Today's Transit for Tomorrow's World

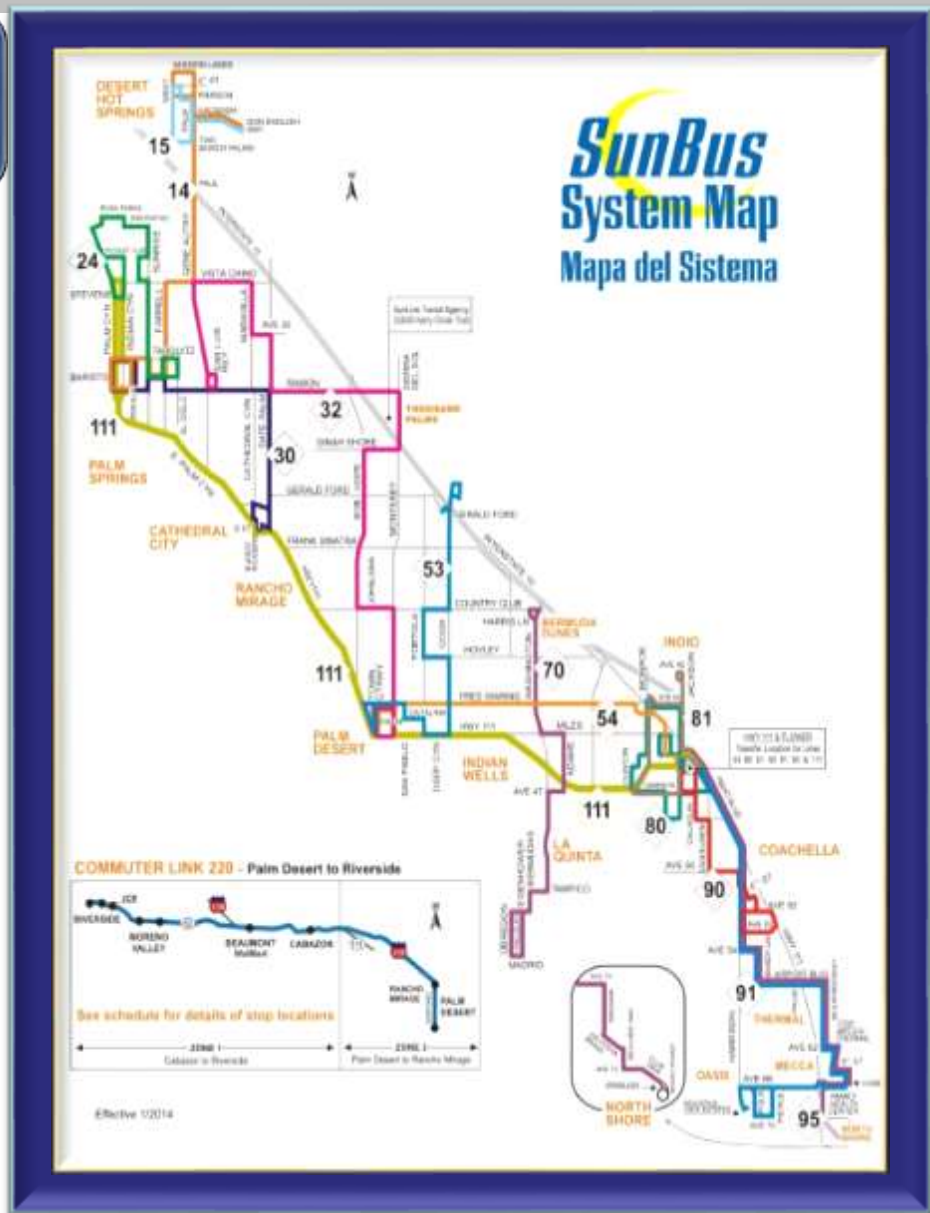
Real Life Experience with Hydrogen Fuel Cell Buses

Tommy Edwards
Chief Performance Officer
SunLine Transit Agency

SunLine Facts

SunLine Operations

- Fourteen (14) local SunBus fixed routes, (1) express line, (1) Riverside Commuter Link, ADA Paratransit
- **61 CNG buses**
- **16 Electric Hydrogen Fuel Cell buses (2 more in production)**
- **4 All Electric Battery BYD buses**
- **39 CNG Paratransit Vehicles**
- Operated 4.3 million revenue miles for 4.5 million passenger trips
- 350 Employees



SunLine Board Policy

Purpose:	Establish a policy advocating the purchase and use of only vehicles fueled by alternative fuels
Policy:	The agency will expand and replace vehicles with the newest zero emission technology available
Actions to be Followed:	1) Zero Emission Vehicles 2) Ultra Low Emission Vehicles 3) Low Emission Vehicles 4) Transitional Low Emission Vehicles **SunLine will, whenever possible, purchase vehicles in the same order as listed above**

- *Approved March 24, 1993*

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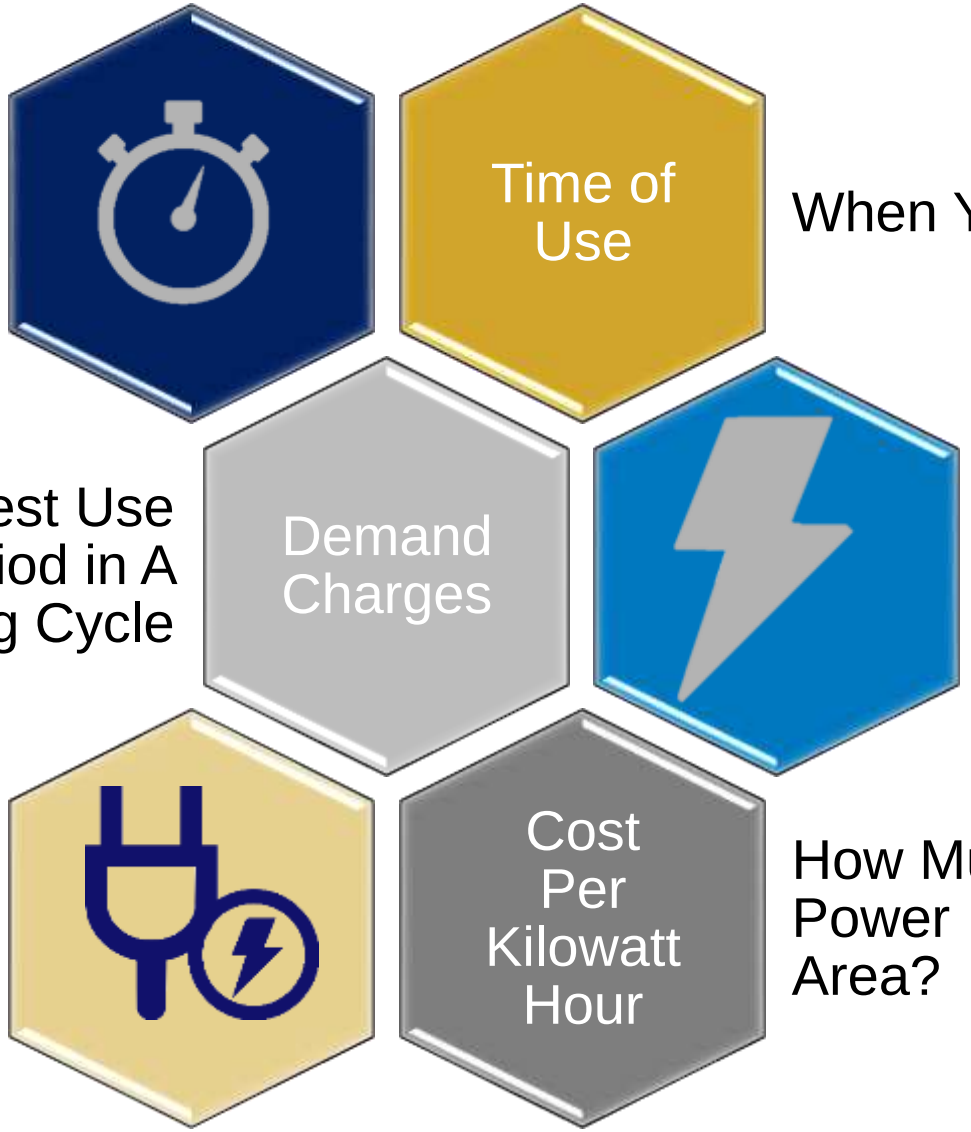
Power 101

Electricity Puzzle



Electricity Basics

Term	Definition	Composition
Kilowatt Hour – can power a microwave for 1 hour	1 watt of power sustained for 1 hour	Unit of energy equal to 3.6 megajoules
Megawatt – can power approx. 600 homes	1 million watts of power	One megawatt is equal to one million watts, or 1,000 kilowatts
Gigawatt – can power approx. 700,000 homes	1 billion watts of power	Unit of electrical energy equal to one billion (10^9) watt hours, one thousand megawatt hours
Terawatt – can power approx. 1 billion homes	1 trillion watts of power	There are 1,000,000,000 kilowatts in a terawatt

Primary Energy Sources

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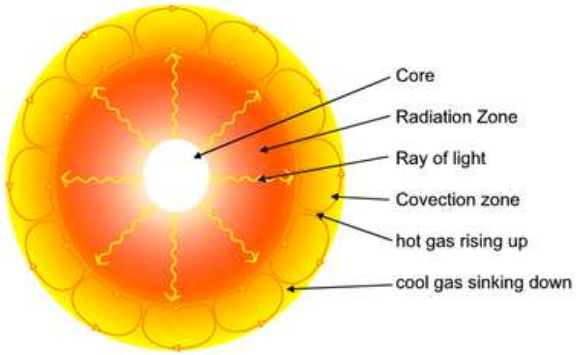
All Energy on Earth is from the Sun!

Sun Energy

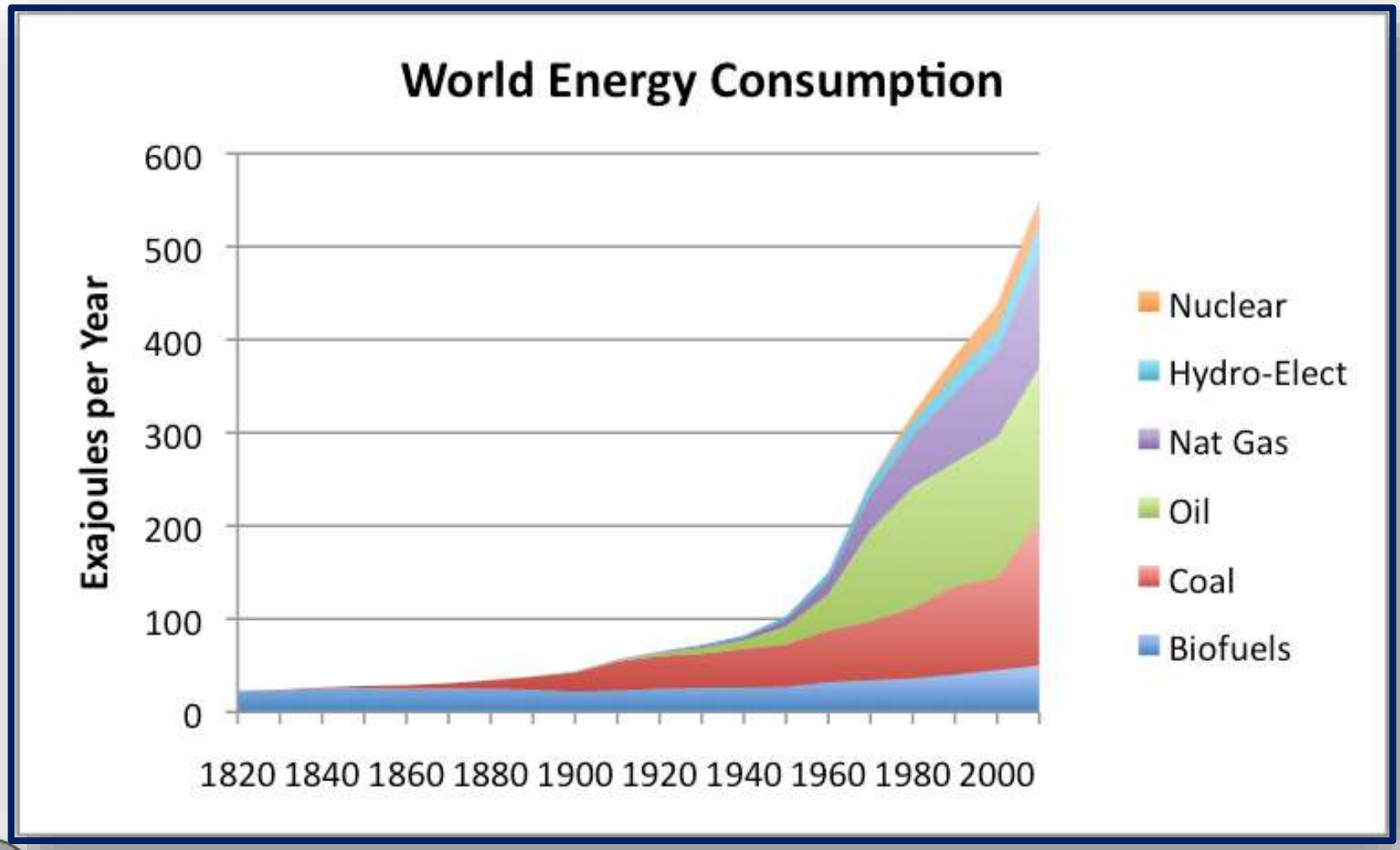
- Dead plant/animal life, heat, pressure (millions – 100s of millions of years) – Fossil Fuels
  - coal, oil, natural gas
- Corn/Trees/Grass (months – years)
  - ethanol, biogas, biomass
- Hydro (weeks – months)
  - evaporation, clouds, rain,
- Wind (days – weeks)
  - Wind turbine
- Solar (instant)



"Energy sustainability requires conversion of resources at the same rate at which they are naturally replenished on earth without externalities"

National Fuel Cell Research Center
UCIrvine

Energy Usage Over Time



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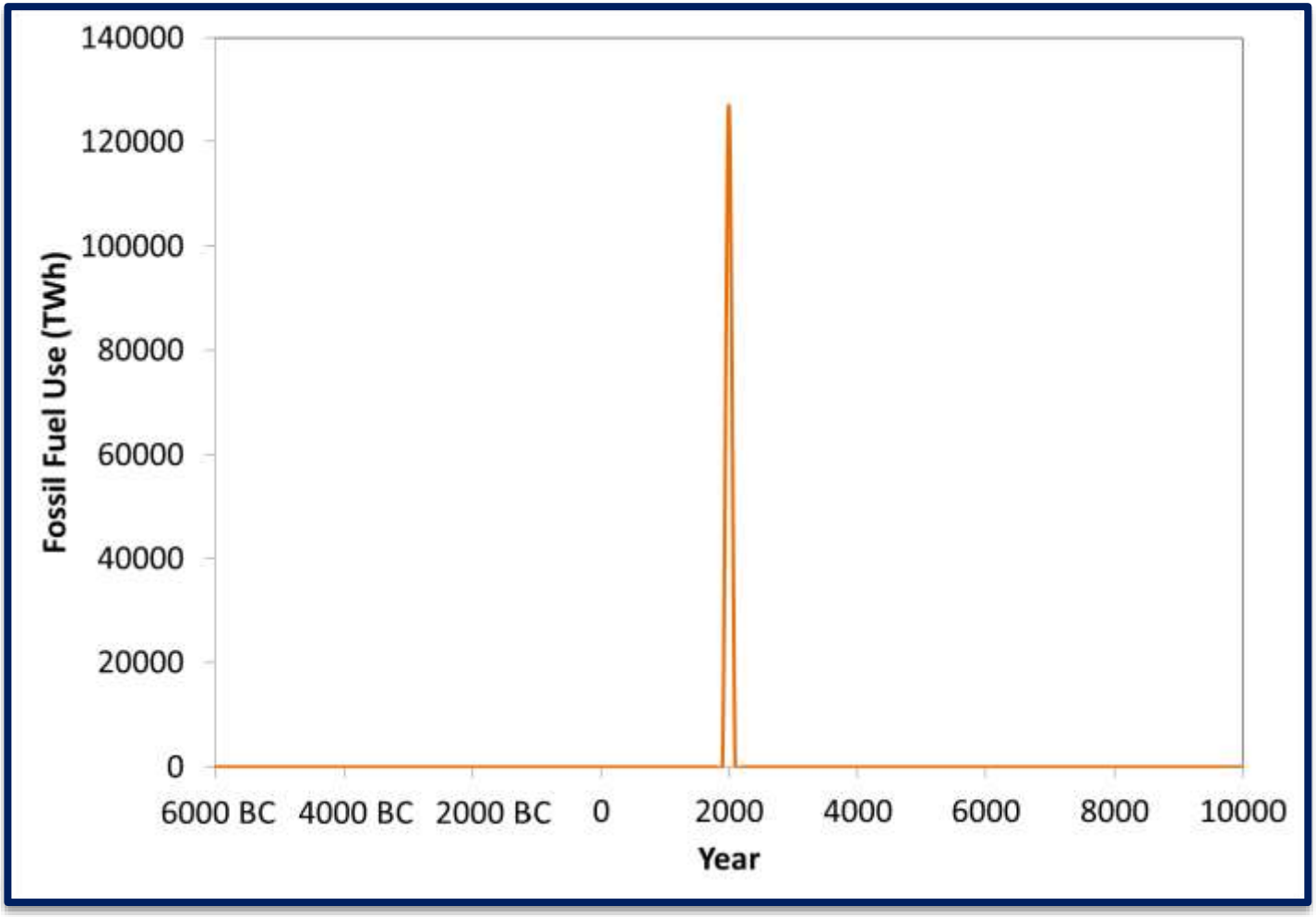
How Fast We're Burning It

Current Practices are Obviously not Sustainable



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Energy Storage

	Solar contribution	Wind contribution	Consumption and storage ratio	Consumption (TWh)	Storage (TWh)
Africa	0.70	0.30	8.39	9,123	1,088
America	0.45	0.55	7.83	38,541	4,919
Asia	0.50	0.50	7.95	80,866	10,178
Europe	0.30	0.70	7.50	26,951	3,592
Oceania	0.50	0.50	7.95	1,625	205
TOTAL				157,106	19,981

That's 19,981 TWh worth of storage needed for just two sources of renewables!


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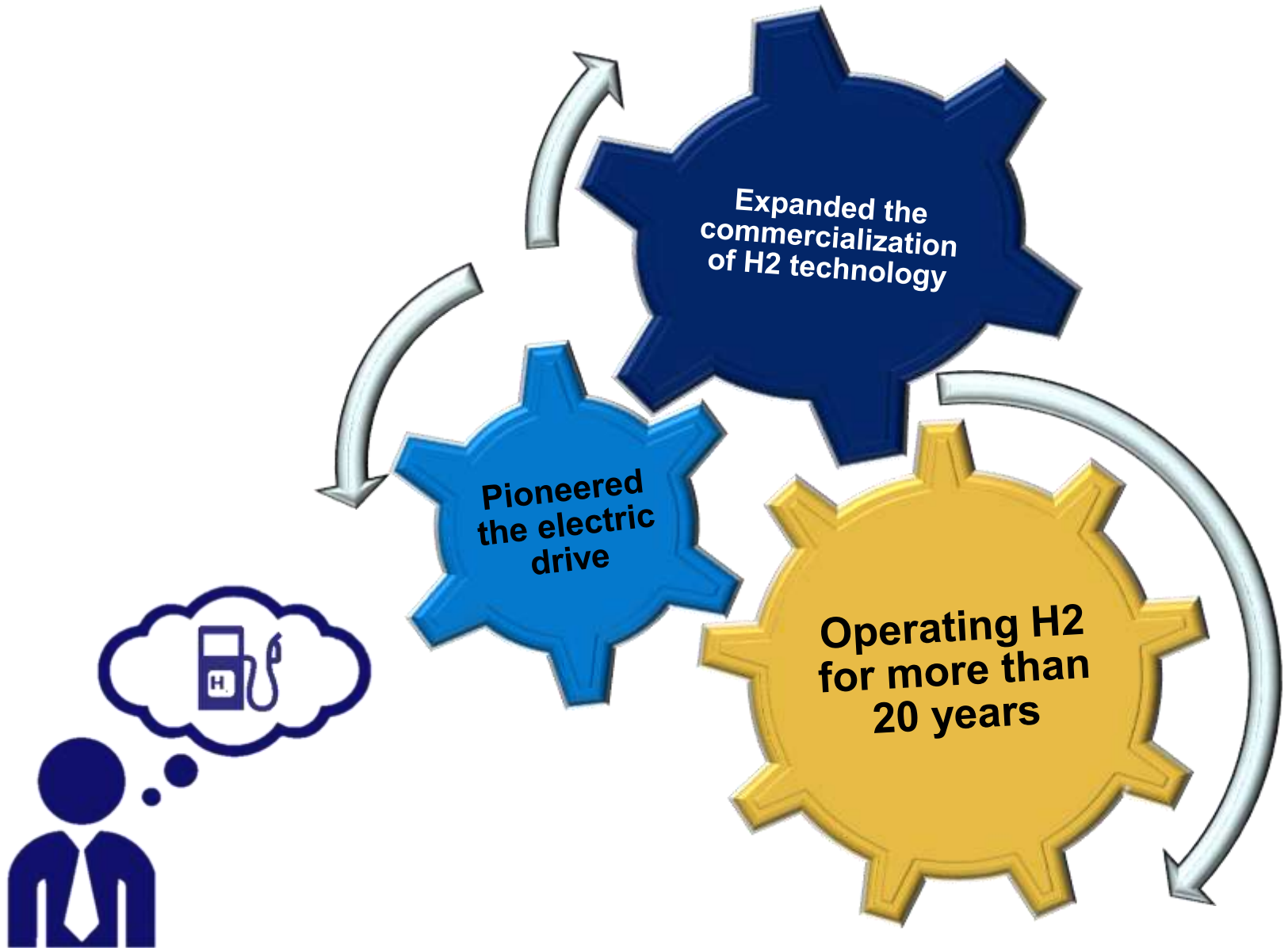
SunLine's Hydrogen Program

SunLine's Hydrogen Program



Fuel Cells Enhance the Performance of Electric Buses

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BALLARD

300 miles

High Daily Ranges
FCEBs excel on long routes and routes with frequent service

Fast Refueling at Depot
FCEBs are compatible with fueling islands and restrictive schedules

Full Route Flexibility
FCEBs are a 1:1 replacement for ICE buses and are not tied to on-route infrastructure

Challenging Terrain
FCEBs excel on hilly terrain and steep grades

Extreme Climates
FCEBs excel in all weather, from cold winters to hot summers

Vehicle Weight
Significant reduction in vehicle weight (can carry more passengers)

Why SunLine Chose Fuel Cell Buses

Fuel cell electric buses are the zero-emission option that can meet SunLine's performance requirements

- Daily temperatures can exceed 115^0 F
- Regular scheduled service is between 100 and 200 miles
- Combination of rural, highway and city routes

A Fuel Cell Bus is an Electric Bus

- Hydrogen powered buses are hybrid fuel cell battery electric buses
- Fuel cell modules generate power from hydrogen to recharge onboard batteries and power the electric drive
- Same maintenance and parts as a battery electric bus, apart from the fuel cell power module and gas tanks

SunLine's Hydrogen Fleet

10

El Dorado National

- Ballard
- US Hybrid
- BAE

New Flyer

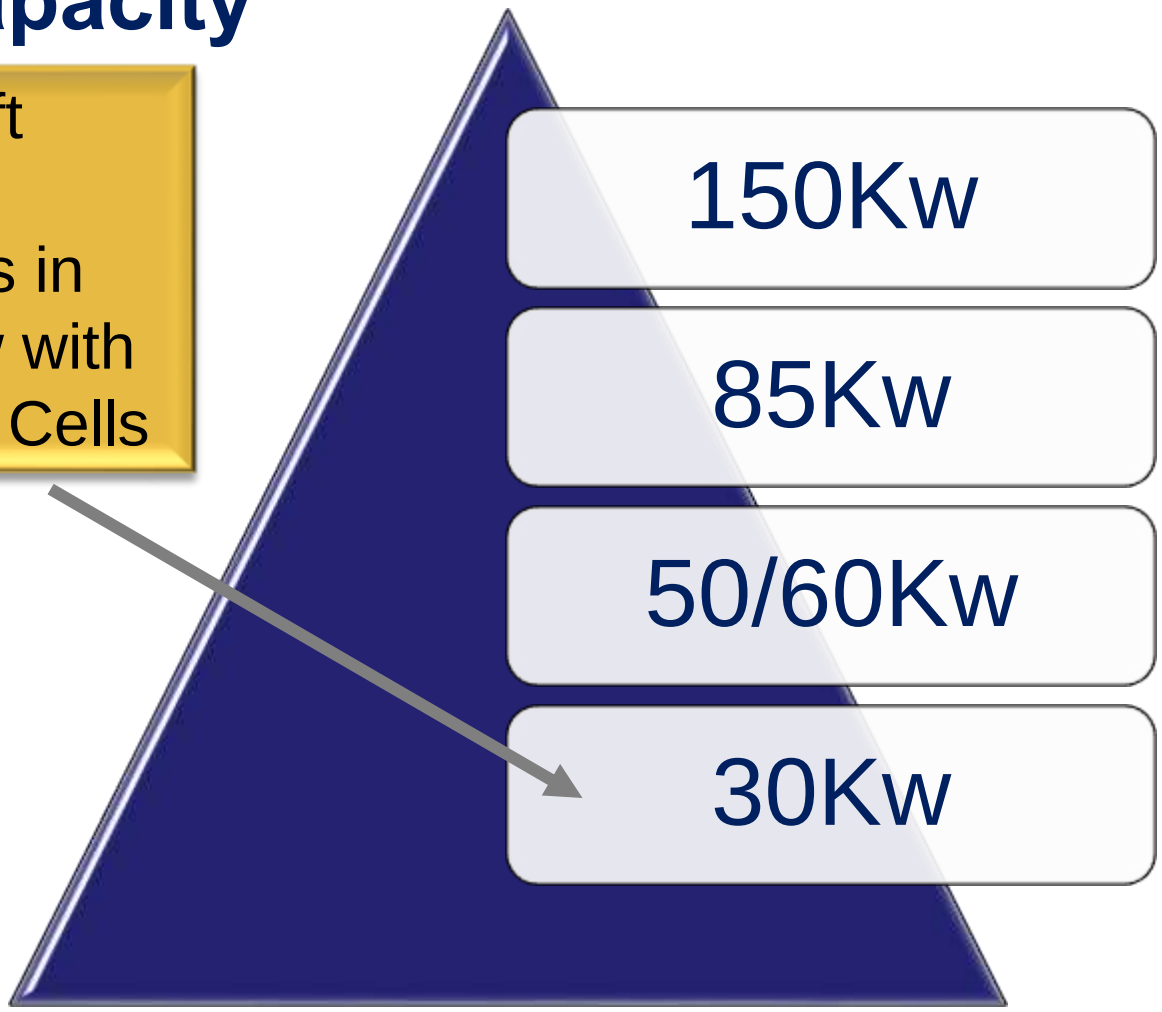
- Ballard
- Hydrogenics
- Siemens

6

SunLine's Hydrogen Program

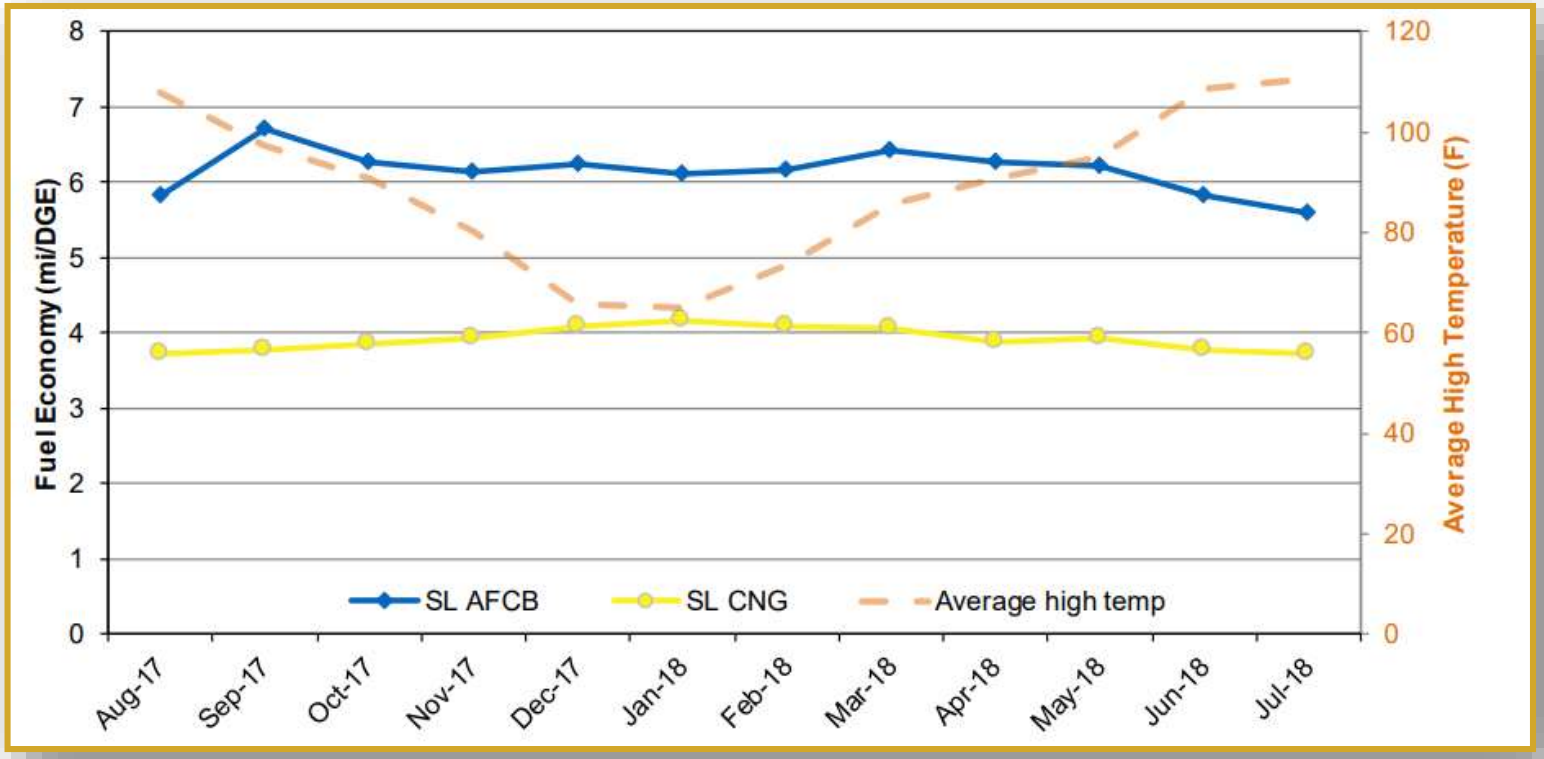
Fuel Cell Capacity

Two (2) 32ft
El Dorado
Shuttle Buses in
production now with
US Hybrid Fuel Cells



Fuel Cell Electric Bus Performance

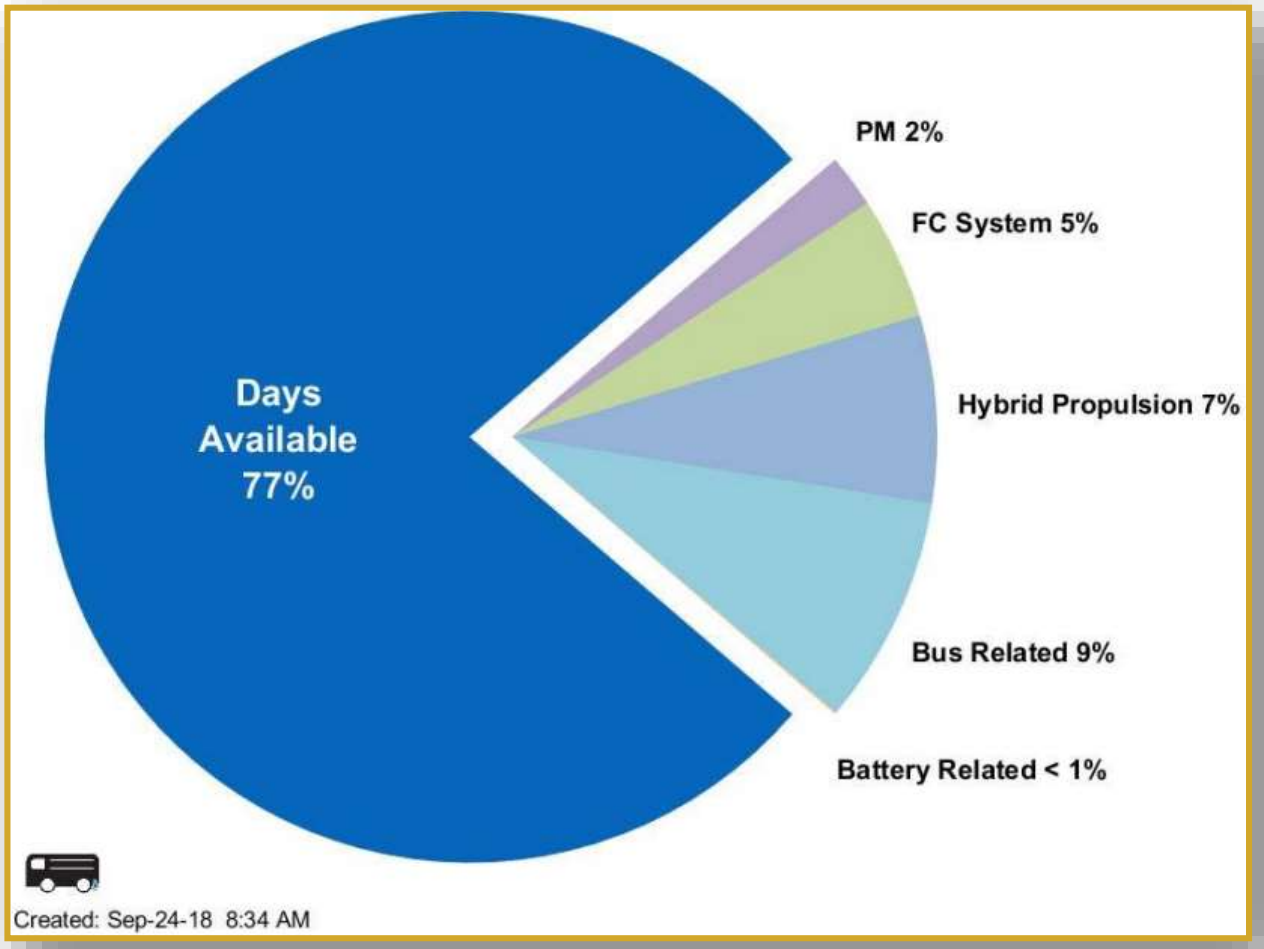
- **Monthly fuel economy for the SunLine AFCBs and CNG buses**



source: NREL 2018

Fuel Cell Electric Bus Performance

- **Availability and reasons for unavailability for the SunLine AFCBs (Aug 2017–Jul 2018)**

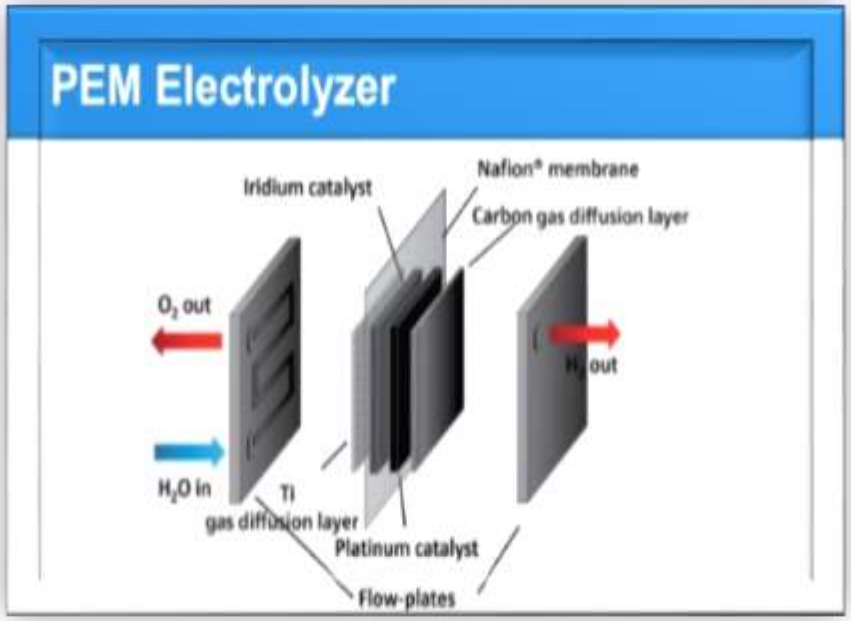


source: NREL 2018

SunLine's Hydrogen Program

In Commissioning

- Proton/Nel PEM Electrolyzer
- 900 Kg per day production
- 60% renewable solar electricity
- 380 Kg use per day
- 2 dispenser fast fill rate
- $8.7 Million CARB Grant
- Public Fueling – 700 Bar expansion for future



SunLine's Hydrogen Program

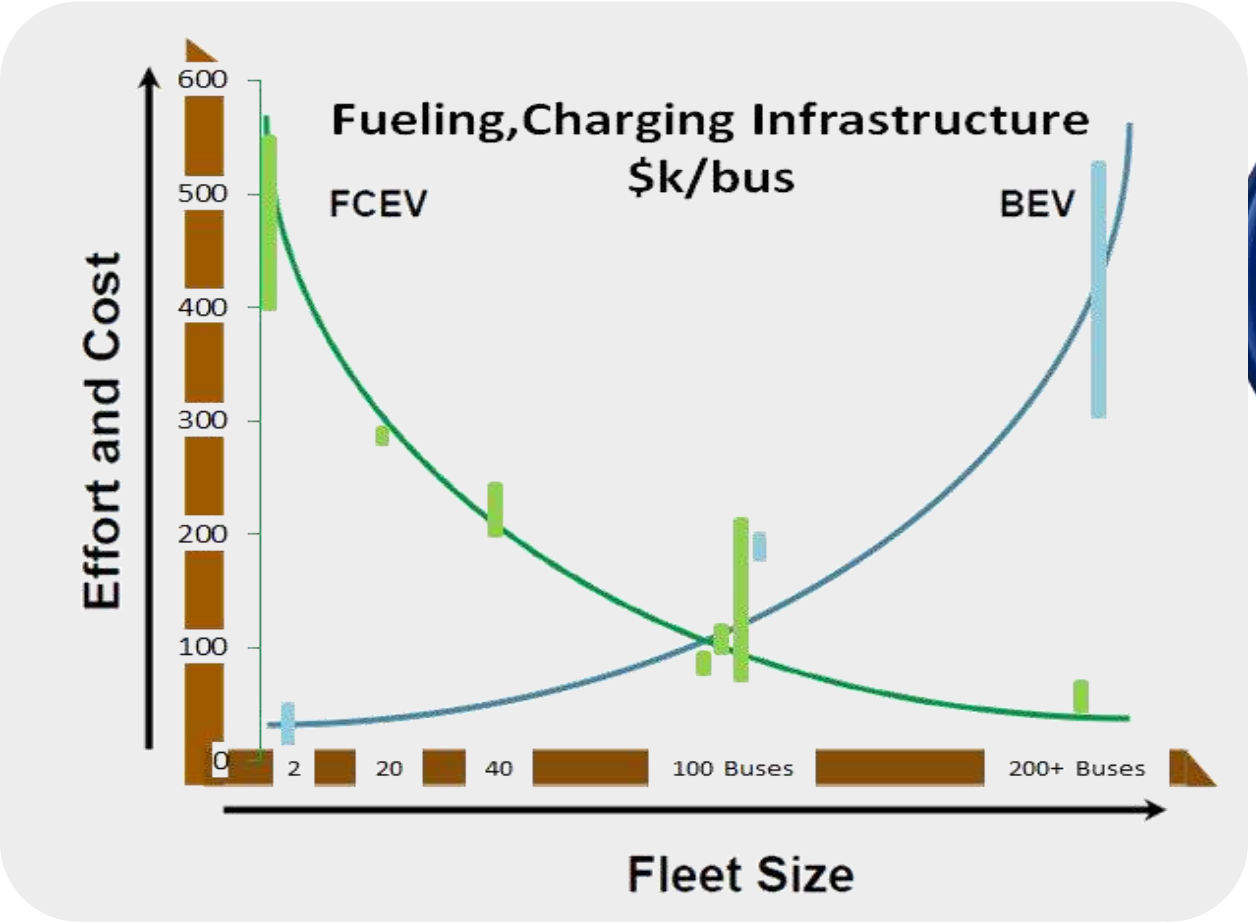
Future Fueling Exploration

- SunLine is looking to add a redundancy system that may include liquid Hydrogen or other solution to include outside purchases that are closer to our facilities
  - Contracted services for Hydrogen escalate to approx. $30 Kg
- We would also like to upgrade our second station in Indio for Hydrogen production and outside sales

H2 Bus Affordability

FC1	2004	3.25M
FC2	2008	2.75M
FC3	2012	2.4M
FC4,5,6	2014	2.1M
5 buses Newest	2019	1.17M

Scaling Up the Fueling Infrastructure



Hydrogen fueling infrastructure is fully scalable

From 2 buses to 100+ buses per depot with incremental CAPEX investment as fleet grows

West Coast Center of Excellence

West Coast Center of Excellence
IN ZERO EMISSION TECHNOLOGY

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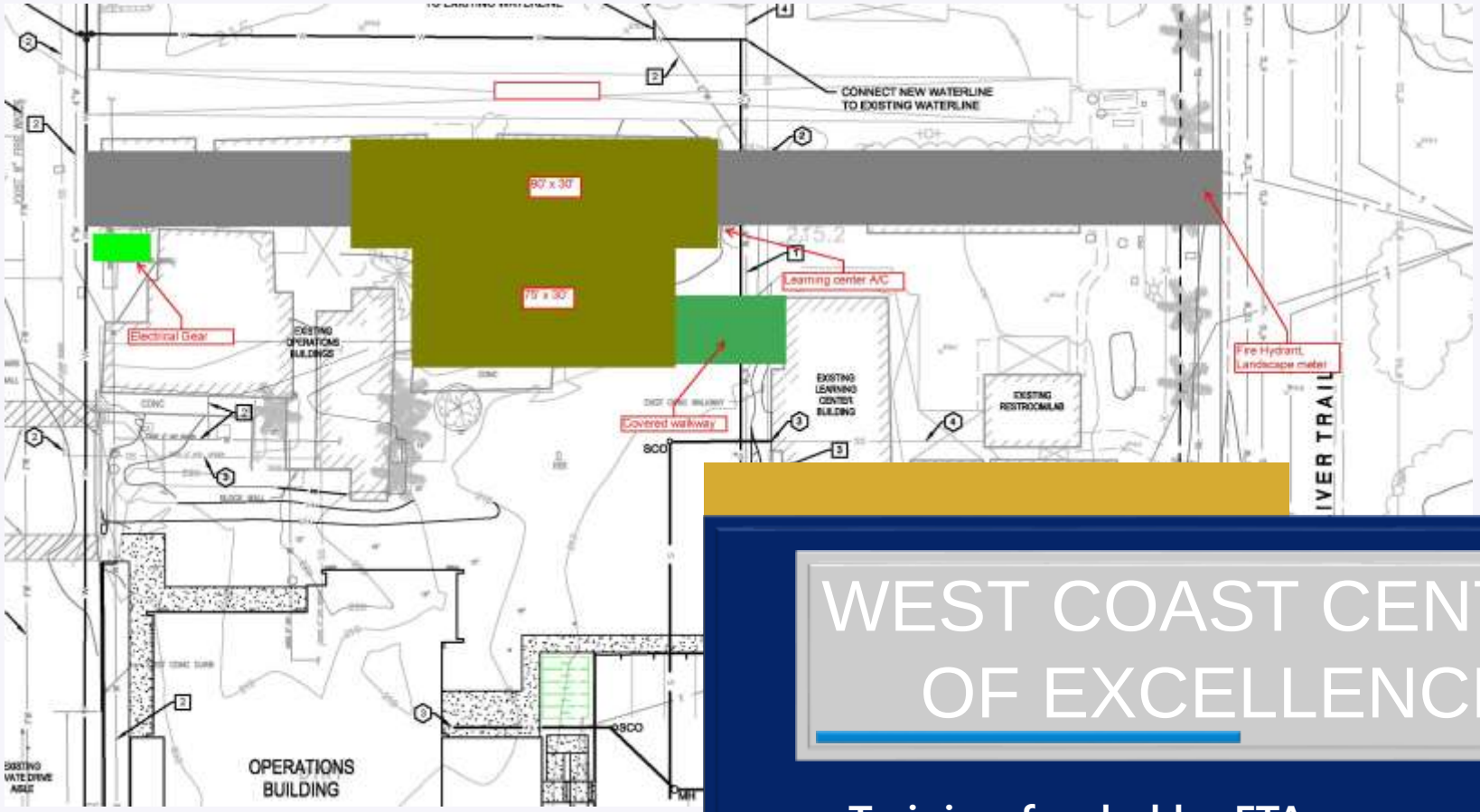
West Coast Center of Excellence

- Funding from FTA and California Fuel Cell Partnership
- For every investment in technology, there is investment in training and learning
  - Will provide on-sight and portable training
  - OEM interest and support
  - Component, maintenance, procurement, planning, and operations training modules
- A site to preserve and enhance those learning investments

West Coast Center of Excellence
IN ZERO EMISSION TECHNOLOGY



WEST COAST CENTER OF EXCELLENCE

- Training funded by FTA
- Infrastructure for Center partially funded by FTA

Completed Training Modules

Advanced Technology Technician Training

Procurement Insights for ZEB purchases

Planning and executing ZEB's in service

Santa Cruz Sentinel

Metro receives training on zero emission buses

SunLine Transit Agency takes workforce training program to Santa Cruz

SunLine Transit Agency's Tommy Edwards talks to Santa Cruz Metro driver James Sandoval, right, about its $1.1 million hydrogen fuel cell, zero emission transit bus. (Dan Coyro — Santa Cruz Sentinel)

Leadership, mission, value creation for a successful ZEB Program

Getting Started

- **What should you do to start a ZEB program?**

Create a Board Policy

- Most Operators assume Hydrogen is too complicated/expensive for their team and their community

Develop a Mission or Focus on ZEB Technology

- Ensure that the agency knows what and why leadership is directing change a in platform
- Develop internal champions who are emerging leaders and believe in the benefits of piloting new technology

Redesign Your Existing System

- We have to “stop selling, what riders aren’t buying”
- Plan your new network using ZEBs
  - Many agencies are looking at more frequent, reduced running times and more productive services

Manufacturer / Operator Relationships

- Ensuring all parties understand risk and work together to solve problems

Key Takeaways

SunLine has made a deep commitment to reducing environmental impacts while delivering world-class transit services

The Hydrogen Fuel Cell Option is absolutely available

SunLine does not use any solid fuel to deliver transit to the Coachella Valley

Zero emission technology works

California's Innovative Clean Transportation Rule is a game-changer for the clean fuels industry

Questions?

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