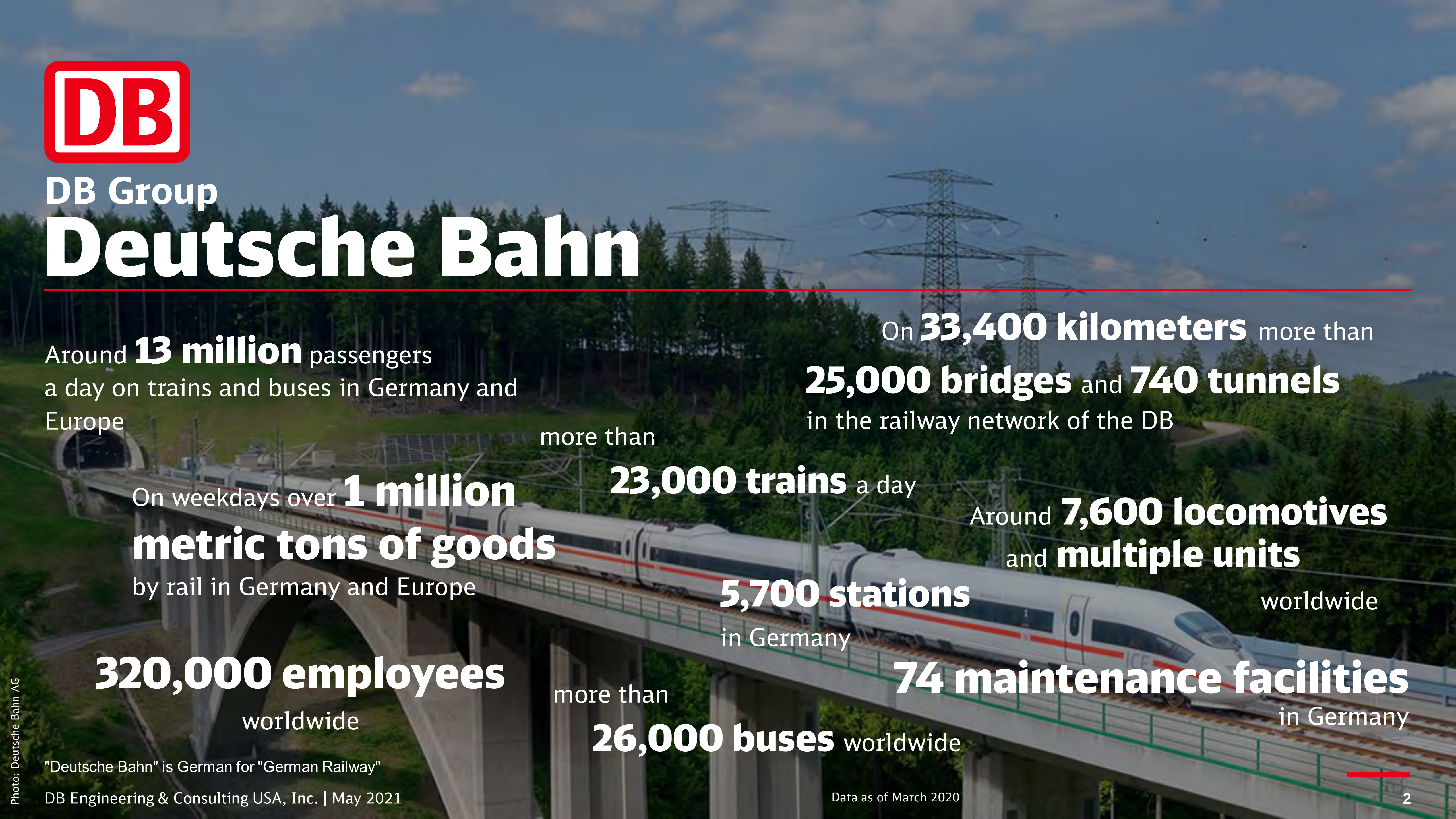


Photo: Deutsche Bahn AG

DB

DB Group

Deutsche Bahn

Around **13 million** passengers a day on trains and buses in Germany and Europe

On **33,400 kilometers** more than **25,000 bridges** and **740 tunnels** in the railway network of the DB

more than **23,000 trains** a day

On weekdays over **1 million metric tons of goods** by rail in Germany and Europe

Around **7,600 locomotives** and **multiple units** worldwide

5,700 stations in Germany

320,000 employees worldwide

more than **26,000 buses** worldwide

74 maintenance facilities in Germany

"Deutsche Bahn" is German for "German Railway"

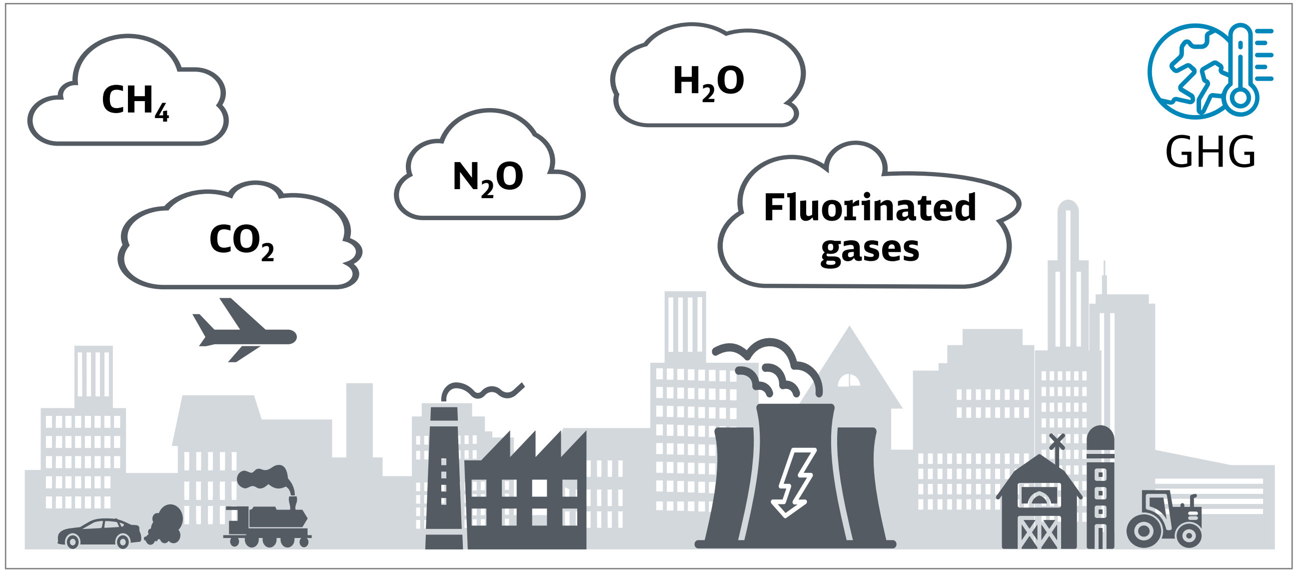
Data as of March 2020

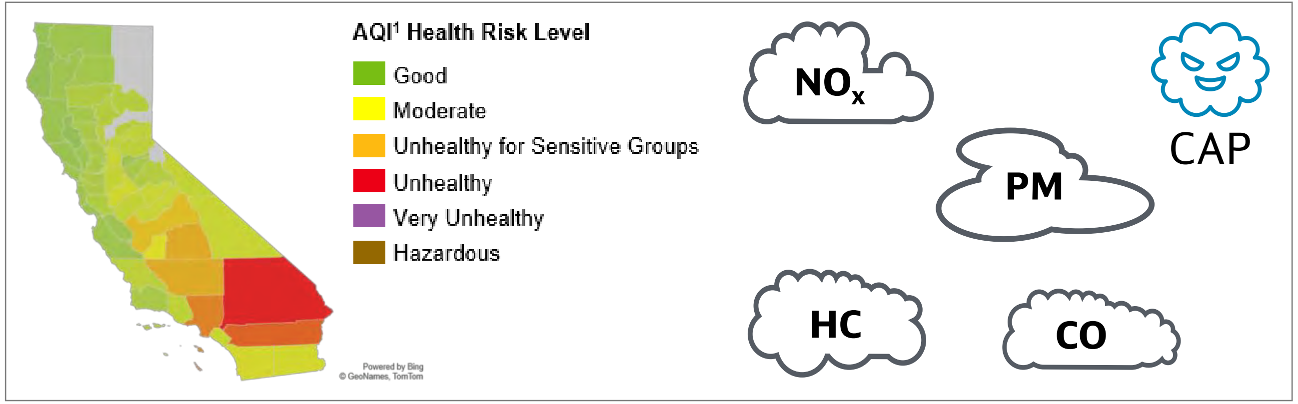
DB Engineering & Consulting USA leverages the expertise of the **world's largest integrated transportation operator,** improving the quality of life in the U.S. by **introducing sustainable mobility solutions**

- Vehicle design, modification and construction
- Techno-economic analysis
- Well to wheel energy and emission assessment
- Concept, implementation and operation
- Sustainable Motive Power & Zero-Emission Technologies
- ZE strategy consulting
- Technology Road Map / Transition Strategies
- Pilot projects / prototyping
- Infrastructure design, modification and construction
- …

Photo: Deutsche Bahn AG

Greenhouse gases (GHG) contribute to climate change and criteria air pollutants (CAP) pose a high risk to people‘s health





Increases:

- allergies
- airborne carcinogens
- lung irritation
- risk of premature death
- …

(1) 90th Percentile AQI1 per county, 2019

History of hydrail

A selection of milestones

Global Hydrail initiative (A)
- First international Hydrail conference, since then annually
- Initiated in the US, events world-wide

BNSF Project(C)
- First hydrail switcher as proof-of-concept
- Locomotive built by Vehicle Projects

CRRC(E)
- First commercial operation of light-rail vehicle /tram

Alstom iLINT(C)
- First commercial regional hydrail multiple unit

NC DOT4(C)
- Hydrail study
- Piedmont passenger: from diesel to hydrail

SBCTA & Stadler(G)
- First commercial hydrail in the US
- Anticipated service in 2024

2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

Vehicle Projects1 mining locomotive(B)
- First hydrail vehicle globally
- Build in the US, demonstrated in Canada

JR East & RTRI2(D)
- Technology demonstration in multiple units/railcars

TIG/m Modern Street Railway(F)
- First commercial operation of hydrail streetcar/tram

5 Commercial mining locomotives(B)
- Built in the US by Vehicle Projects and operated in South Africa

BCRRE3(C)
- First practical hydrail locomotive in Europe

H2goesRail(H)
- Anticipated trial operation in 2024
- Siemens Mireo Plus H

(1) Fuel cell Propulsion Institute, predecessor to Vehicle Projects (2) Railway Technical Research Institute
(3) Birmingham Centre for Railway Research and Education (4) North Carolina Department of Transportation
Illustration Source: (A) Global Hydrail Initiative, (B) Vehicle Projects, (C) Andreas Hoffrichter, (D) RTRI, (E) XinhuaNet, (F) TIG/m, (G) SBCTA, (H) H2goesRail

DB or DB E&C USA team member involvement
DB E&C USA team member emission assessment contributions

Current Worldwide Hydrail Projects

DB

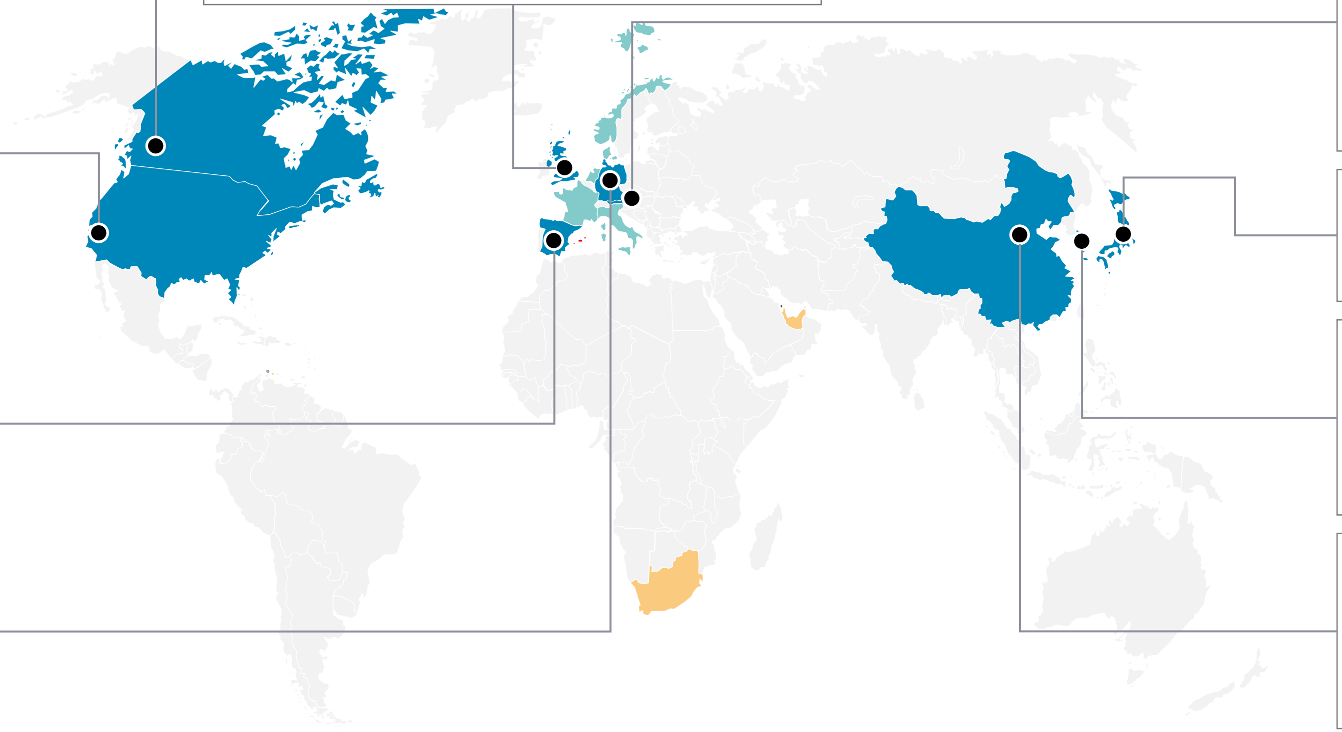
Canada
- Canadian Pacific, AB
- Southern Railway of British Columbia, BC

USA – California
- SBCTA
- TIG/m
- Caltrans
- Sierra Northern

Spain
- Talgo
- X'Trapolis

Germany
- iLINT[1]
- H2goesRail, Siemens & DB

United Kingdom
- HydroFlex, BCRRE & Porterbrook
- Breeze, Alstom & Eversholt
- Vivarail



Austria
- iLINT
- HyTrain
- Switcher

Japan
- JR East, Hitachi & Toyota

South Korea
- KRRI[2] & Hyundai
- KRRI mainline locomotive

China
- CRRC tram
- CRRC Switcher

Multiple unit | Freight

Hydrail projects | Planned iLINT procurement | Streetcar (Aruba, Qatar, Dubai or mining locomotives (SA)

Source: DB research, as of Spring 2021
(1) Alstom Coradia iLINT 2-car multiple unit in commercial operation in 2018
(2) Korea Railroad Research Institute

California is the leader in hydrail efforts in North America with three large ongoing projects

CA regulations

- Off-road vehicles, including rail, are required to be ZE[1] by 2035 according to EO N-79-20
- CARB proposes a spending account for rail emission
- Overall CA targets to reduce GHG by 80%[2] by 2050, carbon neutral by 2045
- Significant hydrogen efforts for other transportation modes and power generation in CA

On going hydrail projects in CA:

- Caltrans plans to transition their fleet to hydrail
- San Bernardino County Transportation Authority (SBCTA) has ordered the first commercial hydrail vehicle in the country
- Sierra Northern Railway is rebuilding a switcher to hydrogen power

Three Projects in California

(1) zero-emission
(2) compared to 1990 levels

THANK YOU!

If you have any questions, please feel free to reach out.

Lynn Harris

Sr. Consultant, Sustainable Motive Power & Zero-Emission Technologies

Lynn.Harris@deutschebahn.com

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LinkedIn:
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Website:
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NEXT UP:

Tim Sasseen

Market Development Manager, US

Ballard Power Systems

BALLARD

Fuel Cell Innovators for Over 40 Years

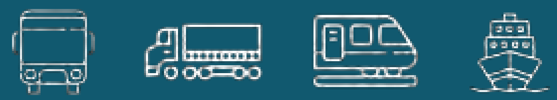
An introduction to Ballard and our unique value proposition

BALLARD

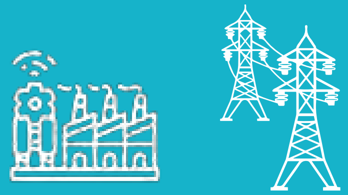
Global decarbonization is putting the focus on hydrogen

The fight against climate change and air pollution is driving the demand for fuel cell technology that converts hydrogen in clean electricity

Hydrogen is a flexible energy carrier and fuel:



in cars, trucks, buses, trains and ships



in industry and for critical infrastructure

BALLARD

Hydrogen powered trains are poised to disrupt the rail industry

The environmental gains of electrification with performance and refueling time comparable to diesel

Long range and route flexibility

Short refueling time

Cost effective route electrification

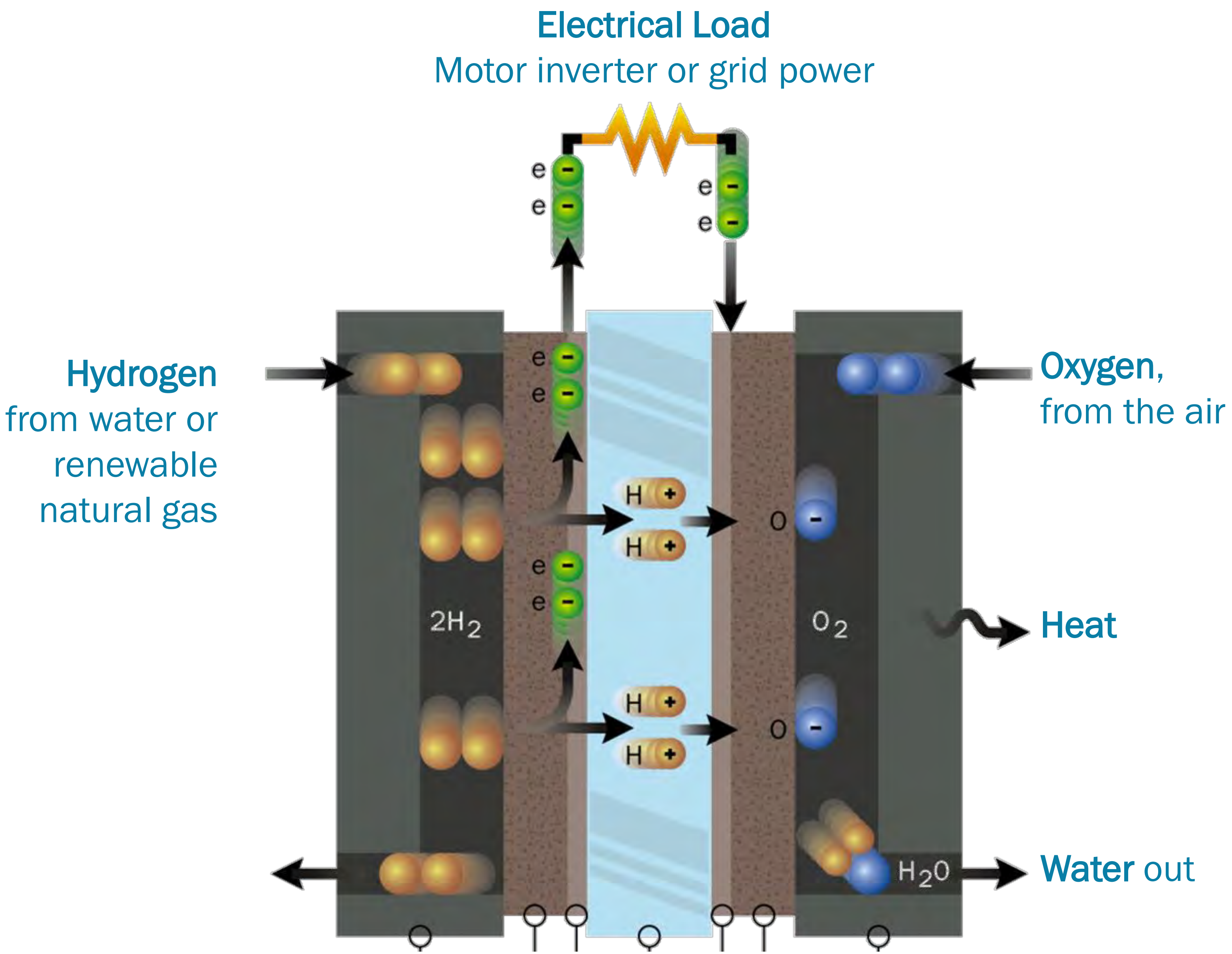
BALLARD

Nearly any train route served by diesel trains can be served by a hydrail train

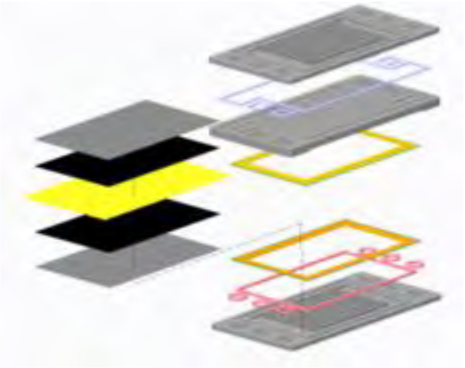
- Suitable applications include multiple units for regional passenger service and locomotives for shunting or freight.
- No requirement for overhead catenary infrastructure and power substations
- Enables gradual electrification (one train at the time) aligned with budget availability

BALLARD

A fuel cell acts like a battery cell, but you feed it hydrogen instead of charging



We continuously invest in our technology and product development



Unit cell components

MEA, bipolar plates

Fuel cell stacks

14th generation

Fuel cell modules

8th generation

Fuel cell vehicle integration

application engineering/ after sales service

Humidified and pressurized system

Freeze-start from -25 °C

IP67 protection

>30,000 hours life time

Case Study: Foshan Gaoming Modern Hydrogen Tram Line

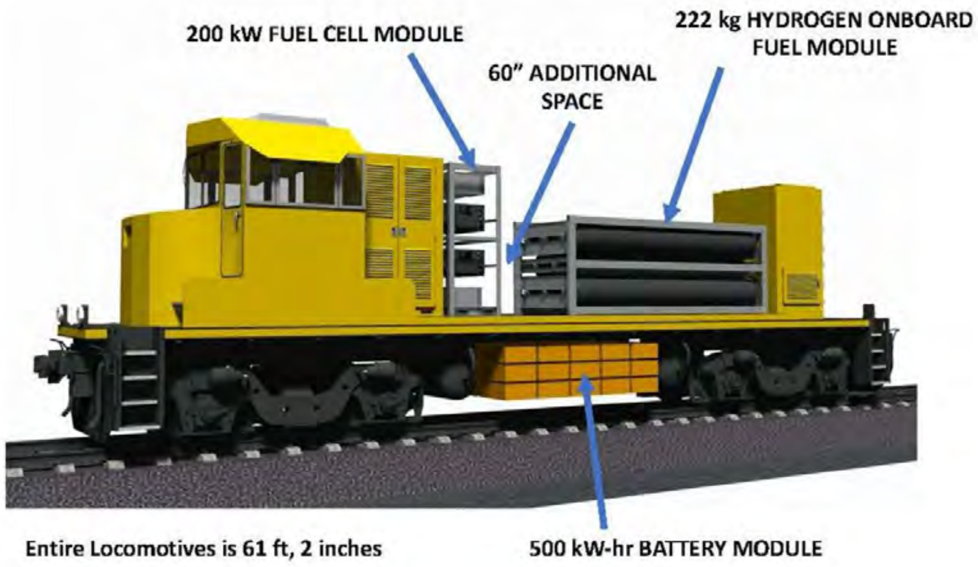
- Agreement with CRRC Sifang to develop 5 fuel cell trams
- Each roof top mounted system is powered by two FCveloCity®-XD fuel cell modules
  - Robust design is weight and noised optimized, with easy service access and built-in fire suppression systems
- Six onboard hydrogen cylinders provide a range of 125 kilometers between refueling
- Maximum speed of 70 kilometers/hour
- Tram line began service in December 2019
  - Has operated >7,400 hours and>73,000 kilometers as of Aug 2020

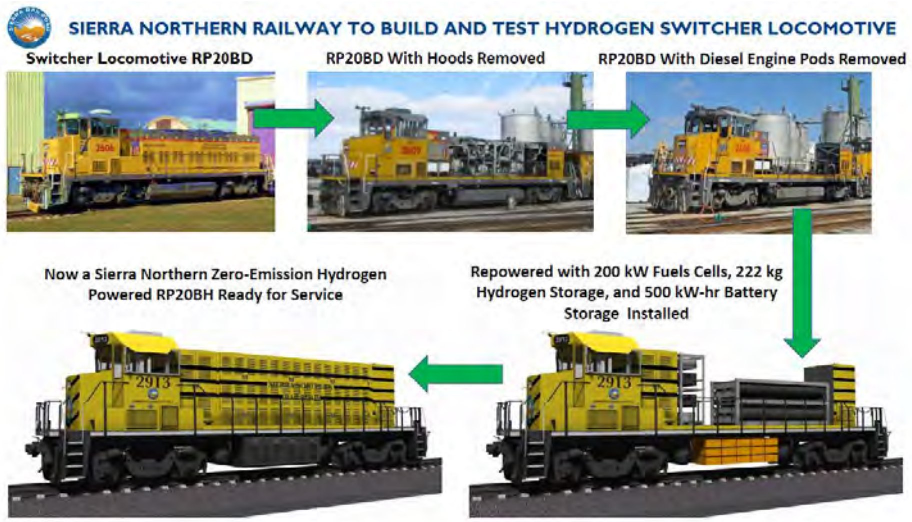
Case Study: Siemens Rail Module Development

- Multi year agreement to develop a fuel cell system for Siemens Mireo® regional commuter train
- Roof top mounted system that leverages Ballard's FCmove™ module with optimized weight and footprint for maximum range
- Prototype module expected to be delivered in September 2021
- Achievements:
    - Freeze start from -25°C
    - Peak efficiency >55%
    - Peak power >200 kW
    - Incorporates rail standards
    - Incorporates Ballard's long life FCgen®-LCS fuel cell stack technology and advanced balance of plant
- Siemens is offering Mireo® fuel cell powered trains to customers

Case Study: Sierra Northern Rail Switching Locomotive

- Sierra Northern Rail will build and deploy a hydrogen-powered switching locomotive, working with Railpower Tech, Optifuel and Ballard
- The fuel cells will work with battery technology to power the locomotive's electric traction motors
- Two 100-kilowatt fuel cell modules will deliver 200kW of electricity to power the locomotive
- Switching locomotives have been identified as the largest contributors to emissions in rail by CARB





Case Study: CP Hydrogen Locomotive Program

- CP will develop North America's first hydrogen-powered line-haul freight locomotive by retrofitting a formerly diesel-powered locomotive with Ballard hydrogen fuel cells
- The fuel cells will work with battery technology to power the locomotive's electric traction motors
- Six 200-kilowatt fuel cell modules will deliver 1.2 MW of electricity to power the locomotive
- Nearly the entire freight locomotive fleet of all railway operators in North America consists of diesel-powered units, representing the industry's most significant source of greenhouse gas emissions

BALLARD

Buses powered by Ballard

- Over 1,000+ buses deployed are powered by Ballard
- Multiple bus platforms with OEMs in Europe, US and China
- Over 25 million kilometers in service
- > 30,000 hours fuel cell stack life demonstrated

BALLARD

Trucks
powered by Ballard

- Over 2,200 urban delivery trucks (3 to 9 tons) in service in China
- Class 8 demonstration truck at Port of Long Beach
- UPS class 7 trucks for California
- 60t truck demonstration project – Alberta
- Refuse trucks in Europe
- Mining trucks in China and South Africa

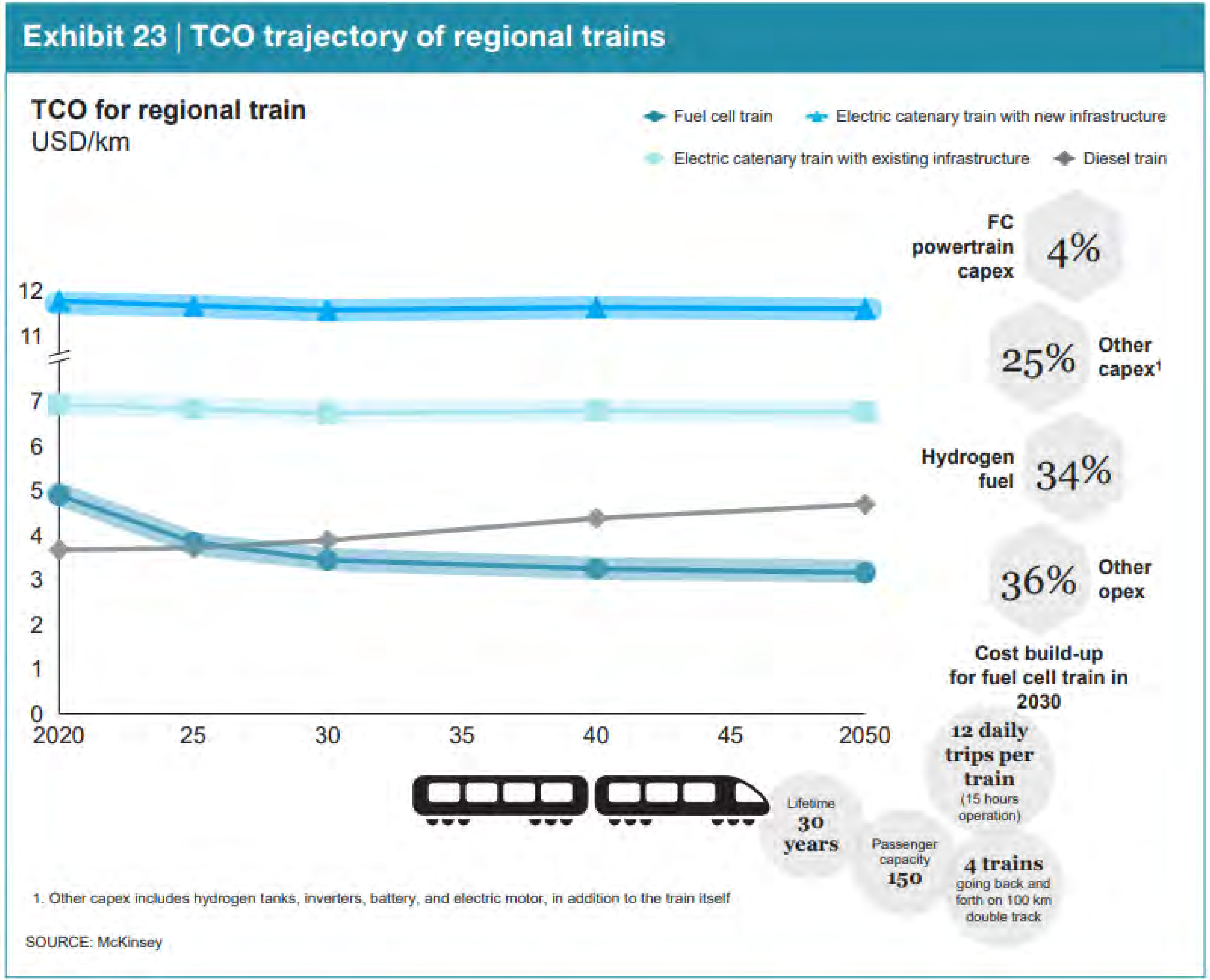
Ballard Marine Projects in Europe

- Megawatt scale systems for cruise ships with ABB
- HySeas III, the world's first sea-going renewables-powered ferry
- Hjelmeland ferry in Norway
- FLAGSHIPS project to power:
    - Norled ferry in Norway
    - River barge in France (ABB)
- ELEKTRA fuel cell river barges in Germany

Cost effective route electrification

"The hydrogen train is already more competitive than electric catenary for a use case with relatively long distance and low frequency."

Hydrogen Council, 2020



BALLARD

Ballard by the Numbers

42 YEARS

900 employees

1,400 patents & applications

26 years Nasdaq
28 years TSX
publicly listed Company

WEICHAI
AngloAmerican
NISSHINBO
大洋电机 BROAD-OCEAN
4 strategic shareholders

1,000+ transit buses

2,200+ trucks

5 TRAIN projects on track

6 SHIPS in development

HIGH-POWER DENSITY stack development program

850 MW fuel cell products delivered

>6.5million MEAs produced

>75million kilometers in operation

>35,000hours operation of fuel cell stack in London buses

2030 commitment to carbon neutrality

BALLARD

FCmove™
8th generation fuel cell power module

35%
reduction in
total life cycle cost

>30,000 hr
operating lifetime

fuel cell stack
is recyclable

50%
reduction in
number of components

-25°C
freeze start
capability

40%
reduction in
product volume

35%
reduction in
product weight

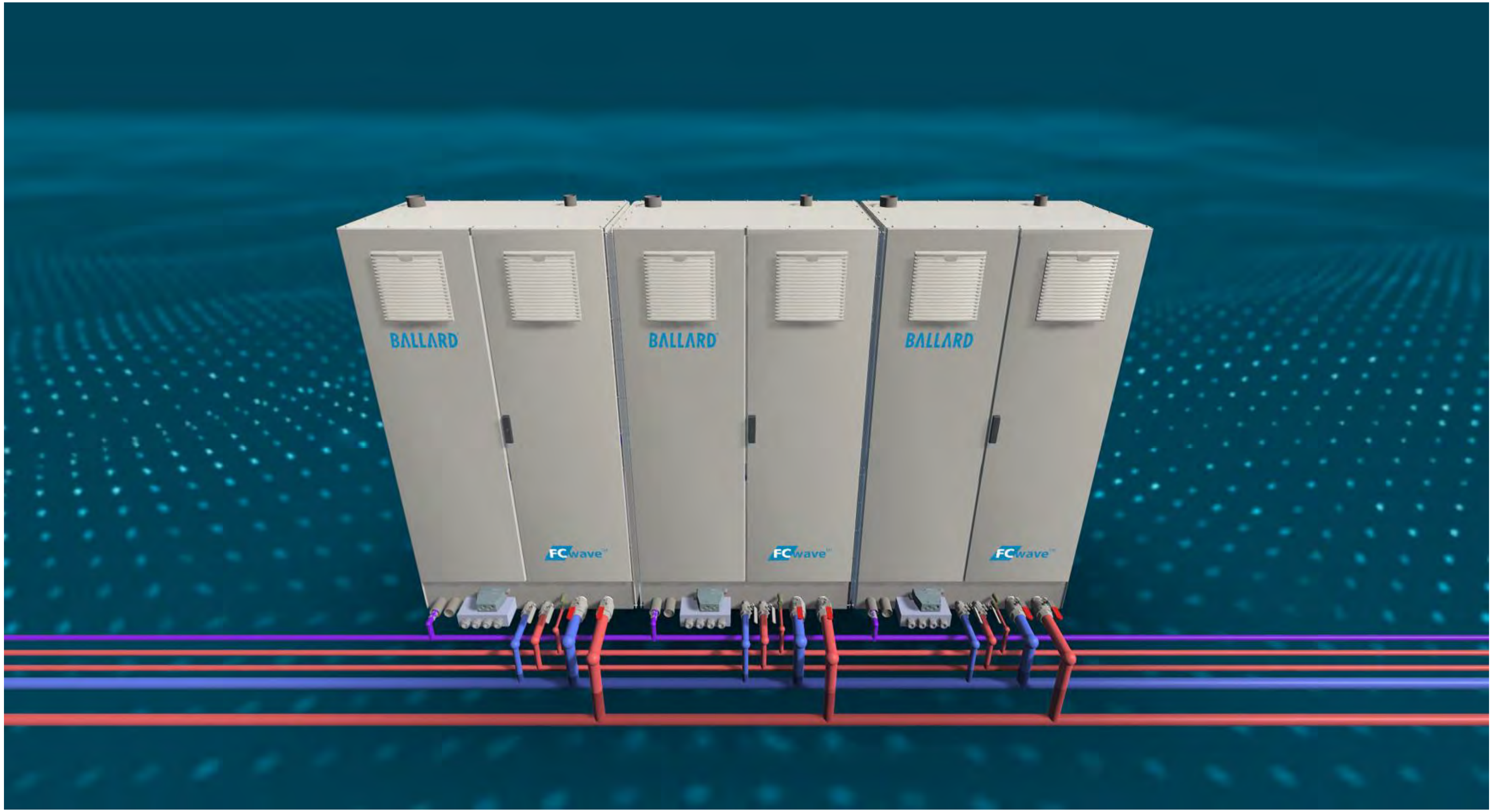
BALLARD

Introducing

FCwave™

The future of zero-emission marine vessels

FCwave™ Modular Installation Layout



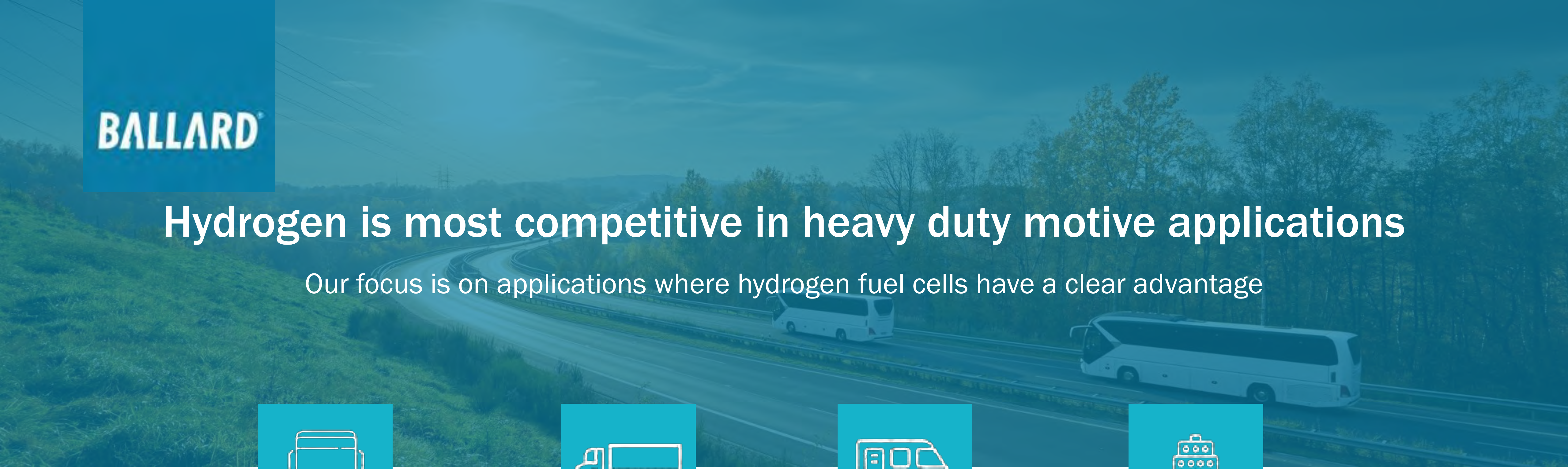
Thank you

Please contact Ballard for more information

Tim.Sasseen@ballard.com

www.ballard.com

Power to Change the World®



Hydrogen is most competitive in heavy duty motive applications

Our focus is on applications where hydrogen fuel cells have a clear advantage

Buses & Coaches

Trucks

Trains

Vessels

Fuel cell technology is needed to decarbonize the heavy duty transportation sector

BALLARD

Addressing the cost reduction challenge:

Ballard's road map to 70% cost reduction

Strategic industrial partnerships

will accelerate fuel cell industrialization and integration

Supply chain

partnership with Mahle will increase access to the automotive supply chain

Ballard’s cost reduction initiatives

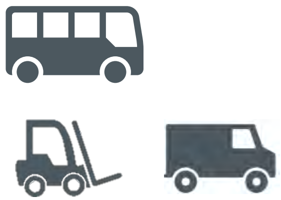
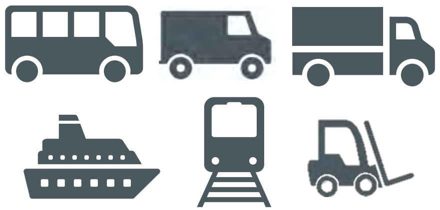
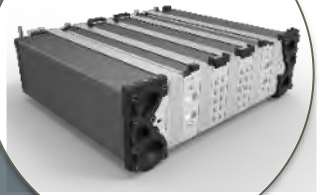
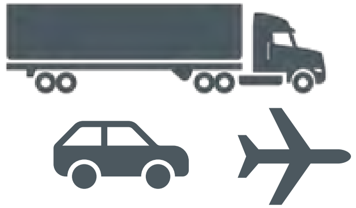
include 6x increase in manufacturing capabilities through continuous manufacturing automation

Recycling/refurbishments

will increase lifecycle and improve FCEV residual value

BALLARD

Today we have three platforms of liquid cooled stacks to address mobility applications

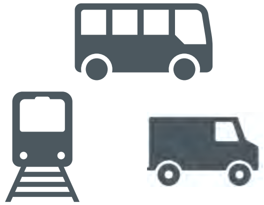
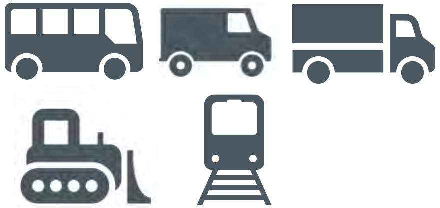
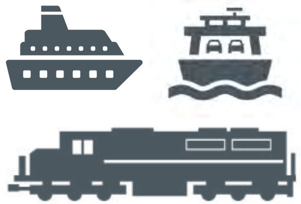
		Power Level	Features	Applications
	FCvelocity®-9SSL	up to 29kW/stack Mobility Stack	▪ >10,000 stacks produced ▪ 15,000hrs ▪ 2.2kW/L* ▪ Operating 70ºC	
	FCgen®-LCS-M	up to 96kW/stack Heavy-Duty Stack	▪ >25,000hrs ▪ 4.5kW/L*(M2) ▪ Freeze start (-30ºC) ▪ Operating 80ºC	
	FCgen®-HPS	Up to 140 kW/stack High Power Stack	▪ Stack technology demonstration platform ▪ 4.3kW/L* ▪ Freeze start (-28ºC) ▪ Operating >90ºC	

* Power density excluding compression hardware

HyZET Hydrogen -Powered Tug Design Study

- CEC funded project with Ballard, ABB, DNV-GL, Crowley/Jensen, Chart Industries
- 90’ Tug with 5MW propulsion, 1.2MW fuel cell + 800kWh battery
- Liquid hydrogen fuel
- Design to assess optimal drive configuration, leading to a ready-for-manufacture design

Ballard's current fuel cell module offering for HD mobility

		Power Level	Features	Applications
	FCveloCity®	30, 85 & 100kW Legacy Mobility Platform (7th generation)	▪ >1,500 modules produced ▪ 15,000hrs ▪ IP 55 ▪ Air and cooling kits	
	FCmove™	70 & 100 kW HD Mobility Engines (8th generation)	▪ >25,000hrs ▪ Freeze start (-25 °C) ▪ Engine bay and roof top ▪ IP6K9K	
	FCwave™	200kW HD Power System Marine & Rail	▪ >25,000hrs ▪ Marine certified ▪ Cabinet configuration ▪ Stand alone or containerized ▪ Multiple modules to MWs	

BALLARD

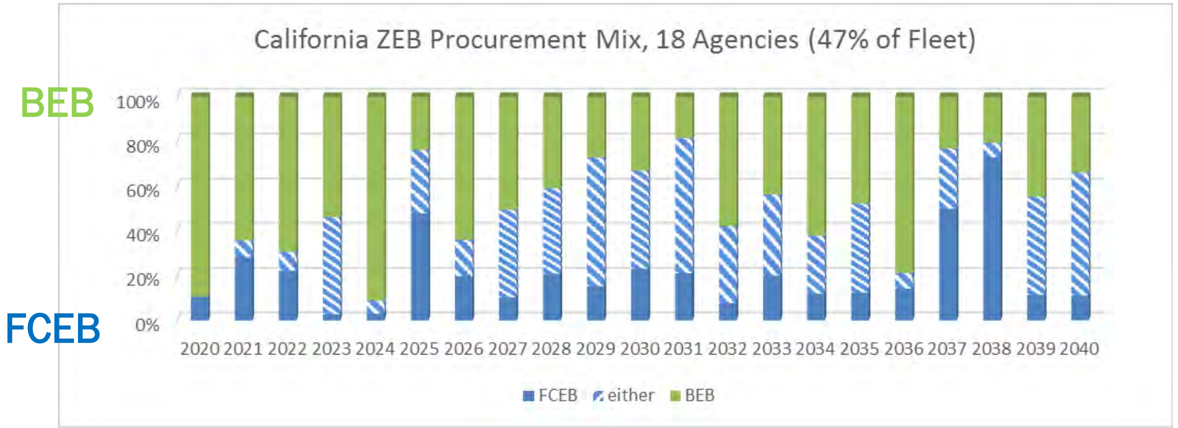
As Result of ICT Planning, there is Growing Demand for FCEBs

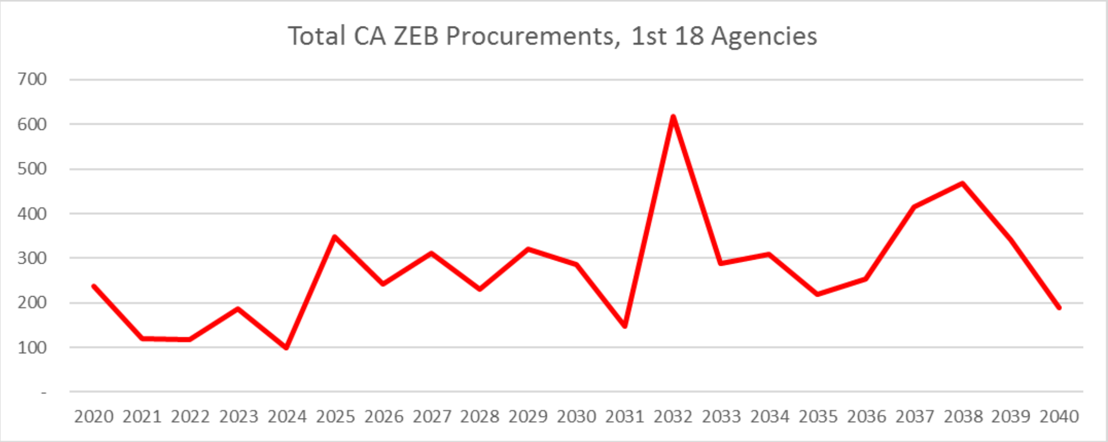
First 18 ICT plans approved by CA transit agencies as of Jan 2021 shows that:

- 24% of all ZEBs deployed will be fuel cell electric buses
- 46% will be battery electric
- 30% will be decided by performance

This represents an opportunity for 2,800 to 6,500 fuel cell electric buses in service, or 71 to 163 tons per day of renewable hydrogen consumption

Data collected from CARB published ICT roll out plans

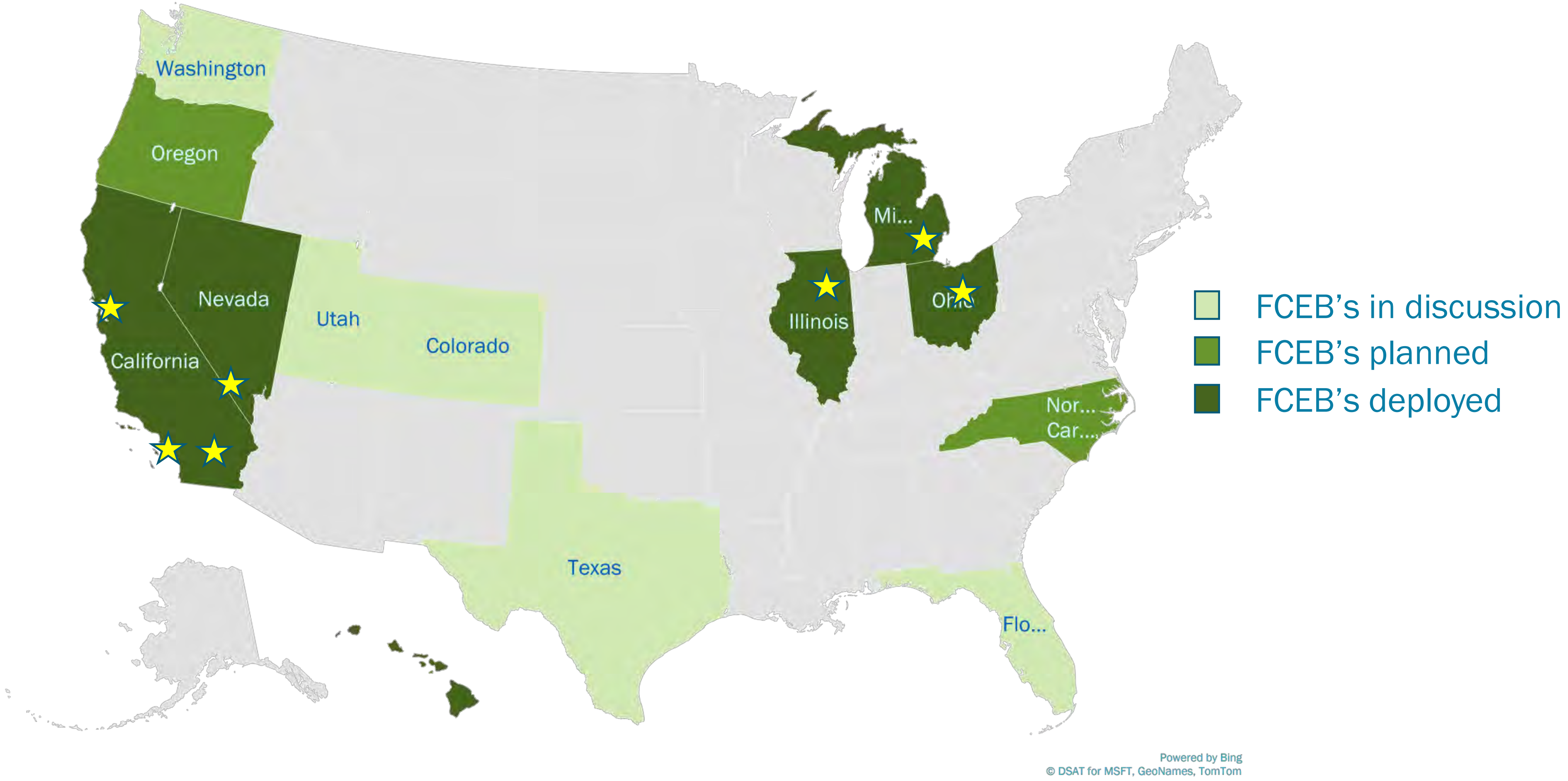




Trains
powered by Ballard

- Light rail systems in China
  - with OEM partner CRRC (Goaming, China)
  - light rail in passenger service since January 2020
- Development project underway with Siemens for hydrogen EMU (MIREO)
- Hydroflex retrofit project in UK with EMU – Porterbrook
- Scottish Rail project UK – EMU retrofit
- North America’s first hydrogen-powered line-haul freight locomotive
- Sierra Northern Railway switching locomotive

Fuel Cell Electric Buses are Spreading Across US



BALLARD

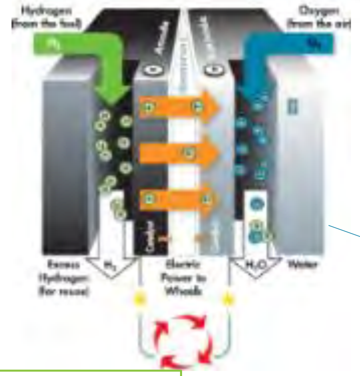
Fuel cell system
generates power onboard the bus

Fuel cell power modules provide 30kW - 100kW of DC power for the transit bus powertrain

Generate electricity from air and hydrogen to recharge batteries and power the electric drive

Ballard has produced over 1,500 power modules for buses and trucks

Hydrogen gas storage
(Typical energy capacity 1250kWh)



Fuel Cell
Solid state DC power generator
Fuel = air and hydrogen

Fuel cell power module

BALLARD

Fuel Cell Module
Multiple fuel cells, with air/fuel/power handling and control

A fuel cell acts like a battery cell, but you feed it hydrogen instead of charging

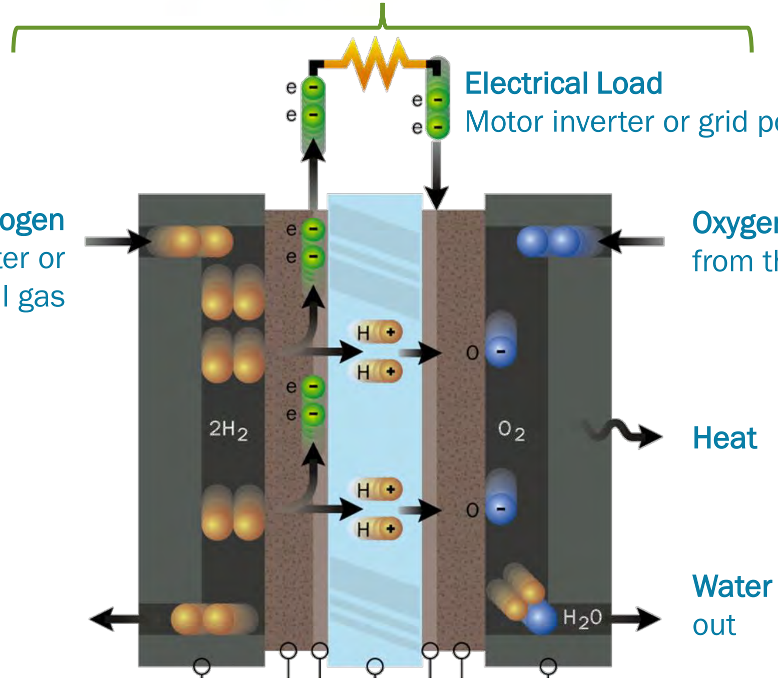
Each **fuel cell power module** provides **30kW - 200kW** of DC power for the powertrain

Generates **electricity from air and hydrogen to recharge batteries** and **power the electric drive**

Ballard has produced over **1,500 power modules** for buses and trucks

Electrical Load
Motor inverter or grid power

Hydrogen
from water or renewable natural gas



Oxygen,
from the air

Heat

Water
out

Fuel Cell

NEXT UP:

Carrie Schindler
Director of Transit and Rail
San Bernardino County Transportation Authority

NEXT UP:

Carrie Schindler
Director of Transit and Rail
San Bernardino County Transportation

PLAN. BUILD. MOVE.

sb cta

San Bernardino County Transportation Authority

Carrie Schindler, PE
Director of Transit & Rail

Diesel Multiple Unit

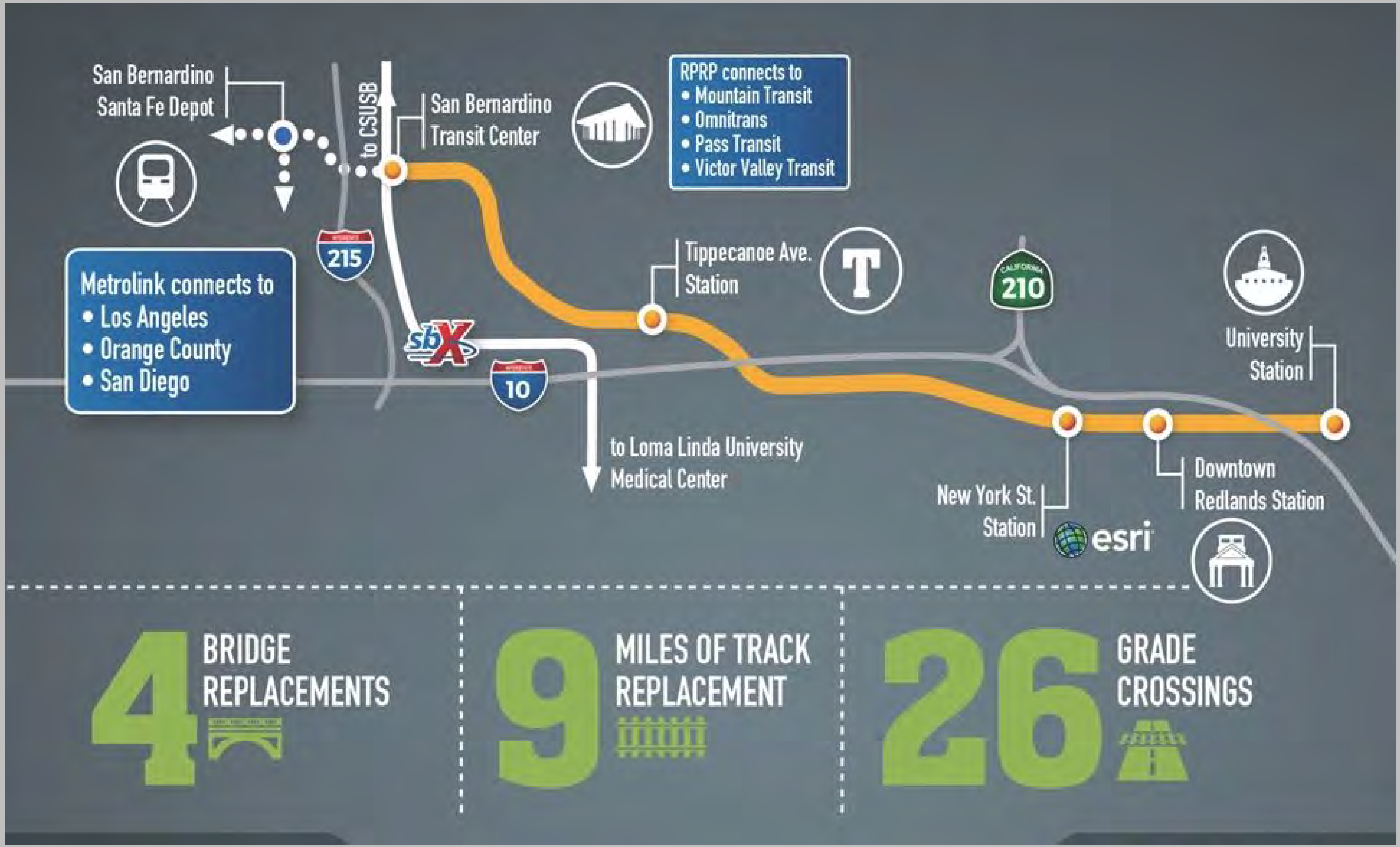
DMU

Zero-Emission Multiple Unit

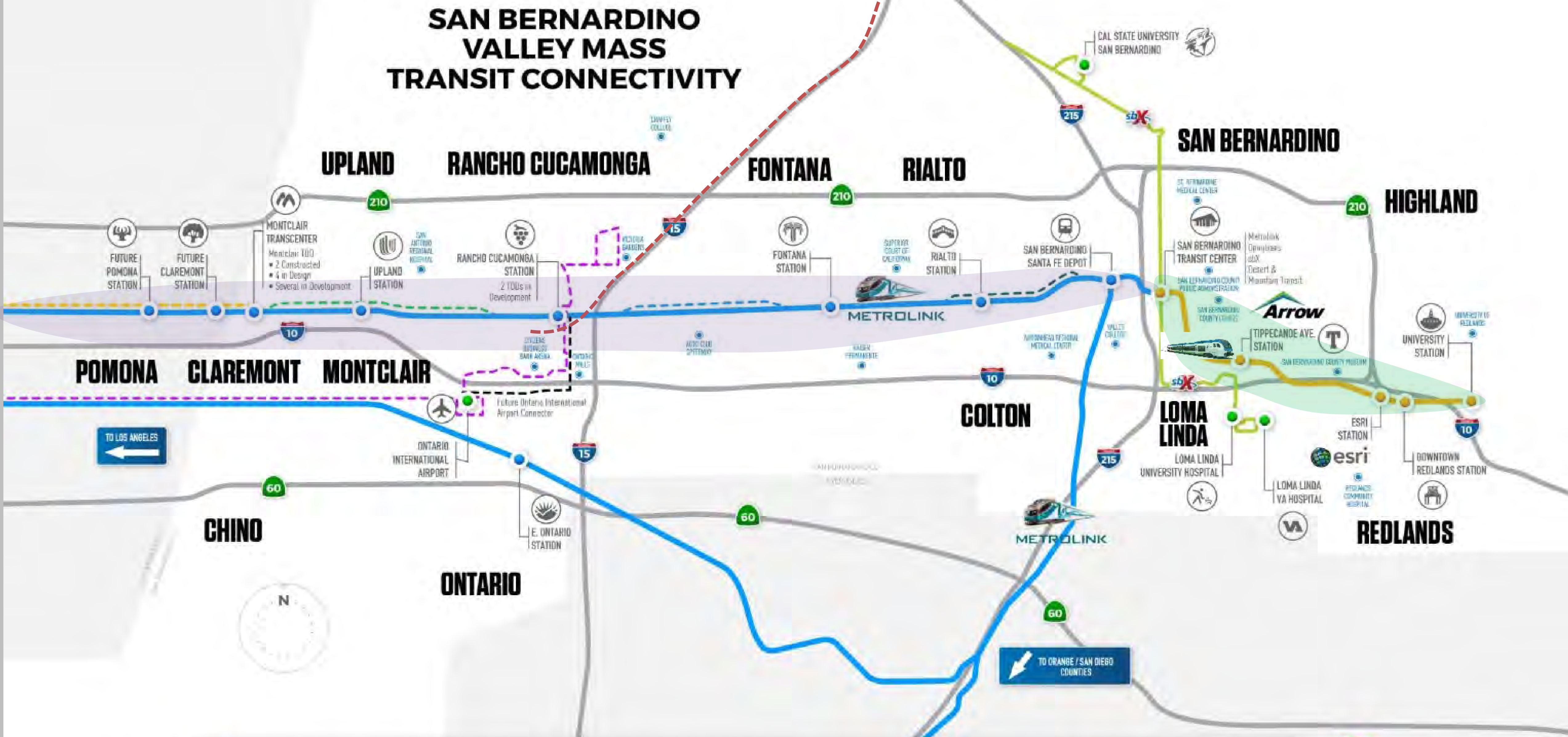
ZEMU

Arrow

Redlands Passenger Rail / Arrow



SAN BERNARDINO VALLEY MASS TRANSIT CONNECTIVITY



LEGEND

- Redlands Passenger Rail (Future Arrow Service)
- Metrolink
- sbX Bus Rapid Transit
- **TOD** Transit Oriented Development
- Ontario International Airport Connector (Future)
- Gold Line (Future)
- Omnitrans West Valley Connector – Phase I
- Central to Archibald Double Track (Future)
- Rancho to Lilac Double Track (Future)
- Fontana to Rancho Cucamonga Double Track (Future)

Funding Agency
California State Transportation Agency

Railroad of Record
Southern California Regional Rail Authority

Regulatory Agency
Federal Railroad Administration

Development Partner
U.S. Department of Energy

Regulatory Agency
South Coast Air Quality Management District

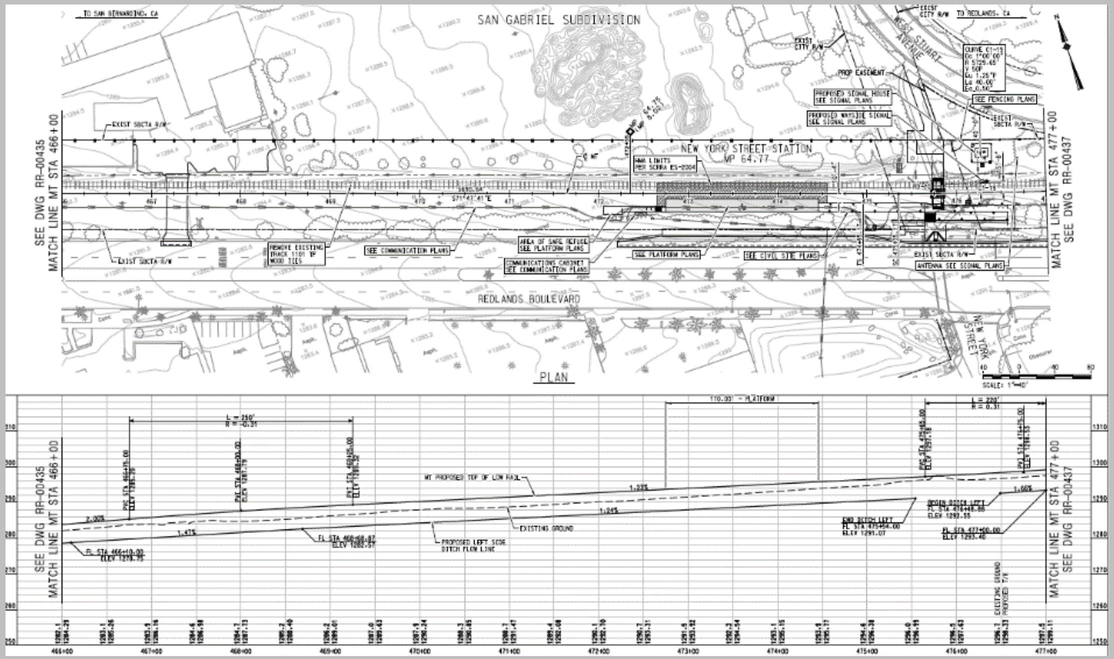
Performance and Energy Usage Modeling

Primary inputs

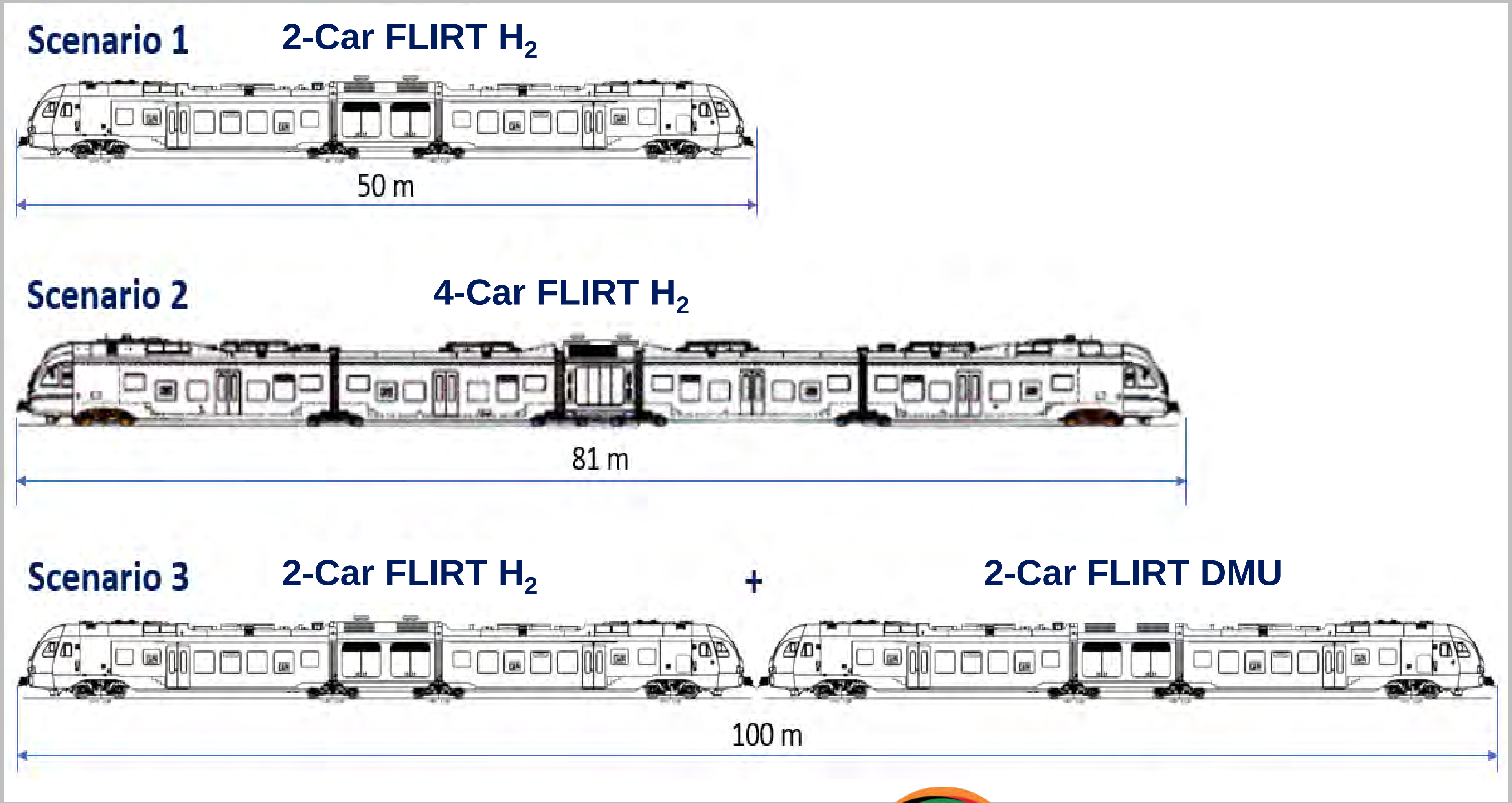
- Vehicle characteristics (mass, loading condition, tractive & braking curves, rotating inertia, electrical efficiencies and auxiliary loads)
- Track characteristics (distances, grades, curves, speed limits and restrictions)

Applications

- Quantify key requirements – power charge/discharge rates and energy storage capacity
- Assess technology feasibility



Energy Usage & Modeling Scenarios



Journey (Round Trip)	Section Length (Miles)	Energy Between Terminals					
		Scenario 1 2-Car ZEMU		Scenario 2 4-Car ZEMU		Scenario 3 2-Car + 2-Car	
		No Regen. Braking (kWh)	With Regen. Braking (kWh)	No Regen. Braking (kWh)	With Regen. Braking (kWh)	No Regen. Braking (kWh)	With Regen. Braking (kWh)
Redlands - SBTC	17.8	236	173	338	254	339	216
SBTC - LA	115.2	1492	1169	1916	1497	2083	1579
Redlands – LA	**133.0**	**1728**	**1342**	**2254**	**1750**	**2422**	**1794**

Selection of Preferred Technology

Cost (20%)	Capital, Operations & Maintenance
Infrastructure (10%)	Right-of-Way, Charging & Fueling, Utilities
Environmental (15%)	Land use, GHGs, Aesthetics, Noise, Socio-Economic
Operations (25%)	Range, Scalability, Reliability, Operations, Life Span
Regulatory Compliance (10%)	FRA , NFPA, CPUC
Implementation Schedule (10%)	Timeline for Planning, Design, Construction phases
Risk Analysis (10%)	Identify and document risks for further analysis

High Level Pre-Screening

Category	Baseline – Arrow DMU	Wayside Power Supply		On-Board Energy Storage System					Hybrid System			
Rail Technology	Diesel	Overhead Contact System (OCS)	Ground Level Power Supply – Third Rail	Battery	Supercapacitor	Hydrogen Fuel Cell	Biofuel	Natural Gas	Hydrogen Fuel Cell + Battery	Diesel + Battery	Biofuel + Battery	Natural Gas + Battery
Relative Capital Costs	Good	Poor	Poor	Moderate	Moderate	Moderate/ Poor	Good	Good/ Moderate	Moderate/ Poor	Good	Good/ Moderate	Moderate
Relation Life Cycle Cost	Moderate/ Poor	Good/ Moderate	Good/ Moderate	Moderate	Good/ Moderate	Moderate	Moderate/ Poor	Good/ Moderate	Moderate	Moderate	Moderate	Moderate
GHG Emissions	Poor	Good	Good	Good	Good	Good	Moderate/ Poor	Moderate	Good	Poor	Moderate	Good/ Moderate
Aesthetics	Good	Poor	Moderate	Good	Good	Good	Good	Good	Good	Good	Good	Good
Range	Good	Good	Good	Moderate	Poor	Good	Good	Good	Good	Good	Good	Good
Scalability	Good	Poor	Poor	Moderate	Moderate	Good	Good	Good	Good	Good	Good	Good
Life Span	Good	Good	Good	Poor	Moderate	Moderate	Good	Good	Moderate	Moderate	Moderate	Moderate
Regulatory Compliance	Good	Moderate	Poor	Moderate	Moderate	Moderate	Good	Moderate	Moderate	Moderate/ Good	Moderate/ Good	Moderate
Result	Baseline	Incompatible	Incompatible	Compatible	Compatible	Compatible	Incompatible	Incompatible	Compatible	Incompatible	Incompatible	Incompatible

2-Car Vehicle Characteristics

Powertrain Configuratio n	HFC Hybrid
Mass (tonnes)	132
Max. Power at Wheels (kW)	700
Powerplant Power (kW)	300
Average Duty Cycle Powerplant Efficiency (%)	49
Battery Power (kW)	828
Battery Capacity (kWh)	138
Battery Charging Efficiency (%)	86

Mass & Volume of Powertrain Types for 16 hour Service Day

Powertrain Type	HFC Hybrid
Fuel Cell System	
Power (kW)	300
Mass (kg)	825
Volume (m^3)	1.5
Hydrogen Tanks	
Pressure (bar)	350
Hydrogen stored (kg)	220
Mass of tanks and hydrogen (kg)	3,150
Volume (m^3)	16.5
Battery System	
Mass (kg)	4,000
Volume (m^3)	4
Total	
Mass (kg)	7,975
Volume (m^3)	22

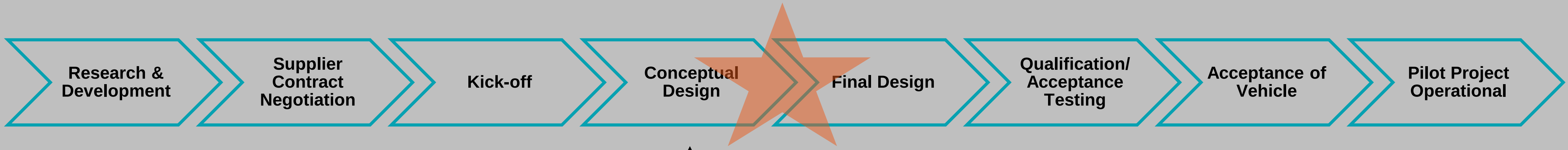
- Runtime performance will be equivalent to the DMU
- Required hydrogen storage and powertrain components could be installed on 2-car vehicle with potentially only daily refueling

	BATTERY		HYDROGEN FUEL CELL HYBRID			
	TRACTION POWER SUBSTATION (TPSS)	WAYSIDE ENERGY STORAGE SYSTEM (WESS)	HYDROGEN DELIVERY	ON-SITE STEAM METHANE REFORMING	ON-SITE ELECTROLYSIS	
CAPITAL COST (TO PURCHASE ONE NEW ZEMU VEHICLE)	$29 M	$31 M	$33 M	$33.8 M	$34.6 M	
ANNUAL O&M COST (TO OPERATE FULL ZEMU ARROW SERVICE 2 VEHICLES)	$769 K	$690 K	$1.2 M	$540 K	$856 K	
EMISSIONS REDUCTION (PERCENTAGE IN COMPARISON TO DMU BENCHMARK)*	60% ↓ 75% ↓ 98% ↓ 97% ↓ 93% ↓ 90% ↓	57% ↓ 100% ↓ 100% ↓ 100% ↓ 100% ↓ 100% ↓	.45% ↓ 25% ↓ 96% ↓ 93% ↓ 90% ↓ 82% ↓	21% ↓ 37% ↓ 96% ↓ 95% ↓ 95% ↓ 79% ↓	-24% ↑ 25% ↓ 95% ↓ 89% ↓ 79% ↓ 71% ↓	55% ↓ 100% ↓ 100% ↓ 100% ↓ 100% ↓ 100% ↓
	CA GRID MIX	IF 100% RENEWABLE			CA GRID MIX	IF 100% RENEWABLE

*EMISSIONS LEGEND

Energy · GHGs · NOx · PM2.5 · PM10 · CO

June 2019



Initiate a regular communication plan with FRA

Technical discussions with FRA

Key FRA elements

- Crashworthiness
- Fire safety
- Inspection
- Vehicle Maintenance
- Record keeping

Key areas of research needs:

- Life cycle costs as compared to other alternative fuels
- Hydrogen storage – ways to increase capacity and flexibility
- Cost reduction regarding renewable hydrogen
- Maintenance facility design – best practices for building facilities of the future
- Component durability and impact resistance (e.g. FRA testing of an LNG tender car)

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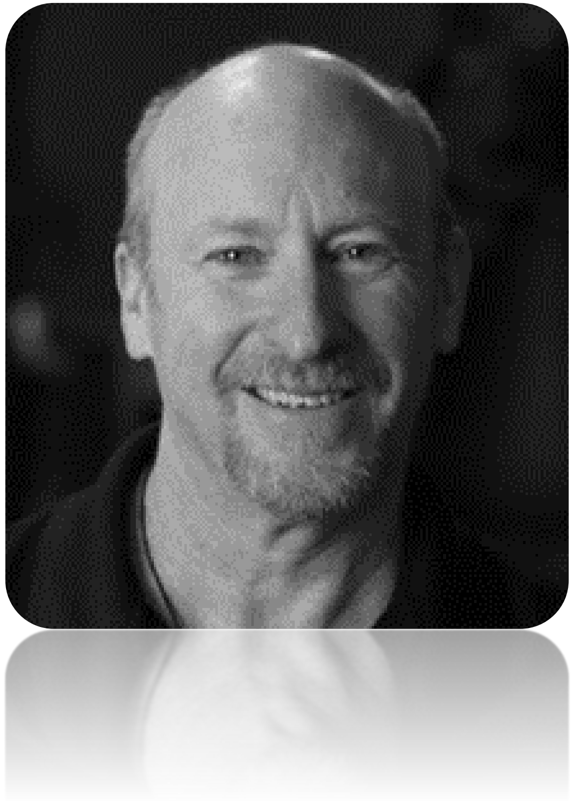


Mike Hart
CEO
Sierra Railroad / Sierra Energy

Advancing Hydrogen Rail in California

Sierra Northern Railway and California Rail

- Sierra Northern Railway (SNR) operates 160+ miles of track in California and owns 37 switcher locomotives
- There are 260 Switcher locomotives operating in California
- More than 500 long-haul locomotives operate in the State

Map of California Rail Lines

Source: CA.gov

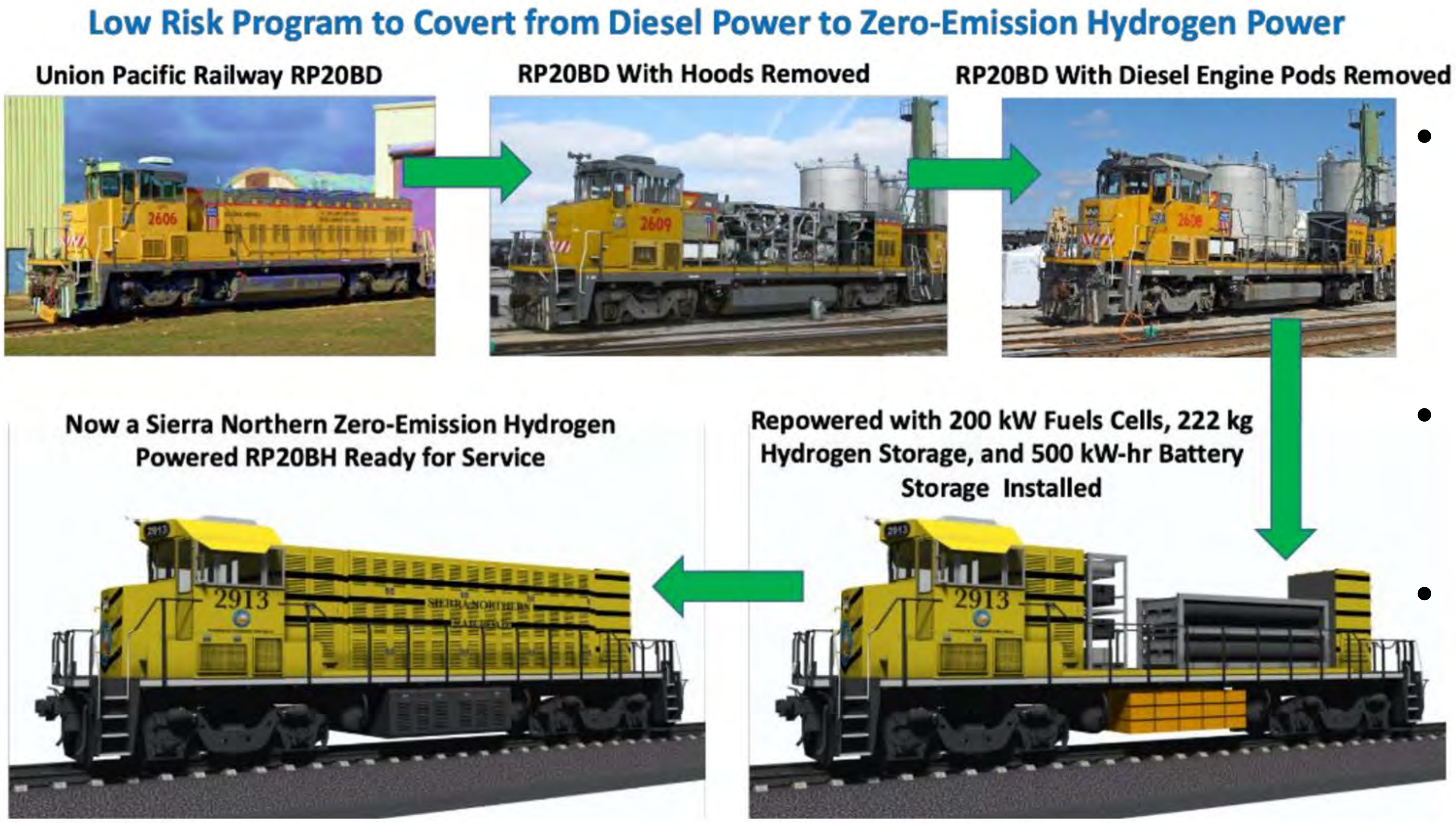
$8 Million for H2Rails Demonstration

The California Energy Commission has awarded $8 million to build and test H2 locomotive and multi-modal fueling station

- **$4M for SNR** to design and build a H2 locomotive demonstrating integration of advanced H2 fuel cell, H2 storage, advanced battery, and systems control technologies
- **$4M for Shell** to develop a multi-purpose H2 fueling station to support locomotives and on-road vehicles, including high-flow H2 dispensing equipment and fueling protocol
- **Project partner, Shell**, commits to building first H2 fueling facility for rail use to be built at the Port of West Sacramento.

Hydrogen Rail Technology

Sierra Northern, is converting a diesel locomotive with a zero-emissions H2 locomotive



- H2 locomotives have **greater energy efficiency** (1.8x) and **lower long-term maintenance costs** (25%) compared to diesel locomotives
- **H2 prices are relatively stable** vs. diesel costs fluctuate based on economic conditions
- **2,550 MT CO2** displaced per locomotive over lifetime, in addition to air pollution reductions

Strategic Partners with Sierra Northern Railway

California Energy Commission grant funding for H2 Locomotive Project

Partner	Role
gti GAS TECHNOLOGY INSTITUTE	Formal applicant to California Energy Commission & Hydrogen safety plan and design review
RAILPOWER Technologies Corp.	Locomotive controls/electronics design. Locomotive design and analysis. System integrator.
BALLARD	Manufacture of fuel cell technology
SoCalGas; SACRAMENTO METROPOLITAN AIR QUALITY MANAGEMENT DISTRICT	Funding Partners and Technical Advisory Committee Members
SIERRA ENERGY	Future: Gasification technology to convert waste into renewable hydrogen

Partner	Role
SIERRA RAILROAD SINCE 1897	Demonstration site owner and operator. Construction and testing of locomotive. Commercialize of locomotive technology.
OptiFuel Systems	Manufacture of locomotive modules. Analysis and integration.
UCDAVIS UNIVERSITY OF CALIFORNIA	Operational analysis of the demonstration locomotive
SHELL	Fueling station for H2 locomotive
valley vision	Provide analysis of impacts and out to disadvantage community surrounding Port of West Sacramento.

Environmental Justice and Carbon Benefits

Zero-emission H2 locomotives provide meaningful health and carbon benefits

- Significant decrease in criteria pollutants contributing to air pollution from displacing diesel
- Noise reduction due to H2 locomotives emitting zero noise or vibration from power generation

Emissions Displaced with Zero-Emission Locomotive	PM 10	HC	NOx	CO	CO2
Annual Savings (lbs)	147	338	4,222	613	225,000
Lifetime Savings (lbs)*	1,031	2,356	29,530	4,288	1,574,229

* An estimated useful fuel cell locomotive life of 25 years.

Sierra Railway Corporation is Uniquely Positioned

Sierra Railway Corporation is the only company in the world with a short line railroad and a gasification technology

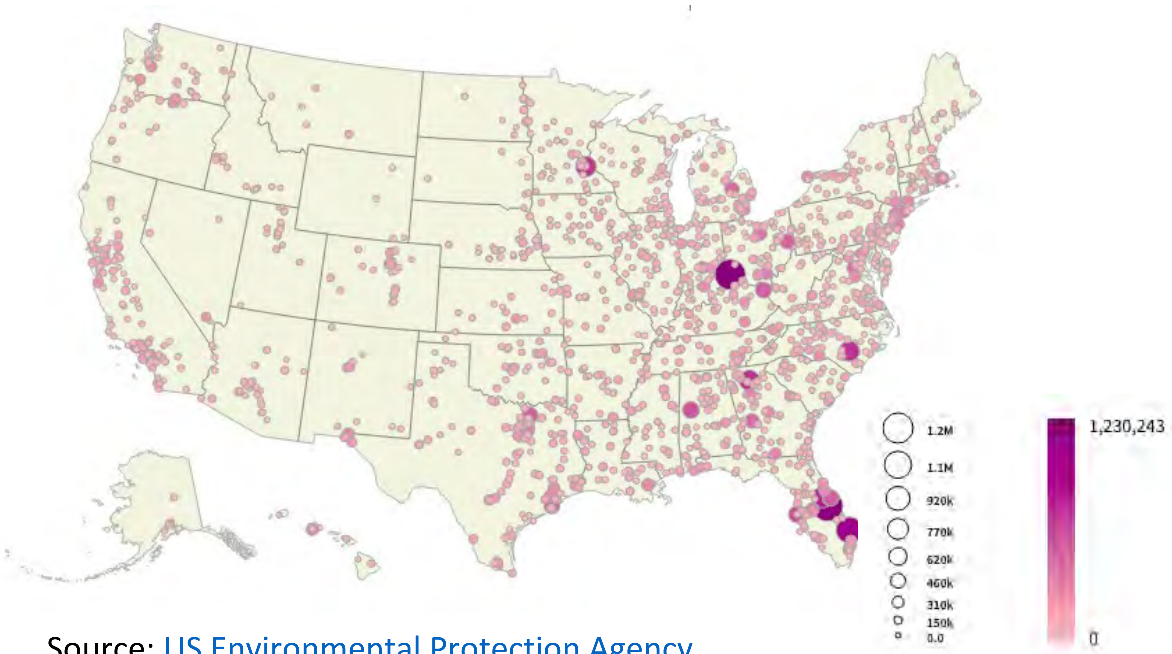
- **2018**: **Sierra Energy** successfully commissions Fort Hunter Liggett project, in partnership with Department of Defense and the U.S. Army, for a 10 ton-per-day system.
- **2019**: Breakthrough Energy Ventures, Cox, BNP Paribas, Twynam, Formica, and the March Fund lead oversubscribed $38M Series A round in **Sierra Energy.**
- **2021**: **Sierra Northern Railway,** receives alongside partners, $8M from the California Energy Commission for locomotive conversion to hydrogen fueling.

Opportunities beyond California: National Scale

Waste and railroad decarbonization problems that exist nationwide

- Waste sector contributes 110.3M tons CO2e annually
- All short line railroads would benefit from federal incentives to reduce emissions and waste tie disposal issue

Location and Emissions for Waste Sector Facilities (MT CO2e)



Source: US Environmental Protection Agency

US Freight Rail Map

Source: Association of American Railroads

Low-Cost Hydrogen Fuel Solves Multiple Problems

"Negative-emissions hydrogen" has a structural cost advantage relating to feedstock supply and is poised to meet expanding hydrogen fuel demand

1 Major cost advantage driven by use of waste materials as feedstock

56M annual tons of biomass waste in CA with landfill reduction goals + increasing waste tipping fees = continuously improving project economics.

2 Structurally increasing demand for clean hydrogen as fuel

CA's statutory goals to build the H2 fuel economy ensure growing demand for FCEVs. CARB can achieve rail decarbonization through H2 locomotive conversion.

3 Gasification can solve multiple environmental problems in California

Universal win for CA with sector strategies for waste, H2 supply, and rail decarbonization — reducing carbon emissions and air pollution, particularly in fence line communities.

Hydrogen Fuel

Sierra Northern Railway
Advancing Hydrogen Rail in California

NEXT UP:

Momoko Tamaoki
Office Chief, Equipment and Assets
Caltrans

Caltrans Intercity Passenger Rail ZE Strategy

Innovations in Hydrogen Rail

Sacramento, CA | May 19, 2021| Momoko Tamaoki | Office Chief, Assets and Equipment, DRMT, Caltrans
momoko.tamaoki@dot.ca.gov

Become an innovation leader in zero-emission mobility

Contributing to a livable environment.

Caltrans is following the State Rail Plan to develop a comprehensive ZE strategy – starting with Intercity, other segments will follow

State Rail Plan requirements and objectives

RAIL PLAN (2018)
California State Rail Plan

FRA Requirements
- Simple collection of reporting data
- Meeting FRA Guidelines
- Closer to the 2013 and other states' rail plans in look and feel

Advancing California's Vision
- Making the case for our strategic Vision
- Communicating through dynamic storytelling
- Providing critical resources to stakeholders
- Shifting compiled lists and basic overviews to appendices

Intercity

Commuter

Urban

Freight

ZE strategy developed

ZE strategy to be developed / under development

Caltrans Intercity ZE strategy

✓ Provide leadership and guidance and serve as a positive benchmark for other railways to act quickly in a coordinated manner

✓ Enable the launch of important initiatives and accelerate the progress

✓ Set goals / targets and provide a structured approach to move towards ZE, incl. setting technological cornerstones

✓ Respond to urgent need and legislation / state mandates

Strategic goals for our intercity fleet to become an innovation leader in zero-emission mobility

CALIFORNIA FLEET MANAGEMENT PROGRAM

1

Decarbonizing our transportation system and improving our air quality

- Gradually substitute fossil fuel with renewable diesel and hydrogen, thereby reducing GHG emissions well-to-wheel
- Upgrade our diesel locomotives with after-treatment systems and introduce hydrogen, thereby progressively decreasing criteria pollutants that have an adverse effect on air quality

2

Increasing our energy efficiency

- Invest in technology and procedures to enable energy-efficient driving as well as regenerative braking
- Invest in ground power for expanded use at layover facilities
- Invest in energy efficient railcars, reducing HEP[1] requirements

3

Fostering leadership and facilitating collaboration in sustainable mobility

- Lead and promote pioneering initiatives in zero-emission vehicles
- Integrate state-wide efforts to accelerate implementation
- Engage in public outreach and promote the benefits of rail

Reduce GHG and criteria pollutants by 2035

-100%

Reduce fuel usage per train mile by 2025

-15%

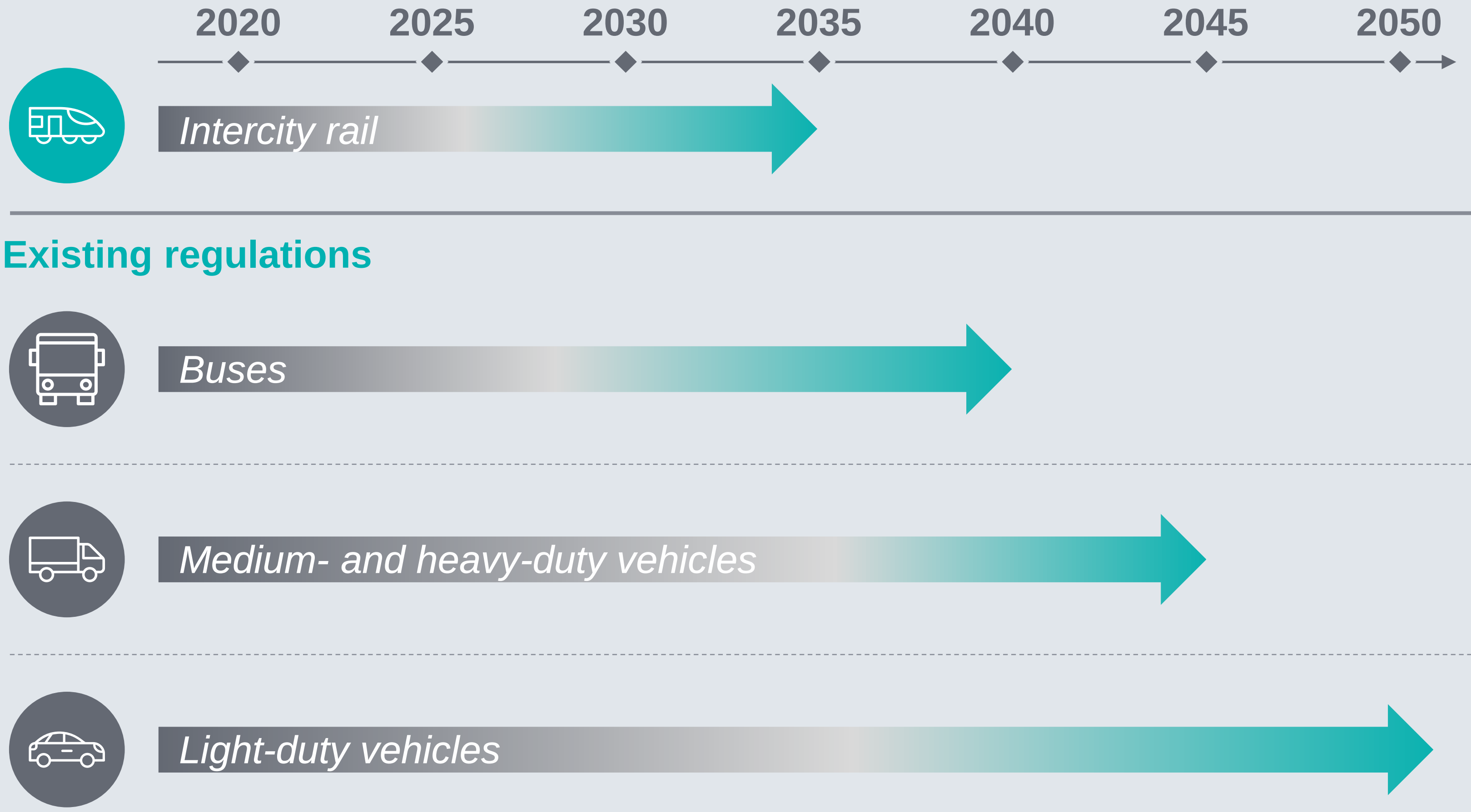
Work with passenger rail agencies to coordinate zero-emission action plan

by 2021

(1) HEP = head-end power (e.g., for HVAC, lighting)

Our goal for intercity rail: Achieve a 100% emission-free fleet by 2035 – taking the lead among other modes of transportation

CALIFORNIA FLEET MANAGEMENT PROGRAM



Caltrans DRMT[1] goal:
Complete intercity fleet ZE by 2035

Innovative Clean Transit Regulation:
- New buses ZE from 2029 onwards
- Bus fleets of public transit agencies fully ZE by 2040

EO N-79-20:
- Trucks fully ZE by 2045 wherever feasible

EO N-79-20:
- In-state sales of new passenger cars and trucks 100% ZE from 2035

(1) DRMT = Division of Rail and Mass Transit
Sources: CARB, Caltrans, Governor's Office

Responsibilities for California's intercity rail are divided between state, JPAs and railway undertaking operators

transferred administration and marketing duties for IPR[1]

Contract

Access to rail infrastructure

State of California (Caltrans)

- Long-term strategic planning (e. g. California Transportation Plan 2040)
- Provide funding for IPR[1]
- Rolling stock procurement and ownership
- Planning, organizing, coordinating and directing rail related projects
- Oakland maintenance facility oversight including improvement plans

Joint Powers Authorities (JPA)[2]

- Oversight and management of the day-to-day operations
- Negotiating changes to the current contract or selecting another qualified operator
- Management and administration of the rolling stock
- Marketing and establishment of fares
- Planning for future service improvements

Railway Undertaking Operators[3]

- Procurement of rolling stock
- Operation of passenger/freight trains (on board staffing, station services, ticketing)
- Maintenance of rolling stock (in some cases different company/legal entity)

Right-of-Way Owner (Host Railroads)

- Provide access to rail infrastructure
- Maintenance of infrastructure
- Provide train dispatching services
- Provide station operations and maintenance

- Transport freight

1 IPR = Intercity Passenger Railway 2 Capitol Corridor, San Joaquin, LOSSAN 3 Currently only Amtrak for intercity lines; commuter lines have other operators

Our fleet: Caltrans provides the equipment for three intercity corridors – services are managed by regional Joint Powers Authorities

CALIFORNIA FLEET
MANAGEMENT PROGRAM

California's Intercity Passenger Rail

Intercity diesel-electric locomotive fleet

F59PHI (EMD)
Year introduced: 1991 / 2001
Emission standard: Tier 2
Active fleet: 13

SC-44 (SIEMENS)
Year introduced: 2017
Emission standard: Tier 4
Active fleet: 24

Focus of our zero-emission (ZE) strategy

Targets will be achieved through a mix of measures: reducing energy consumption combined with technological changes and use of renewable power

CALIFORNIA FLEET MANAGEMENT PROGRAM

Additionally: hybrid solutions

Levers		Prioritized solutions						
Tank-to-Wheel	Main on-board energy	*CA diesel*	*Renewable diesel*	*Natural Gas*	*Renewable gas*	*Batteries*[1]	*Hydrogen*	*Electric*[2]
Tank-to-Wheel	After-treatment	*Below Tier 4*	*Tier 4*	*Tier 5*[3]	*No aftertreatment, zero emission*			
Tank-to-Wheel	Energy efficiency	*Energy-efficient driving*	*Regenerative braking*	*HEP reduction*				
Tank-to-Wheel	Ground power usage	*HEP usage – no ground power usage*	*At maintenance facilities only*	*At maintenance and layover facilities*				
Well-to-Tank	Feedstock sourcing	*Fossil sources*	*Mix of fossil and renewable sources*	*Renewable sources*				

Total emission reduction potential | Intermediate solution | Preferred long-term solution

(1) As hybrid with Hydrogen (2) Power supplied by complete continuous wayside electrification (3) No dedicated investment in Tier 5 but transition to ZE immediately

Primary power for Caltrans intercity fleet: renewable diesel to reduce emission and hydrogen to achieve zero-emission

CALIFORNIA FLEET MANAGEMENT PROGRAM

Today → *Low-emission transition technologies* → *Zero-emission technologies (incl. hybrids)*

Dimension	Diesel	Ren. Diesel	Natural Gas	Ren. Nat. Gas	Batteries	Hydrogen	Electrification[2]
Environ-mental	Requirements not fulfilled	Mediocre	Mediocre	Mediocre	Good	Excellent	Good
Technical / operational	Excellent	Excellent	Good	Good	Inferior	Good	Excellent
Economical (LCC)	Inferior	Mediocre	Mediocre	Mediocre	Good	Good	Requirements not fulfilled
Synergistic	Inferior	Mediocre	Inferior	Mediocre	Good	Good	Inferior
	Status quo	***Feasible***	***Impractical***	***Impractical***	***Impractical*** (as stand-alone)	***Favored***	***Not feasible*** (system-wide)
	Emission targets cannot be achieved even with after-treatment systems	Emission reduction compared to regular diesel, likely transition technology, limited modifications needed	Possibly transition technology but requires new re-fueling infrastructure and motive power modifications	Possibly transition technology but requires new re-fueling infrastructure and motive power modifications	Suited for hybrid solution but not suitable as sole power source for intercity due to long range requirements	Most suited option according to initial analysis	Electrification requires large capital invest-ment and has ROW[1]-implications but can be utilized where available in dual-mode.

(1) ROW = Right of Way
(2) Considering system-wide electrification
Source: DB assessment

Rating: Excellent, Good, Mediocre, Inferior, Requirements not fulfilled

Driving toward zero-emission intercity rail: Start with renewable diesel, followed by after-treatment upgrade incl. energy efficiency, and Hydrail[1]

CALIFORNIA FLEET MANAGEMENT PROGRAM

2020-2021

Develop and adopt ZE strategy in accordance with EO-N79-20

Set goals and provide a structured approach to move towards ZE, incl. setting technological cornerstones

2023

Entire fleet is operated on renewable diesel

Start rollout of after-treatment upgrades, use renewable diesel only

GHG: -55%; Criteria pollutants: -10%

2025

Entire fleet upgraded to Tier 4 and increased energy efficiency

Start trial operation of hydrogen pilot[2]

GHG: -60%; Criteria pollutants: -25%

2027

Hydrogen pilot completed

Start rollout of fleet conversion towards hydrogen

GHG: -60%; Criteria pollutants: -25%

2035

Fleet transitioned to ZE

All motive power vehicles use zero-emission primary energy source[3]

GHG: -100%; Criteria pollutants: -100%

Emission reduction per train mile compared to 2020 levels: GHG, Criteria pollutants

(1) Adjustment of strategy possible, if technological breakthrough occurs (2) Retrofitting existing F59 locomotive with H_2 powertrain – if successful, consideration of rollout to remaining fleet
(3) Currently, hydrogen-hybrid (hydrail) is the best option, suplemented with dual-mode where feasible

THANK YOU!

ANY QUESTIONS?

Q&A

- Submit your question in the Q&A Panel on your right.

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Development Specialist
California Hydrogen Business Council

Lynn Harris
Senior Consultant - Sustainable Motive Power & Zero-Emission Technologies
DB Engineering and Consulting USA

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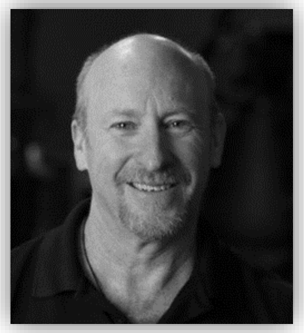
Market Development Manager, US
Ballard Power Systems

Carrie Schindler
Director of Transit and Rail
San Bernardino County Transportation Authority



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